STATION BULLETIN 234 JUNE, 1928

The Removal of Spray Residue from Apples and Pears

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CONTENTS

SUMMARY

(1) A thorough study of cleaning methods should be made before spray residue removal is attempted. Serious difficulties may be encountered unless this is done.

(2) Chemical analyses offer the only reliable basis for determining whether fruit sprayed with arsenicals requires cleaning to meet the various tolerances.

(3) Cleaning by such mechanical means as brushing and wiping can be advised only in cases where very light spray programs have been followed. Owing to the possibility of injury to the fruit, it is questionable whether mechanical cleaning methods should ever be used in the case of pears. Such methods are less injurious to apples.

(4) Washing has proved to be far more effective than mechanical cleaning. When properly done washing has enabled Oregon apples and pears to meet the world tolerance.

(5) Of the many compounds tested none has proved superior to weak solutions of hydrochloric acid. This acid is usually effective at strengths of $\frac{1}{3}$ to $\frac{2}{3}$ percent actual acid (1 to 2 gallons per hundred). It is questionable whether it should be used at strengths greater than 1 percent actual acid (3 gallons per hundred).

(6) When tanks of 150- to 250-gallon capacity are used the acid solution should be changed at the end of each day's run.

(7) It is very essential that the fruit be thoroughly rinsed following the acid treatment. A spray of clean water as the fruit leaves the machine is highly beneficial in removing acid, soluble arsenic, dirt, and decay spores.

(8) The use of lime in the rinse bath is recommended for trial on apples. It is not recommended for pears at this time.

(9) Although drying is desirable, no serious difficulties have resulted from small amounts of moisture left on washed fruit at packing time. Water, apparently, does but little harm when the acid and arsenical residue have been thoroughly removed.

(10) The formation of wax retards the solvent action of the washing solution. To insure effective cleaning and to reduce arsenic injury and decay, fruit should be harvested at the proper time and should be washed immediately after picking.

(11) The improper use of oil sprays may cause serious complications in the removal of arsenical residues.

(12) Deep submersion must be avoided in the case of apples. Submersion just beneath the surface for a few seconds seems to do no harm, but may cause injury if continued for several minutes. Submersion apparently causes no trouble in pears.

(13) The use of disinfecting compounds is not recommended at this time.

(14) General recommendations for the operation and supervision of washing machines are given.

(15) A simple method for the determination of the acid strength is outlined.

The Removal of Spray Residue from Apples and Pears

By

HENRY HARTMAN, R. H. ROBINSON, and S. M. ZELLER.

INTRODUCTION

Rapid progress has been made in the solution of the spray residue problem during the past two years. The cleaning of fruit by the chemical washing method has been generally adopted not only in the United States, but also in foreign countries. Many commercial fruit washing machines have been used successfully for the first time in the history of the deciduous fruit industry.

Practically all of the commercial packers and orchardists in Oregon installed fruit washing machines and used them throughout the 1927 season. Approximately 90 percent of the apple and pear crop was cleaned by the hydrochloric acid washing method. The remaining portion came largely from districts where only light sprays had been applied and where cleaning was unnecessary.

With the assistance of the Oregon Agricultural Experiment Station, chemical laboratories were established in the various fruit districts and analyses were made throughout the season. More than 3,000 chemical analyses were made of samples representative of the washed fruit. These analyses show that about 90 percent of the total crop of 3,700,000 boxes as prepared for market was below .01 grain of arsenous oxide per pound of fruit. The remaining portion showed slightly above this amount but was well within the domestic tolerance.

The cost of washing as done last season ranged from one to five cents per box. Standardization and perfection of the process will doubtless reduce these costs so that washing will be considerably more economical than mechanical cleaning.

Washing when properly done has resulted in no serious injury to the fruit. On the contrary it has generally added to the appearance of the product, and there is some evidence that under certain conditions it has contributed to keeping quality.

Since the washing method was being used for the first time, difficulties were necessarily encountered. Faulty equipment and lack of information as well as lack of care were responsible for a certain amount of spoilage, and for ineffective cleaning.

Naturally, too, special local conditions of tillage, spraying, and harvesting resulted in some problems for individual growers or localities which will require unusual precaution until more effective remedies for such special problems have been developed through experimental work.

For this reason effort is made in this report to point out and to emphasize such phases as relate to efficiency in cleaning and to the prevention of injury. No attempt is made to cover the experimental work and results in detail, as a summary of the results obtained during the past season seems sufficient at this time.

Part I of the report deals with methods and processes of cleaning, with special reference to troublesome problems and features of cleaning. Part II pertains to the effects of cleaning on the fruit itself. Part III is a resumé of the work done on disinfectants in relation to the washing process.

PART I. CHEMICAL PHASES PERTAINING TO THE REMOVAL OF THE SPRAY RESIDUE FROM APPLES AND PEARS

By

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INTRODUCTION

This part of the bulletin deals with various chemical phases of the spray residue problem. Some of the discussions are based upon laboratory observations but most of them have been confirmed by practical commercial tests. While definite conclusions have been drawn and recommendations made, it must be kept in mind that one season only of practical experience has been gained, and necessarily with more experience the conclusions may be changed.

In the tables the data are presented to exemplify a condition. To avoid confusion and conserve space one only of a series of tests or analyses may be given in a table. Numerous other observations have been made in order to justify the conclusions.

The following discussion pertaining to the cleaning of fruit by the washing process assumes the use of hydrochloric acid as the cleaning reagent. All of the commercial washing machines operating in Oregon during the 1927 season used hydrochloric acid as the solvent. One type of machine on the market uses a warm solution of sodium carbonate and borax as the cleaning reagent. Since this machine did not operate in Oregon last season, we cannot give information gained by experience regarding it.

SPECIAL CONDITIONS THAT MAKE DIFFICULT THE REMOVAL OF THE SPRAY RESIDUE

During the harvest season of 1927, conditions that prevented the removal of the spray residue below the .01 tolerance were studied. It was apparent from the observations that most of the interfering conditions can be corrected if proper precautions are taken. The principal causes that prevent the removal of the residue by the washing process may be explained as follows:

1. **Wax secretions on fruit in excessive amounts coat the lead arsenate particles and prevent the effective removal of the residue by the acid treatment.** Wax forms on the fruit as it matures. If, therefore, the fruit is allowed to hang on the tree after the proper harvest time, or if it is stored at common storage temperatures, it ripens and the wax forms rapidly. As the wax develops on the surface of the fruit during the ripening process, it covers the lead arsenate particles and protects the latter from the solvent action of the acid or other washing solutions.

During the 1927 harvest season, the analyses of practically all varieties of apples showed that the early pickings were easily and effectively cleaned by the washing process. Later in the season the analyses showed ineffective cleaning, owing to the formation of wax on the fruit.

Invariably the lots of fruit that could not be cleaned were varieties that should have been harvested three or four weeks previously. Approximately 10 percent of the fruit harvested in Oregon during the past season analyzed above the .01 tolerance after it had been processed in the washing machine. Most of this was owing to the formation of wax that protected the residue from the solvent action of the acid.

If the fruit is harvested at the proper time and processed in the washing machine immediately after picking, no difficulty should be experienced from wax interference.

2. **Oil spray that remains on the fruit at harvest time likewise protects the residue from the solvent action of the acid and prevents effective cleaning.** When certain grades of oil spray, especially the heavier types of oil, are applied in combination with or after heavy applications of lead arsenate, the combined residue formed probably will last until harvest. The protective effects of the oil thus interfere with the removal of the residue. Especial care should be taken, if oil sprays are used, to select a recommended summer oil and use the smallest amount of lead arsenate possible consistent with satisfactory control. This information can best be obtained from the Agricultural Experiment Station or local branch station.

When oil-spray lead-arsenate combinations are not properly used and when applied too late in the season, the stem cavity of the fruit is filled with the combined residue, making it practically impossible to wash the fruit below the .01 tolerance. This applies especially to apples. Table I reports results that exemplify an excessive use of oil and lead arsenate sprays. The fruit was sprayed according to the following schedule:

Calyx May 14, lead arsenate 2 to 100.
First cover June 7, oil 3/4 to 100 plus lead arsenate 2 to 100.
Second cover June 24, oil 3/4 to 100 plus lead arsenate 2 to 100.
Third cover July 6, oil 3/4 to 100 plus lead arsenate 2 to 100.
Fourth cover August 2, lead arsenate 3 to 100.
Fifth cover August 22, lead arsenate 3 to 100.

The fruit sprayed in accordance with the above schedule was harvested October 1, or about three months after the last oil spray was applied. Portions of the fruit from each sprayed plot were washed in two different commercial washing machines. Analyses were made before and after washing the fruit. Table I reports the result of the analyses.

