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# REMOVAL OF SPRAY RESIDUE FROM APPLES AND PEARS IN THE PACIFIC NORTHWEST

By H. C. DIEHL, *Associate Physiologist, Office of Horticultural Crops and Diseases,* D. F. FISHER, *Senior Pathologist, Office of Horticultural Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture;* HENRY HARTMAN, *Associate Horticulturist, Oregon Agricultural College Experiment Station;* J. R. MAGNESS, *Horticulturist, State College of Washington Agricultural Experiment Station;* and R. H. ROBINSON, *Chemist, Oregon Agricultural Experiment Station*[1]

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## INTRODUCTION

Although not all of the problems involved in the removal of spray residues from apples and pears in the Pacific Northwest have yet been solved, it is now possible to form certain conclusions based on the experimental work and commercial experience of the past two years and to derive from them suggestions for future procedure.

The removal of spray residue may be divided into two phases: (1) The actual cleaning of the fruit and (2) the influence of cleaning treatments upon fruit injury and storage diseases. Although the former is the ultimate objective, it can not be attained satisfactorily unless the latter is given proper consideration.

Both aspects of the problem have been investigated at the laboratories of the Bureau of Plant Industry at Wenatchee, Wash., and by the State agricultural experiment stations of Oregon and Washington.

[1] Joint contribution from the United States Department of Agriculture, the Oregon Agricultural College Experiment Station, and the State College of Washington Agricultural Experiment Station. Prepared by the writers in cooperation from the results of their independent investigations. The names of the writers are arranged in alphabetical order without reference to seniority or their contributions to the preparation of this circular.

The investigations have been conducted throughout with the purpose of devising safe methods for cleaning apples and pears satisfactorily to the world tolerance of 0.01 of a grain of arsenic as arsenic trioxide per pound of fruit. The suggestions in this circular are made with this tolerance in view.

The summarized suggestions for the removal of spray residue from the fruit will be given under the following headings: (1) General aspects of spray-residue removal, (2) cleaning fruit by wiping or brushing, and (3) cleaning fruit by solvent methods.

## GENERAL ASPECTS OF SPRAY-RESIDUE REMOVAL

Plans for cleaning spray residue from the fruit should start with the beginning of the spraying program.

Experience has