TABLE I. ANALYSES OF FRUIT SPRAYED WITH OIL-LEAD ARSENATE COMBINATIONS

Combination spray used	As_2O_3 on fruit before washing	As_2O_3 after washing in machine No. 1	As_2O_3 after washing in machine No. 2
	gr. per lb.	*gr. per lb.*	*gr. per lb.*
1. Lead arsenate + oil, medium ¾-100	.0961	.0571	.0661
2. Lead arsenate + oil, light ¾-100	.0524	.0255	.0179
3. Lead arsenate + oil, medium 1½-100	.1097	.0467	.0346
4. Lead arsenate + oil, light 1½-100	.0492	.0407	.0284
5. Lead arsenate + oil, medium 1½-100	.1152	.0464	.0179
6. Lead arsenate + oil, light 1½-100	.0488	.0165	.0192

It is apparent from the above results that fruit sprayed in accordance with this spray schedule could not be cleaned below the .01 tolerance. These observations emphasize the necessity of avoiding the excessive use of oil lead-arsenate spray combinations.

How near harvest the proper grade of oil sprays may be used without interfering with the removal of the residue cannot yet be definitely stated. This depends upon the grade of oil, weather conditions, and the amount of oil lead-arsenate spray used during the season. The orchardist is cautioned not to use oil-spray lead-arsenate combination on apples that have grown to such a size that the stem cavity will retain any spray run-off. The caked residue in the stem end of the apple causes most of the difficulty, and prevents effective cleaning.

The proper use of the correct grade of oil, however, should prevent complications in its effect upon the removal of the spray residue.

3. **Excessive spray deposits or large spots of residue on fruit cannot be removed below the .01 tolerance by processing once through the commercial fruit washing machine.** On account of heavy codling-moth infestation double strength spray combinations are sometimes used throughout the growing season. Occasionally an unnecessary late spray is applied. As a result, thick spots of the residue accumulate, especially in the calyx and stem end of the fruit. Since the cleaning of such heavily sprayed fruit requires a longer exposure to the solvent action of the acid, a second treatment through the washing machine is necessary. Barring complications resulting from wax formation, a second treatment in the washing machine is usually effective. This difficulty may, however, be avoided by the more rational use of sprays.

4. **Deposits of dust, sand, and other air-borne particles on the spray residue protect the latter, retard the solvent action of the acid, and prevent effective cleaning.** Where clean cultivation of the orchard is practiced and windy climatic conditions prevail, abnormal amounts of dust particles permeate the air. After an application of spray the dust settles on the wet fruit, and forms a tenacious film of residue. If air particles settle on wet spray after or during several spraying operations, the layer of residue may be so thick in the stem end of the fruit that the acid treatment in washing machines cannot dissolve the arsenate protected by the dust layer.

During the harvest season of 1927 it was found impossible to remove the residue from the stem end of a portion of the fruit grown in clean cultivated orchards. Apparently the apples, hanging in such a position that the stem end cavity retained excessive amounts of spray run-off and dust, were most difficult to clean.

At this time suggestions only can be made that may facilitate cleaning of the residue when protected by dust deposits.

Facilitating the removal of the residue by the use of various compounds. Of the conditions described above which influence the removal of the spray residue, the complications caused by dust deposits are most difficult to overcome. By the exercise of care the other conditions may be avoided. In order to learn whether the retarding action of dust on the removal of the residue could be overcome, controlled laboratory experiments were carried on in which various chemical combinations were used that might facilitate the solvent action of the acid.

In this study each of the various chemical compounds was mixed with the lead arsenate and sprayed upon the fruit as a combination spray. The sprayed fruit was then treated in hydrochloric acid to remove the residue in a similar manner to treatment of the fruit in the washing machine. In order to learn what combinations dissolved rapidly, the treatment in the acid was limited to one minute. Analyses were then made to ascertain how much of the arsenical residue still adhered to the fruit.

In another series of laboratory observations Celite dust was added to the combination spray of various compounds with lead arsenate to learn whether any of these combinations would facilitate the cleaning of the residue when the dust is present. The fruit treated in this manner was also washed in hydrochloric acid and analyses made to ascertain the effectiveness of any combination.

Table II reports the analyses before and after treatment in acid for the removal of the different combination residues.

TABLE II. ANALYSES SHOWING THE BENEFICIAL EFFECTS OF CERTAIN COMBINATIONS ON THE REMOVAL OF THE RESIDUE

Combination spray used	Length of treatment in acid	As_2O_3 before treatment	As_2O_3 after treatment
	minutes	*gr. per lb.*	*gr. per lb.*
1. Lead arsenate only, 2-100	1.0	.121	.051
2. Lead arsenate only, 2-100	1.0	.092	.038
3. Lead arsenate + $CaCO_3$, 4-100	1.0	.108	.003
4. Lead arsenate + $Ca(OH)_2$, 4-100	1.0	.087	.004
5. Lead arsenate + bordeaux, 4-4-50	1.0	.089	.003
6. Lead arsenate + com. bordeaux, 10-100	1.0	.084	.004
7. Lead arsenate + $Al_2(SO_4)_3$, 1-100	1.0	.078	.041
8. Lead arsenate + Na_2CO_3, 4-100	1.0	.098	.032
9. Lead arsenate + dust	1.0	.150	.060
10. Lead arsenate + dust + $CaCO_3$, 4-100	1.0	.147	.007
11. Lead arsenate + dust + $Ca(OH)_2$, 4-100	1.0	.132	.009
12. Lead arsenate + dust + bordeaux, 4-4-50	1.0	.108	.012

Only a part of about 40 combinations tested are reported in the above table. Most of these showed no improvement in facilitating the removal of the residue while others would be impractical for orchard use.

From the analyses it will be observed that where lead arsenate only was used, the short-time treatment did not clean the residue below the .01 tolerance. Where either calcium carbonate, hydrated lime, or bordeaux mixture was combined with the lead arsenate the residue dissolved very rapidly. Only a trace of the arsenical remained on the fruit after the short time treatment in acid. In combinations No. 7 and No. 8 aluminum sulfate and sodium carbonate were combined with the lead arsenate. These two combinations are included in the table to exemplify materials that apparently had no effect on facilitating the solvent action of the acid.

The combinations given in the lower part of the table contained Celite dust in the mixture. It will be noted that where lead arsenate and dust only were used six times the .01 tolerance remained on the fruit after treatment. When, however, calcium carbonate, hydrated lime, or bordeaux mixture were used in the combination, the fruit was cleaned effectively even in the abnormally short time treatment. No other combinations among the number tried facilitated the removal of the residue and the results obtained, therefore, are not reported.

In considering these results it must be kept in mind that the observations were carried on under controlled laboratory conditions. Although the fruit was kept a week before the acid treatment, the residue adhered loosely to the surface and could be wiped off easily. Necessarily residue in this physical condition would dissolve rapidly. Before final recommendations can be made in regard to the addition of any material, such as hydrated lime or bordeaux mixture, to the lead arsenate to facilitate the removal of the residue, orchard experiments must first be carried on to confirm the laboratory results. These tests will be made during the 1928 season and the results will be reported at the termination of the work.

Recommendation for the use of hydrated lime or bordeaux mixture. While definite recommendations cannot be made for the use of either hydrated lime or bordeaux to facilitate the removal of the residue, the benefits that may accrue from its use warrant the addition of one or two pounds to each 100 gallons of spray in the last two lead-arsenate applications. This amount will not reduce the toxicity of the arsenical nor cause spray injury. Also, if lime is used in the last cover spray, it may reduce calyx injury that often occurs in the various fruit districts of Oregon, owing to the formation of water-soluble arsenic after the early fall rains.

It is well to emphasize at this time that where lime may be used in the last two cover sprays to facilitate the removal of the residue, or to prevent calyx injury, or where bordeaux mixture is applied before harvest to control anthracnose, it is assumed that hydrochloric acid will be the solvent reagent used in the washing machine. It is questionable whether any solvent other than acid will remove effectively the residue where lime or bordeaux has been used in the combination spray. Several machines will be used in Oregon this season that employ a mixture of soda ash and borax as the solvent reagent. This solvent will not dissolve either lime or bordeaux mixture. Orchardists, therefore, who plan to wash their fruit in these machines are advised not to use lime or bordeaux spray in their spray combinations this season. Unquestionably neither lime nor bordeaux will facilitate the removal of the residue when a mixture of borax and soda ash is used as the solvent. On the other hand, field tests should be made to learn whether these materials will actually retard the solvent action of the soda ash and borax solution. These tests will be made during the coming season.

THE UTILIZATION OF WARM HYDROCHLORIC ACID TO FACILITATE THE REMOVAL OF THE SPRAY RESIDUE

A serious problem confronts fruit packers and orchardists who, for unavoidable reasons or through carelessness, have been unable to wash their fruit before wax forms. Both laboratory and field tests have been carried on in the endeavor to overcome the protective effects of wax that prevent the solvent action of the acid in the cleaning process.

Numerous tests were made using small amounts of wax solvents such as carbon tetrachloride, chloroform, gasoline, benzene, and others in the acid wash, in order to dissolve enough of the wax to expose the residue to the solvent effect of the acid. None of these tests, however, proved successful. Up to the present time most beneficial results have been obtained by the utilization of warm acid. The advantages and the limitations of the use of warm acid, as discussed below, should be carefully considered by the packing house operator and orchardist.

The advantages and the effectiveness of warm acid in the removal of the spray residue. The utilization of higher temperatures is beneficial for the removal of the residue in two ways. It accelerates the solvent action of the acid, and it tends to soften the wax and permits contact of the acid with the lead arsenate particles.

When a comparatively small amount only of wax has formed on the fruit and the arsenical residue is not excessive, the warm acid cleans fruit effectively while treatment at lower temperatures does not remove the residue below the .01 tolerance. Also tests have shown that when the fruit is very heavily spotted with spray it will be effectively cleaned by warm acid during the short time exposure in commercial washing machines, where otherwise it would be necessary to process twice if washed at lower temperatures. The results given in Table III exemplify the possibilities offered in the utilization of warm acid for the removal of the residue.

TABLE III. THE BENEFICIAL EFFECTS OF WARM ACID IN CLEANING THE SPRAY RESIDUE FROM APPLES

Variety	Condition	As_2O_3 before treatment	As_2O_3 after treatment at 70° F.	As_2O_3 after treatment at 95° F.
		gr. per lb.	*gr. per lb.*	*gr. per lb.*
Spitzenburg	No wax	.118	.014	.006
Newtown	No wax	.109	.012	.005
Spitzenburg	Medium wax	.086	.018	.005
Spitzenburg	Medium wax	.052	.013	.007
Jonathan	Medium wax	.079	.012	.004
Newtown	Medium wax	.068	.018	.008
Newtown	Medium wax	.096	.021	.008
Arkansas Black	Medium wax	.023	.008	.003
Arkansas Black	Medium wax	.042	.012	.004

The above results show unquestionably that acid between 90° and 95° F. will remove the residue from fruit more effectively than acid at lower temperatures. The condition of the fruit described as "medium wax" is relative only, and refers to the amount of visible wax. Apparently a medium amount of wax is not sufficient to surround the lead arsenate particles and protect them from the solvent action of the acid at 95° F. Furthermore, at this temperature the wax is softened and the mechanical force of the cleaning spray combined with the increased solvent effect of the warm acid cleans the fruit below the .01 tolerance.

Attention is called to the first two samples in the table where practically no wax had formed on the fruit. These samples were not cleaned at 70° F. mainly on account of the badly spotted condition which required a longer time exposure to clean at that temperature. Processing twice through the washing machine cleaned the fruit effectively. At 95° F., on the other hand, these samples were cleaned below the .01 tolerance by processing once.

Very waxy, heavily sprayed fruit cannot be cleaned by acid heated from 90° to 95° F. While the above results show the benefits derived from the use of warm acid, there are limitations to its practical use for removing the residue. First and most important is the possibility of injury to the fruit if allowed to stay in the acid longer than a certain time. As mentioned elsewhere, very waxy fruit is not injured as easily at high temperatures as fruit with little or no secondary wax. It is impossible, however, to judge the length of time very waxy or only medium waxy fruit may be exposed to higher temperatures without causing injury.

In addition to possible injury to the fruit from the use of warm acid, all lots cannot be cleaned effectively by the utilization of acid heated as high as 95° F. When fruit had been heavily sprayed, and excessive amounts of wax had formed before treatment, heating the acid did not remove the residue below the .01 tolerance. Table IV reports the analyses of waxy apples washed in commercial washing machines at the temperatures indicated.

TABLE IV. ANAYSES OF FRUIT NOT CLEANED BY TREATMENT IN ACID AT 90° - 95° F.

Variety	Condition	As_2O_3 before treatment	As_2O_3 after treatment at 70° F.	As_2O_3 after treatment at 95° F.
		gr. per lb.	*gr. per lb.*	*gr. per lb.*
Jonathan	Very waxy	.081	......	.014
Spitzenburg	Waxy	.070	......	.016
Spitzenburg	Very waxy	.056	.028	.026
Newtown	Waxy	.064	.027	.019
Newtown	Waxy	.072	.019	.011
Arkansas Black	Very waxy	.062	......	.014
Newtown	Oil sprayed	.053	.014	.012

The results in Table IV show clearly that some waxy fruit cannot be effectively cleaned by washing in acid heated to 95° F. Furthermore, it is difficult to judge from the waxy appearance of the fruit whether or not it can be cleaned with warm acid. Some lots that seemed very waxy were effectively cleaned while others apparently less waxy could not be washed below the .01 tolerance.

When a heavy spray schedule has been followed throughout the season especial care should be taken to wash the fruit at the proper time. The analysis of the Spitzenburg lot showed ineffective cleaning on account of this neglect. These apples were sprayed heavily and allowed to hang nearly three weeks after the proper harvest time.

The use of acid heated to 95° F. was also found ineffective for the removal of the residue where oil sprays had been improperly used. The apples designated "oil sprayed" in the table had received three applications of oil spray, the last one being applied July 6. The fruit was harvested three months later, and then treated in one of the commercial washing machines at 70° and 95° F. The results show ineffective cleaning at both temperatures.

Because all lots of waxy fruit cannot be effectively cleaned by the utilization of warm acid and because possible injury may follow the improper use of the heated solution, every effort should be made to clean the fruit before enough wax forms to prevent the removal of the residue at normal temperatures. If the fruit is harvested at the proper time and washed immediately after picking, or before the wax forms, this difficulty will be avoided.

The washing of cold storage fruit. During the rush of the harvest season the packer is sometimes unable to wash and dispose of fruit as rapidly as it is delivered to the packing house. Consequently, the fruit is often stored temporarily in the packing house or left piled up in the orchard until it can be handled. During this period of temporary storage wax develops very rapidly and soon forms in sufficient quantity to prevent the effective removal of the residue by the acid wash. In order to avoid this difficulty fruit may be stored temporarily at cold storage temperatures and washed at a more convenient time. Analyses of apples picked at the proper time, then placed immediately in cold storage, and washed later, have shown effective cleaning. Even after eight months' storage, acid at 63° F. cleaned Spitzenburg apples below the .01 tolerance. When fruit cannot be washed immediately after picking and cold storage space is available, the fruit should be stored temporarily and washed later.

The washing of fruit by the orchardist. The removal of the spray residue by acid treatment is a chemical process and more than ordinary care must be exercised to do the work satisfactorily. While the washing probably can best be done at the central packing house, there is no reason why the individual orchardist cannot successfully wash his own fruit, if he will carefully follow the directions outlined. There may be conditions that make it necessary for the orchardist to wash his own fruit if it is to be cleaned below the .01 tolerance. Under these circumstances one or a group of orchardists should obtain a small-type commercial washing machine. As the fruit is harvested each day it may be washed immediately after picking, without danger of complications.

The effect of "spreaders" and "deflocculents" on the removal of the residue. There are available on the market several brands of commercial spreaders, and a few commercial brands of arsenate of lead that contain so-called "spreaders" or "deflocculents." The deflocculents present in commercial arsenate of lead consist of a small amount of an organic colloid that tends to hold the arsenate in suspension and may have some spreading properties. The various commercial spreaders contain mixtures of skim milk powder, casein, and lime, or some other protein such as dried blood dissolved in an alkali. During the 1927 season conflicting reports and claims were made regarding the effect of these materials on the removal of the residue by acid treatment. No opportunity was afforded to obtain practical data by treatment in the commercial washing machines of fruit sprayed with the various spreaders. Controlled laboratory studies were made, therefore, to learn whether these materials retarded the solvent action of the acid.

Apples were sprayed with two applications of the various combinations and allowed to stand a week before treatment for the removal of the residue. Table V reports the data obtained.

TABLE V. THE EFFECTS OF COMMERCIAL SPREADERS AND DEFLOCCULENTS ON THE REMOVAL OF THE RESIDUE

Apples sprayed with combinations below	Length of treatment in acid	As_2O_3 before treatment	As_2O_3 after treatment
	minutes	*gr. per lb.*	*gr. per lb.*
1. Lead arsenate only, 2-100	1.0	.092	.038
2. Lead arsenate + commercial spreader No. 1	1.0	.071	.059
3. Lead arsenate + commercial spreader No. 1 + $Ca(OH)_2$, 2-100	1.0	.058	.003
4. Lead arsenate + commercial spreader No. 2	1.0	.062	.009
5. Lead arsenate + commercial spreader No. 2 + $Ca(OH)_2$, 2-100	1.0	.068	.004
6. Lead arsenate + commercial spreader No. 3	1.0	.072	.005
7. Lead arsenate + commercial spreader No. 3 + $Ca(OH)_2$, 2-100	1.0	.091	.004
8. Lead arsenate + casein-lime spreader, 2-100	1.0	.072	.006
9. Commercial lead arsenate No. 1 containing spreader	1.0	.088	.042
10. Commercial lead arsenate No. 1, containing spreader + $Ca(OH)_2$, 2-100	1.0	.076	.003
11. Commercial lead arsenate No. 2, containing spreader	1.0	.085	.050
12. Commercial lead arsenate No. 2, containing spreader + $Ca(OH)_2$, 2-100	1.0	.081	.009

From the above results it will be observed that the submersion treatment was for one minute only. The time of treatment was limited in order to emphasize the retarding effects of any of the mixtures.

In general, the results bring out the beneficial effects of the hydrated lime on the removal of the residue. The commercial spreaders No. 2 and No. 3 and the casein-lime spreader all contained some hydrated lime. As a consequence these mixtures dissolved very rapidly. The addition of more lime (2 to 100) slightly increased the solvent action of the acid.

Commercial spreader No. 1, however, had a pronounced retarding action. Further treatment for five minutes did not remove the residue below the .01 tolerance. Apparently this spreader cemented the lead arsenate particles together and prevented contact with the acid. When lime was added, however, the retarding effects were overcome and the residue was effectively removed in one minute's treatment.

Attention is called to the commercial lead arsenates which contain deflocculents. These arsenicals were removed in about the same time as the lead arsenate that contained no deflocculent. There may have been perhaps a very slight retarding action, owing to the limited protective effect of the deflocculent. The addition of hydrated lime to this class of arsenical also facilitates its removal.

The mechanical cleaning or wiping of lightly sprayed or dusted fruit. Data obtained during the past two seasons have shown conclusively that it is impossible to clean effectively, either by hand wiping or by machine wiping, fruit that shows much above the .01 tolerance. Also, as reported elsewhere in this bulletin and in a former report, injury to the fruit may result if the wiping method is followed.

In some districts very little spray is necessary for codling-moth control. Also, a few orchardists dust instead of spray. At harvest time a small portion only of the fruit from these orchards may show above the .01 tolerance. It may be advisable, therefore, to wipe fruit in this condition. Where more than a small portion is above the tolerance, it will be more economical to clean the fruit in the washing machine.

The number of spray applications necessary to exceed the .01 tolerance. It cannot be stated definitely how many sprays may be applied during the season and yet avoid the necessity of washing. This depends upon climatic conditions, the concentration of the sprays applied, and possibly the thoroughness of the job. Chemical analyses of the most heavily sprayed fruit, carefully selected from the orchard, will best indicate whether or not the fruit should be washed. It has been assumed by many that fruit sprayed with one calyx and one cover spray will not require cleaning. Table VI reports the analyses of fruit taken from several orchards that exceeded the tolerance after only the calyx and one cover spray had been applied during the season.

TABLE VI. ANALYSES SHOWING THE MINIMUM NUMBER OF SPRAYS THAT MAY BE OVER THE .01 TOLERANCE

Variety	Number of sprays	Concentration lead arsenate used	As_2O_3 on fruit
			gr. per lb.
Spitzenburg	Calyx and 1 cover	4-100	.011
Spitzenburg	Calyx and 1 cover	-------	.013
Ortley	Calyx and 1 cover	-------	.013
Ortley	Calyx and 2 covers	-------	.041
Newtown	Calyx and 1 cover	4-100	.013
Newtown	Calyx and 1 cover	4-100	.014
Mixed	Calyx and 1 cover	4-100	.029
Jonathan	Calyx and 1 cover	2-100	.007
Newtown	Calyx and 1 cover	2-100	.004

It will be observed that the residue exceeded the tolerance when the lead arsenate was used at the rate of 4 pounds to 100 gallons. The analysis of fruit from all orchards that had used a calyx and one cover spray, 2 to 100, was below the tolerance. Some orchards showed below the tolerance at 4 to 100. In order to insure a safe procedure regarding the advisability of washing, the most heavily sprayed samples should be collected in a survey of the orchard and analyzed shortly before harvest.

RECOMMENDATIONS PERTAINING TO THE SUPERVISION AND OPERATION OF THE COMMERCIAL WASHING MACHINE

The successful operation of any of the commercial fruit washing machines depends upon the care exercised by the person in charge of the washing process. Aside from keeping the machine well oiled and in good mechanical condition it is necessary that good judgment be exercised in controlling the various chemical phases. The correct acid concentration must be maintained; a good stream of fresh water must be kept running through the rinsing tank; the pressure at the pumps and pipes must be held constant; the pipes and screens should be cleaned as often as necessary; these and other duties should occupy the attention of one responsible person.

The following general directions and recommendations are given for the operation of the commercial washing machines. No difficulty should be experienced if these rules are carefully observed.

Precautions for handling acid. Commercial hydrochloric acid, commonly called muriatic acid, is the solvent reagent used in most of the commercial washing machines. This acid is shipped in glass carboys, holding about ten gallons of the concentrated acid. The carboys should be marked 20° Baumé. This is the equivalent of about 32.1 percent actual hydrochloric acid.

A carboy "inclinator" or "dipping rack" will be found convenient to aid in pouring the acid from the carboy. A syphon may be substituted for the inclinator but will be found slower.

A wooden bucket or porcelain pitcher or kettle holding about one gallon and marked accurately at each quart division should be used to measure out the acid.

Care should be exercised in handling the acid, since it will attack metal, cloth, and leather, unless neutralized immediately by soda or lime. Either soda, hydrated lime, or the carbonate of lime will be satisfactory. A package of baking soda or a bucket of hydrated lime in suspension in water, should be available to neutralize any acid spilled on the clothing or body.

The strength of acid to be used in the various commercial washing machines. During most of the season's operations the concentration of the acid should be 7 quarts of the concentrated acid to each 100 gallons of water, or about .5 percent actual acid. Early in the season before any traces of secondary wax are formed and where only a small amount of residue is present on the fruit, lower dilutions of acid will be effective in removing the residue. One gallon of the concentrated acid to each 100 gallons of water will be found satisfactory.

If conditions are complicated by the use of oil sprays, the formation of wax on the fruit, or abnormally heavy deposits of the spray over the fruit, an adjustment in the strength of the acid will be necessary. Under these circumstances more definite information should be obtained from the Agricultural Experiment Station or the chemist who may be assisting in the fruit washing program.

Instructions pertaining to the care of the acid tank. When the acid tank is filled for the first time water may be added and then the amount of concentrated acid necessary depending upon the capacity of the tank. Since the fruit carries away certain amounts of the acid, it will be necessary to replenish the tank at intervals. How often this will be required depends upon the amount of fruit put through the machine and the size of the acid tank.

The loss of acid solution should be compensated for by replenishing from a storage barrel. A 50-gallon wooden barrel having a wooden spigot attached at the bottom with a rubber hose connection to the acid tank, will be found convenient for this purpose. This reserve tank should contain slightly stronger acid than used in the washing machine acid tank. When .5 percent acid is being used, the reserve tank should have 2 gallons of the acid in 100 gallons of water, or 1 gallon of the concentrated acid to the 50-gallon barrel.

At times during the washing operations, influencing factors may require a careful watch for changes in the acid strength. For example, when wet fruit is put through the machine the acid will be diluted by this further addition of water and change the acid strength possibly to half the initial concentration after processing 500 boxes. If either lime or bordeaux has been used in any of the sprays, part of the residue on the fruit will react with the acid and lower the strength by neutralization. When such fruit is being processed in the washing machine, care should be taken to keep the acid strength up to the normal requirement. The exact acid strength of the solution in the tank may be determined by a simple, accurate method. A description of the apparatus and the procedure to follow for making the determination will be described below.

The acid tank of the washing machine should be drained at least every other day, and preferably each night. If the washing machine is operated continuously during the 24 hours, or during two shifts, the tank should be drained and washed out each day. An added precaution, possibly unnecessary, would be to spray the empty tanks, conveyors, and other parts of the machine with a strong solution of formaldehyde. Two gallons of the commercial formaldehyde to 100 gallons of water is sufficiently strong for this purpose.

Care of the rinse-water tank. The care of the rinse-water tank is most important. Neglect of this part of the washing operation may mean the loss of fruit from acid burn and from decay caused by decay organisms that might have been effectively washed off. A strong stream of fresh water should be run continuously in the far side of the water tank, and out of the side near the acid tank. It is preferable that some arrangements be made whereby the fresh water can be sprayed on the fruit as it leaves the rinsing tank. By this method all fruit leaving the machine will receive a spray of fresh water that has not recirculated through the rinse tank. Too much emphasis cannot be placed on the importance of this phase of the washing process.

Neutralizers for the wash water. If care is taken to wash off thoroughly all traces of acid by perfecting the rinse water washing system, it should be unnecessary to use any neutralizing chemical in the rinsing tank. When, however, very strong acid has been used in cleaning the fruit or if the fresh-water rinse system is ineffective, it may be advisable to add a neutralizing reagent to the water tank. For this purpose hydrated lime, calcium carbonate (very finely ground limestone), or sodium bicarbonate (baking soda), may be used. Last season sodium bicarbonate was used mainly. During the past year, however, laboratory experiments indicate that either hydrated lime or calcium carbonate may be preferable to the soda.

The amount of the neutralizing agent that should be used depends upon variable conditions. If very strong acid is used in cleaning the fruit, the neutralizer must be added more often. A large volume of fruit processed through the machine or rapid displacement of water in the rinsing tank will also require excess neutralizing reagents. For latest recommendations pertaining to the use of a neutralizing reagent write to the Oregon Agricultural Experiment Station or consult the operating chemist assisting in the fruit district.

Limestone for the neutralization of spilled acid. Cleanliness around the packing house is essential. Very often the strong acid or dilute acid from the acid tank has been spilled on the floor around the washing machine. After most of the water evaporates the hydrochloric acid is given off as a gas, which is irritating to workers and also causes rusting of any metal in the vicinity. If the floor is concrete the acid will attack the concrete. This damage may be avoided by the use of ordinary limestone. If the limestone is spread around the washing machine, or mixed with sawdust and spread upon the floor, it will immediately neutralize any acid that is spilled, and thus prevent the acid fumes. Limestone may be obtained from any seed or fertilizer dealer. Since it is very low in cost it may be used in large amounts with little expense.

Washing machines should not be overloaded. Each washing machine on the market has an estimated capacity which should not be exceeded. When this is done fruit must necessarily go through the machine in two or even more layers, which lowers the efficiency of the cleaning process. Besides not cleaning properly, the acid cannot all be effectively washed off as it goes through the rinse water. This precaution is especially necessary for the flotation type machine. If overloaded, the fruit may be submerged too far below the surface of the acid and the pressure may force acid through the calyx into the core of the apple. This would then cause decay of the fruit.

Fruit should not be left in the washing machine during rest periods or when it is necessary to discontinue operations. The machine should be run long enough, if possible, to allow the fruit to pass entirely through the machine.

A DESCRIPTION OF THE APPARATUS AND METHODS FOR THE DETERMINATION OF ACID STRENGTH

Any careful washing machine operator can determine the strength of the acid in the acid tank and maintain the desired concentration. The following equipment will be necessary:

- One 10 c.c. bulb pipette
- One 10 c.c. measuring pipette, graduated in .1 c.c.
- One 2-ounce bottle
- Standard sodium bicarbonate: 23.0 gram to 1,000 c.c. containing methyl orange indicator.

The pipettes may be obtained from any dealer in chemical apparatus. The standard sodium bicarbonate solution may be obtained from the Oregon Agricultural Experiment station or the local druggist if necessary. If obtained from the druggist, request should be made that the bicarbonate be dissolved in one liter (1,000 c.c.) of water, to which has been added enough methyl orange indicator to produce a good yellow color. The total equipment described above should not cost much more than $1.00.

Methods for determining acidity. In order to determine the strength of the acid proceed as follows:

Fill the bulb pipette with acid from the acid tank, drawing it into the pipette by suction. Let the excess acid flow out until even with the mark on the upper part of the pipette. Then allow the measured acid to drain into the two-ounce bottle.

Next fill the measuring pipette from the standard sodium bicarbonate solution. Adjust the level of the liquid with the 0.0 c.c. mark. Let flow slowly into the bottle containing the measured acid, shaking the bottle meanwhile. At the point where the color of the acid changes from red to yellowish, note the number of cubic centimeters (c.c.) of soda that has been used. This will indicate directly the percent acid strength.

For example, if 5.3 c.c. of the standard sodium bicarbonate were used to neutralize 10 c.c. of the acid, the strength of the acid would be .53 percent.

Precautions. Always use the bulb pipette for measuring out the acid and the other pipette for the soda. Rinse out the bulb pipette with the acid to be tested.

PART II. EFFECTS OF SPRAY RESIDUE REMOVAL ON THE KEEPING QUALITY OF APPLES AND PEARS

By

HENRY HARTMAN

Studies to determine the effects of spray residue removal on the keeping quality of apples and pears were carried on during the seasons of 1926 and 1927. Attention was given especially to the causes and prevention of such forms of injury as have resulted from cleaning by various methods. The data were obtained from laboratory experiments and from field tests in the various fruit districts of the state. More than 4,000 lots of fruit have been under observation in the course of these studies.

THE EFFECT OF CLEANING BY MECHANICAL MEANS

Cleaning by such mechanical means as wiping and brushing has resulted in injury under certain conditions.

Pears. In the case of pears, for example, mechanical cleaning, as practiced during the past two seasons, has caused injury of several types, and it is questionable whether pears should ever be cleaned by this method. Tender-skinned varieties, such as Comice, have frequently displayed serious discoloration as a result of mechanical cleaning. In some instances this trouble did not appear until the fruit had reached prime eating condition. Serious losses were sustained here and there from "pinhole rot," following brushing treatment, the bristles penetrating the epidermis and inoculating the underlying tissue with blue mold spores. This trouble was especially prevalent in Winter Nelis treated late in the season. The rough handling incident to mechanical cleaning was responsible for more or less bruising, and in the case of Anjou resulted in many stem punctures. Excessive loss of weight was encountered especially in the long keeping varieties. This frequently resulted in slack packs at the end of the storage period.

Apples. Injury from mechanical cleaning has been less pronounced with apples than with pears. So long as the treatment was not too severe, and so long as the fruit was kept at high humidities, no serious injury occurred. Wiped apples held at low humidities, however, showed excessive loss of weight at times. This was especially true of varieties such as Spitzenburg, when the fruit was stored without wrapping. Apparently the wax or "bloom" that is on the fruit at picking time has much to do with loss of weight in apples. If the original wax is removed or disturbed, the fruit, apparently, is subject to loss of weight, even though secondary wax comes on in abundance during storage. In some cases there was positive evidence that mechanical cleaning of apples resulted in the spread of decay organisms.

EFFECT OF WASHING

Washing, when properly done, results in no serious injury to the fruit. On the contrary, washing generally adds to the attractiveness of the product, and there is some evidence that under certain conditions it may contribute to keeping quality. It is true that serious difficulties with washing have been encountered, and that losses have been sustained. This was to be expected, however, since washing was undertaken on a huge scale with new and untried equipment and with but a few people who had had experience with the method.

HYDROCHLORIC ACID

Considered from the standpoint of effect on the fruit, no washing compound thus far tested has proved superior to weak solutions of hydrochloric acid. This compound has been used with equal success on both apples and pears. Since it is a non-oxidizing substance, it causes no discoloration in punctures or in the stem and calyx cavities. Fruit treated with hydrochloric acid presents a clean, attractive appearance. When used at temperatures below 90° F. this acid does not react with the wax or protective covering of the fruit. Consequently, the natural wax or "bloom" is not removed and excessive loss of weight does not occur. Hydrochloric acid is a volatile compound and disappears of its own accord in case rinsing has not been thoroughly done. There is no danger, therefore, that acid will be on the fruit when it is delivered to the consumer.

BASIC COMPOUNDS

Under ideal conditions it is possible to wash fruit with basic compounds, such as sodium hydroxide, without serious injury. The margin of safety, however, appears to be much smaller with bases than with hydrochloric acid. Such factors as strength of solution, temperature of solution, and length of treatment must be under control at all times if injury is to be avoided. Bases, as a rule, react with waxes and undoubtedly remove some of the protective covering. Darkening around the lenticels has been encountered in fruit treated with bases. This has been especially true in the case of red-blushed pears. Basic compounds tend to darken the russet on such varieties of pears as Bosc and Winter Nelis. Bases such as might be used in washing operations are non-volatile and consequently remain on the fruit in cases of improper rinsing.

THOROUGH RINSING NECESSARY

The work of the past season has again demonstrated that rinsing is a very important feature of washing operations. The washing solution must be removed if injury is to be avoided. This is especially true when fairly high acid concentrations are used. A trace of acid in the rinse bath apparently does no harm, but strong acid left in the calyx or stem cavities may result in considerable injury. To insure proper rinsing agitation of the water is necessary. A mere plunge into still water does not remove all of the acid. The best results have been obtained when the rinse water has been sprayed or sluiced on to the fruit. A fresh-water spray just as the fruit leaves the machine seems to be highly beneficial.

The effectiveness of rinsing can generally be determined by applying the tongue to the calyx end of the fruit as it comes from the machine. A sharp, biting sensation is experienced if all of the acid has not been removed.

USE OF NEUTRALIZING COMPOUNDS

It is somewhat difficult to determine at this time the role that neutralizing compounds should play in washing operations. Although washing, in the main, has been satisfactory without the use of such compounds there is reason to believe that they are desirable under certain conditions. This appears to be especially true in the case of apples washed with strong acid solutions and in cases where water is not available in quantity.

Good results have been obtained in an experimental way with lime used in small quantities in the rinse bath. There is but little doubt that lime brings about a quicker and more complete removal and neutralization of the acid. Lime tends to leave a slight white residue on the fruit, and to overcome this a fresh-water spray is necessary as the fruit leaves the machine. While lime appears to be perfectly safe on apples, there is some question regarding its use on pears, especially with the russet varieties. At any rate there seems to be no need of neutralizing compounds in the case of pears.

Baking soda (sodium bicarbonate) has been used as a neutralizing compound in the rinse bath. So far as neutralization of the hydrochloric acid is concerned, baking soda is highly satisfactory, but it is probably not entirely effective in preventing injury from such water-soluble arsenic as may be formed from the reaction of hydrochloric acid and arsenate of lead. Lime, on the other hand, seems to be more desirable in that it changes both hydrochloric acid and water-soluble arsenic into harmless compounds. Lime is also cheaper in price and appears to be easier to use.

EFFECT OF MOISTURE

Although the most satisfactory results have been obtained when the fruit has been dried before packing, no serious difficulties have resulted from the presence of small amounts of moisture on washed fruit. When rinsing has been thoroughly done, and when the residue has been removed, no injury has occurred that could definitely be attributed to water. There is a difference between washed and unwashed fruit in this respect. As will be noted later, fruit coated with arsenical residue is susceptible to injury if it remains wet for any length of time. The same is true of fruit that has not been properly rinsed. Acid left on the fruit is apt to be more injurious if drying is delayed. This has been especially noticeable in the case of apples washed in boxes where the cavities remained full of water for some time.

According to the observations of the past two seasons, moisture on the fruit at packing time has not consistently increased the amount of decay. A summary of the results obtained in 1927 shows 2.2 percent blue mold decay for the fruit packed dry and 1.7 blue mold for the fruit packed wet. The fruit packed dry shows 3.4 percent decay from anthracnose and perennial canker, while the fruit packed wet shows 3.9 percent decay from these organisms.

Some of the drying devices now in use are unsatisfactory in that they cause too much rough handling. Efforts in the development of drying equipment should be directed to the production of devices that necessitate as little handling as possible.

TABLE VII. MOISTURE IN RELATION TO BLUE MOLD DECAY IN APPLES

Variety	Kind of storage	Packing treatment	Date of examination	Number of apples examined	Percent blue mold decay
Yellow Newtown	Common	Dry	11/17/27	312	1.2
		Wet	11/17/27	315	.9
	Cold	Dry	2/15/28	862	.9
		Wet	2/15/28	578	.5
Spitzenburg	Common	Dry	11/17/27	192	2.6
		Wet	11/17/27	195	3.6
	Cold	Dry	2/15/28	179	4.4
		Wet	2/15/28	178	1.9

Fruit packed in a wet condition dries quite readily in both cold and common storage provided the relative humidity is not too high. It is perhaps wise to keep the humidity of storage rooms as low as possible during the time that wet fruit is being stored. Dry wrapping paper absorbs considerable moisture and in many instances fruit wrapped in paper actually dries faster than fruit put away unwrapped. This is true even when oiled wraps are used.

TABLE VIII. MOISTURE IN RELATION TO ANTHRACNOSE AND PERENNIAL CANKER DECAY IN APPLES

Variety	Kind of storage	Packing treatment	Date of examination	Number of apples examined	Percent anthracnose and perennial canker decay
Yellow Newtown	Common	Dry	11/17/27	994	1.2
		Wet	11/17/27	510	.4
	Cold	Dry	2/15/28	1138	1.6
		Wet	2/15/28	543	.3
Spitzenburg	Common	Dry	11/17/27	370	5.0
		Wet	11/17/27	379	8.1
	Cold	Dry	2/15/28	363	5.8
		Wet	2/15/28	371	7.3

EFFECT OF WARMED SOLUTIONS

The effect of warmed acid solutions on the keeping quality of fruit became a factor when heating was employed to facilitate cleaning of waxy fruit. So far as observed, no serious effects resulted from solutions below 110° F. provided the treatment was relatively short. Most of the observations with fruit subjected to warmed solutions, however, were made on fruit treated late in the season after considerable of the secondary wax had formed. There is still some question as to the effect of warmed solutions on newly harvested fruit, and until this is definitely known it will probably be best to wash such fruit only at the prevailing temperatures.

CORE PENETRATION

With the general adoption of the washing method, it became apparent that penetration of the washing solutions into the centers of open-cored fruits constituted a problem of considerable importance. This was

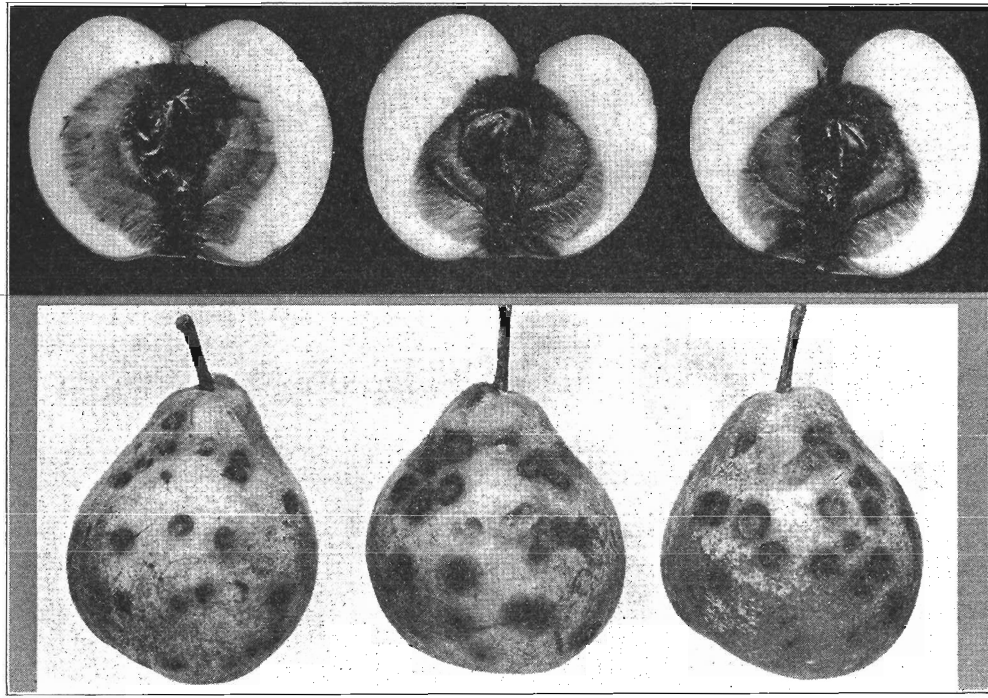

Fig. 1. Upper. Blue mold decay following acid penetration into open-cored apples. Lower. Blue mold or "pinhole rot" following severe brushing treatment.

especially true since core penetration in some cases was causing considerable core injury and decay.

Studies on core penetration were carried on throughout the past season. These studies have shown that injury from this cause is influenced by several factors and that erroneous conclusions may be drawn unless all of these are taken into account. It is safe to assume that the following factors, at least, have bearing on core penetration:

(1) Prevalence of open cores.
(2) Size of opening into the cores.
(3) Concentration of washing solutions.
(4) Length of washing treatment.
(5) Nature of washing treatment.
(6) Nature of rinsing treatment.
(7) Amount of contamination in washing and rinsing baths.

NATURE OF INJURY FROM PENETRATION

Injury from core penetration is manifested in several ways depending upon the extent of the penetration and the nature of the chemicals used. In the case of acid penetrations, mild cases of injury are characterized by discoloration of the calyx tube and the walls of the seed cavities. In the serious cases, decay from blue mold usually follows shortly after treatment. Occasionally it is caused by organisms other than blue mold. Formaldehyde penetration usually results in severe discoloration of the tissue including and surrounding the core. Decay, as a rule, does not follow formaldehyde penetration but may occur when formaldehyde and hydrochloric acid are used in combination. Penetration of strong basic compounds, such as sodium hydroxide, causes considerable injury, and, as in the case of acid, decay follows in many cases. Water penetration does but little damage, although the experimental data show a slightly higher percentage of blue mold decay following the entrance of water. Penetration of lime-water apparently results in no serious injury.

CORE PENETRATION AS INFLUENCED BY THE METHOD OF WASHING

It is now recognized that some penetration occurs no matter what method of washing is employed. With most methods, however, the amount of penetration is negligible and practically no damage results. Serious injury from penetration has been confined almost entirely to cases where the deep submersion method was employed. Depth of submersion and length of treatment materially affect penetration. Submersion for five minutes at depths of twelve inches or more practically fills the centers of all open-cored fruits and in such cases decay usually follows. Even at depths of three and four inches much penetration occurs if the treatment is continued for any length of time. The practice of washing in boxes, especially when the boxes are completely submerged, results in considerable penetration.

No great amount of penetration has been noted when the fruit was floated on the surface. When the flotation method is used, however, the fruit should travel through the machine in a single layer and the length of treatment should not be extended beyond the time required for cleaning. Occasional submersion just beneath the surface for a few seconds does not seem to cause a great deal of penetration. Washing by the spraying and sluicing methods has resulted in no serious injury from penetration, provided the length of treatment has not been too long. If the spraying and sluicing treatment is extended to several minutes, considerable penetration may occur.

PENETRATION AFFECTED BY STRENGTH OF SOLUTIONS

The severity of the injury from penetration is influenced to a considerable extent by the strength of the solutions used. Hydrochloric acid used at the rate of three gallons per hundred causes much more penetration injury than when used at the rate of one gallon per hundred. This doubtless accounts for some of the variation in results from deep submersion last season.

PREVALENCE OF OPEN CORES

Attempts to ascertain the prevalence of open cores in varieties of apples have resulted in no very definite conclusions. Some lots within a variety often revealed a high percentage of the trouble, while other lots of the same variety were comparatively free from it.

The larger sizes usually showed a higher percentage of open cores than the smaller sizes of the same varieties. This fact is shown by Tables IX and X which indicate the relation of size of fruit to the prevalence of open cores in Jonathan and Tompkins King.

TABLE IX. THE RELATION OF SIZE OF FRUIT TO THE PREVALENCE OF OPEN CORES IN TOMPKINS KING APPLES

Sizes	Percent open cores
150 and smaller	4.0
150 to 100	15.1
100 and larger	21.3

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

Sizes	Percent open cores
150 and smaller	6.2
150 to 100	11.4
100 and larger	36.8

Trees bearing light crops usually show a greater number of open cores than do the trees bearing full crops. Ortley of the "sheepnose" type is practically all open-cored. Even well-formed Ortley shows a high percentage of the trouble. Grimes, Winesap, Newton, and Rome are usually free from it except in the very large sizes. Jonathan, Spitzenburg, Gravenstein, and Delicious, on the other hand, reveal many open-cored specimens.

Practically no open cores were found in pears. Apparently it is safe to assume that the commercial varieties of pears are free from this defect.

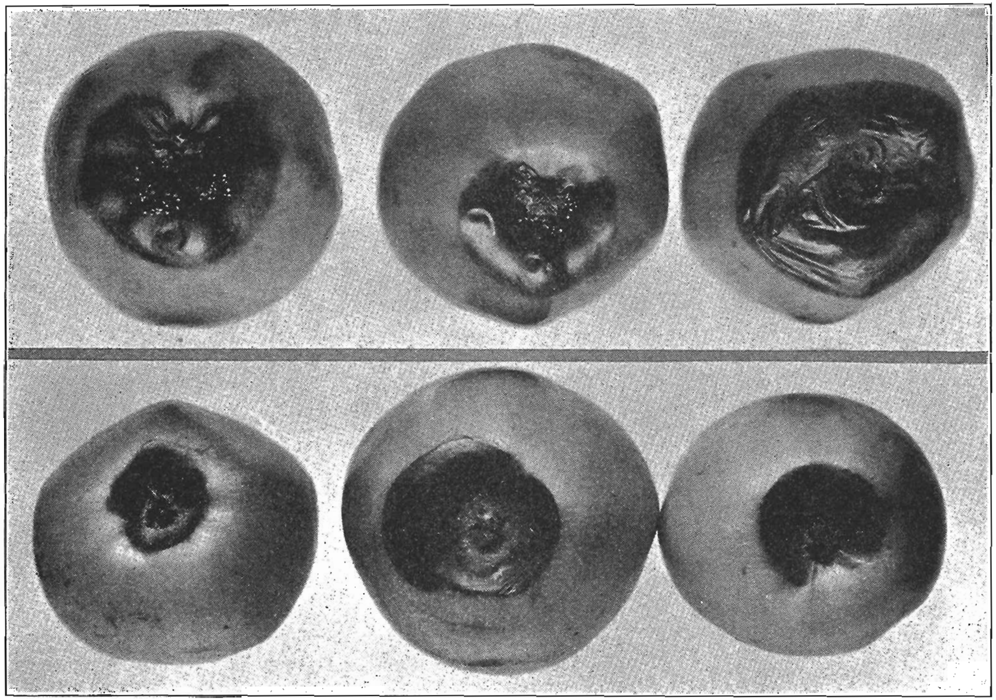

Fig. 2. Upper. Blue mold decay following calyx injury from deep submersion.
Lower. Perennial canker decay following calyx injury from arsenic.

CALYX INJURY

It now appears that calyx injury in apples is generally of two kinds: (1) that caused by solvents and (2) that caused by soluble arsenic.

Calyx injury from solvents. Calyx injury from hydrochloric acid and other solvents occurred here and there during the past season. This injury when visible from the outside appeared as tan-colored areas involving the calyx lobes and surrounding tissue. Frequently the injury was confined to the calyx tube and could not be detected from outward appearances. With continued storage the injured areas became darker in color and not infrequently became infected with blue mold. Occasionally they became infected with anthracnose and perennial canker.

Calyx injury from acid appears to be due almost entirely to improper rinsing. Any method of washing that leaves strong acid in the calyx region is apt to cause this type of injury. Calyx injury in apples has been quite common following the deep submersion method of washing. This method seems to saturate the calyx region with acid and makes thorough rinsing impossible. The length of the washing treatment and the strength of solutions used affect calyx injury to a considerable extent.

TABLE XI. THE RELATION OF DEPTH OF SUBMERSION TO CALYX INJURY AND CALYX DECAY IN CLOSED-CORED APPLES

Yellow Newtown — Common Storage

Lot No.	Depth of submersion (inches)	Acid concentration	Length of treatment (minutes)	Percent calyx injury	Percent calyx decay
		%		%	%
1	check	.66	5	0.0	0.0
2	floatation	.66	5	0.0	0.0
3	4	.66	5	5.2	10.6
4	8	.66	5	10.8	7.1
5	12	.66	5	14.0	17.8
6	18	.66	5	12.1	11.3
7	24	.66	5	21.0	18.4
8	48	.66	5	17.5	19.3
9	60	.66	5	24.4	16.2

TABLE XII. THE RELATION OF DEPTH OF SUBMERSION TO CALYX INJURY AND CALYX DECAY IN CLOSE-CORED APPLES

Variety	Treatment	Percent calyx injury	Percent calyx decay
		%	%
Newtown	Submerged 1 inch for 5 minutes in .66 percent acid solution..........	.0	3.1
Newtown	Submerged 60 inches for 5 minutes in .66 percent acid solution	31.0	27.5
Winesap	Submerged 1 inch for 5 minutes in .66 percent acid solution..........		
Winesap	Submerged 60 inches for 5 minutes in .66 percent acid solution	13.0	27.1

Calyx injury from arsenic. As already announced by Fisher and others, soluble arsenic is probably a common cause of calyx injury in apples. From casual observations this type of injury differs from acid injury in that the affected portions are dark in color even in the early stages. Under the conditions that exist in certain Oregon districts arsenic injury is frequently followed by decay from perennial canker and anthracnose. Occasionally it is followed by blue mold. The so-called "calyx end rot" of past years was apparently a combination of arsenic injury and decay.

It now appears that arsenic injury may occur whenever apples that are coated with arsenical residue become wet either before or after picking. The prevalence of this trouble during the past season was undoubtedly associated with the extended rainy weather that prevailed preceding and during harvest.

The results of the past season show that arsenic injury after picking was eliminated to a large extent by prompt and efficient washing, which removed the residue from the fruit.

There is some evidence that soluble arsenic accumulating in the washing solution may cause calyx injury at times. This appears to be true especially when the soluble arsenic content of the solution becomes high from continued use and when rinsing has not been thoroughly done. Difficulty from this source, however, seems to be eliminated by frequent change of the washing bath and by efficient rinsing. The use of lime in the rinse tank, also, seems to aid in eliminating this trouble.

TABLE XIII. THE EFFECT OF LIME-WATER ON CALYX DECAY IN APPLES WASHED WITH STRONG ACID SOLUTIONS

Yellow Newtown—Common storage

Rinsing treatment	Acid concentration	Length of acid treatment (minutes)	Percent calyx decay
	%		%
Rinsed with water	1.5	5	12.5
Rinsed in lime-water followed by fresh water	1.5	5	0.0

ACID BURNING

Acid burning on the faces of the fruit has rarely occurred as a result of washing. When acid burning did occur it could usually be traced to carelessness, such as leaving the fruit in the machine during the noon hour or allowing the pipes in the rinsing section to become clogged. Occasionally it occurred when the fruit was placed in boxes that were saturated with acid solution.

EFFECT OF WASHING ON MATURITY

The statement has been made at times that washing tends to hasten maturity. To obtain information on this factor, a large number of tests were conducted with both apples and pears in 1926. The results of these tests reveal no consistent difference in the rate of maturity of washed and unwashed fruit. The washed fruit did not ripen faster than did the unwashed fruit.

BRUISING IN WET FRUIT

Some apprehension existed last season over the possibility of injury to fruit handled while in a wet condition following the washing treatment. This fear was based on the observation made in past years that apples which have stood in the rain tend to become turgid and are susceptible to bruising. Injury of this nature, however, has not been a factor in washed fruit. The length of the washing treatment, apparently, is so short that turgidity is not increased to any extent.

DECAY IN WASHED FRUIT

At the beginning of the past season some apprehension existed regarding the possibility of decay following the washing treatment. It was feared that with repeated use the baths might become contaminated and thus afford a means of dissemination for decay spores. While losses from decay have occurred here and there, it now appears that washing done with proper equipment and under reasonably sanitary conditions does not consistently increase the percentage of decay. There is considerable evidence, in fact, that washing may bring about a reduction of decay under certain conditions.

A summary of the results obtained with commercial and experimental lots during the past season shows 2.9 percent blue mold decay in the unwashed fruit while the washed fruit shows 2.7 percent decay from this cause. The data on decay from anthracnose and perennial canker show that on the basis of the total number of infections the unwashed fruit developed 9.5 percent decay while the washed fruit developed only 2.5 percent decay. This was aside from calyx decay following arsenic injury, which was severe in the unwashed fruit but practically negligible in the washed fruit.

TABLE XIV. THE EFFECT OF WASHING ON BLUE MOLD DECAY IN APPLES (COMMERCIAL AND EXPERIMENTAL LOTS)

Treatment	Number of lots under observation	Number of apples examined	Percent blue mold decay
			%
Unwashed	61	3231	2.9
Washed	107	5342	2.7

TABLE XV. THE EFFECT OF WASHING ON PERENNIAL CANKER AND ANTHRACNOSE DECAY IN APPLES

Variety	Kind of storage	Date of examination	Treatment	Number of apples	Number of infections
Spitzenburg	Common	11/17/27	Unwashed	340	102
			Washed	373	21
Spitzenburg	Cold	2/15/28	Unwashed	360	70
			Washed	352	28
Yellow Newtown	Common	11/17/27	Unwashed	1014	65
			Washed	1077	10
Yellow Newtown	Cold	5/29/28	Unwashed	694	67
			Washed	739	36

CONTAMINATION OF BATHS

It is true that the washing and rinsing baths do become contaminated with spores by repeated use. This is true not only when rotted fruit goes through the machines but even with clean fruit the spore population of the baths increases during the day's run. It appears, however, that spores in either the washing or rinsing bath are not particularly harmful, especially if the fruit is subjected to a thorough spray of clean water as it leaves the machines. As further precaution it is well to keep the baths as clean as possible by frequent renewal and by avoiding the passage of contaminated fruit through them.

The condition of the fruit at the time of treatment has material bearing on the possibility of infection from washing solutions. Fruit that is free from cuts and other types of physiological injury is practically immune to infection while fruit that is firm and in good condition is much less susceptible to infection in punctures than fruit that is soft and overripe.

CAUSES OF DECAY IN WASHED FRUIT

The serious cases of decay that have occurred here and there in washed fruit were undoubtedly due to several causes. Deep submersion, as already pointed out, was responsible for the trouble in many instances. Decay from this cause occurred in both open- and closed-cored apples. Improper rinsing has been responsible for decay, since calyx injury from acid and from arsenic is frequently followed by blue mold, perennial canker, or anthracnose. Rough handling prior to and during the washing treatment has undoubtedly increased decay at times.

WAX DEVELOPMENT

The matter of wax development on apples and pears is of special significance owing to the difficulties that waxy fruit presents from a cleaning standpoint. Wax is a normal constituent of the epidermis of most deciduous fruits, and undoubtedly contributes to keeping quality.

From the standpoint of time of development wax on apples and pears is of two distinct kinds. First, there is the primary wax or "bloom" which is on the fruit at picking time; and, second, there is the secondary wax which usually comes on after harvest and which is definitely associated with the ripening process. So far as observed the difficulties in cleaning have been confined entirely to apples covered with secondary wax. Although apples picked at the proper time are usually quite free from secondary wax, they soon become waxy if held at prevailing temperatures. Apples placed in cold storage immediately after picking usually remain fairly free from wax for some time.

Wax development varies considerably with varieties. In the case of apples, Arkansas Black, Winesap, and Spitzenburg are inclined to become very waxy. Most varieties of pears develop but little secondary wax. Bartlett usually becomes quite waxy as it turns yellow but in the main the wax problem in the case of pears is negligible.

WASHING SHOULD BE DONE PROMPTLY

The experiences of the past season have again demonstrated that it is best to wash immediately after picking. Aside from the difficulties of cleaning fruit after heavy wax development has taken place there are several reasons why washing should not be delayed. Drying conditions are usually more favorable early in the season. There is less possibility of contamination if the fruit is washed while in good physical condition. There is, also, less possibility of mechanical injuries such as bruises and stem punctures. If arsenic injury after picking is to be avoided it is essential that the residue be removed promptly. Fruit washed at picking time usually presents a more attractive appearance than that washed while in a waxy condition. Dirt and decay spores are more easily removed early in the season.

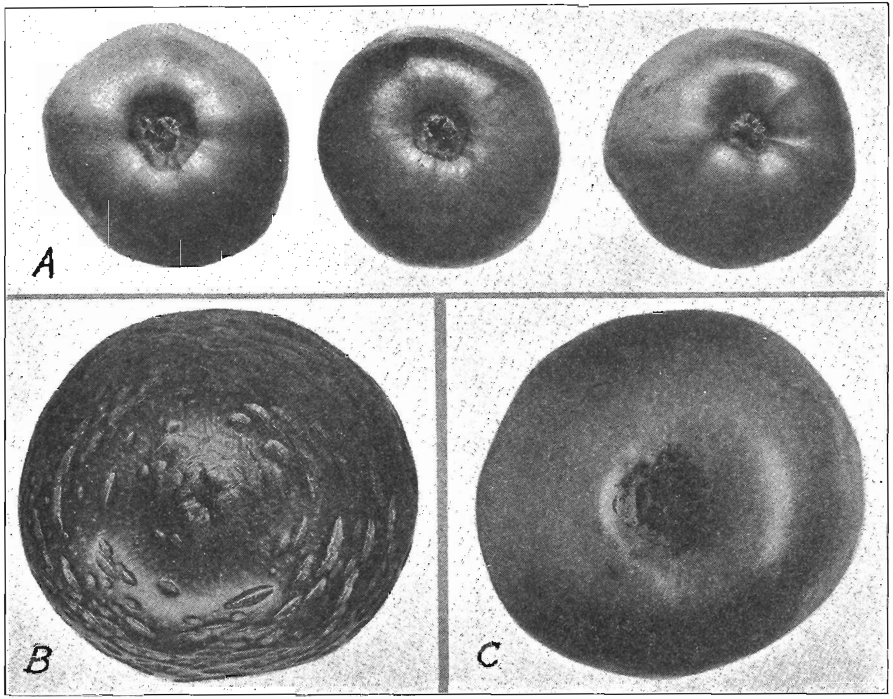

Fig. 3. (A) Calyx injury from improper rinsing. This type of injury is often followed by decay.
(B) A severe case of acid burning. This apple remained in the acid bath for several hours.
(C) Brownish residue resulting from rinsing with unclean water.

PART III. DISINFECTANTS

By

HENRY HARTMAN and S. M. ZELLER

A great deal of work was done during the past two seasons with the aim of finding disinfectants that might be used in connection with the washing process. It was hoped that some substance might be found that would tend to keep the baths free from contamination and that might destroy, in part at least, such spores as may be attached to the fruit as it travels through the washing machines.

A large number of tests were carried on, under both field and laboratory conditions. Many compounds, including all the common disinfecting agents, were tried in various ways and in various combinations. More than 3,000 lots of fruit treated with disinfectants were under observation during the two seasons.[1]

In the early experiments such chemicals as formaldehyde and certain boron compounds offered some promise. The laboratory tests with these materials, in fact, were very encouraging. When tried under field conditions, however, the results have been less satisfactory and no compound thus far tested has been found to be thoroughly effective under the conditions imposed by washing when done on a commercial scale. A summary of the results obtained with formaldehyde on commercial lots of apples shows 3.9 percent decay from all causes in the fruit washed with hydrochloric acid alone, and 3.8 percent decay in the fruit washed with hydrochloric acid and formaldehyde. While some lots showed a reduction in blue mold decay none of the lots showed a reduction in decay from anthracnose and perennial canker.

There are probably several reasons why disinfectants have not been effective under practical conditions. First, infection, in many instances, has already started before washing takes place, and disinfectants apparently are powerless in arresting decay in such cases. Second, the length of treatment and the strength of solutions permissible are insufficient to destroy such spores as may remain attached to the fruit. The fact that disinfectants must be removed from the fruit as part of the washing treatment undoubtedly reduces their effectiveness. Third, while the spores that are washed off into the solutions may in time be killed by disinfectants, viable spores are present from the supply that is constantly coming in. Fourth, the chances of reinfection following the washing treatment nullify the effects of disinfectants in many cases.

EFFECT OF DISINFECTANTS ON THE FRUIT

Disinfecting compounds such as formaldehyde, boric acid, and borax, when used moderately cause no serious injury to apples and pears. In case rinsing is not thoroughly done, however, formaldehyde may cause calyx injury and pitting around the lenticels, especially on newly harvested apples. When used at high concentrations formaldehyde causes considerable darkening of the tissues in stem punctures and other abrasions. At times this injury extends for some distance into the flesh. Formaldehyde penetration into open-cored fruits causes severe discoloration.

[1]A full report by S. M. Zeller covering the work on disinfectants is to be published at a later date.

It now appears that at ordinary temperatures formaldehyde could not be used in the acid bath at strengths greater than two quarts of commercial formalin per hundred gallons of solution. At temperatures approximating 100° F. the concentration would probably have to be reduced to one quart per hundred. Formaldehyde could not be used in the rinse water under any condition.

OBJECTIONS FROM HEALTH STANDPOINT

There are some objections to the use of formaldehyde in that fumes from it may be obnoxious to workers around the machines. This is especially true when it is used in the spray or sluicing types of machines where some of the formaldehyde is atomized into the air. It is much less objectionable when used in machines of the flotation type.

ACKNOWLEDGMENTS

The authors have been assisted in the work of the past season by other members of the Station staff, and by some commercial organizations. Among those who have rendered valuable aid are: Leroy Childs, W. S. Brown, J. S. Jones, J. W. Thaanum, Hood River Apple Growers Association, Rogue River Valley Fruit Growers League, and others.

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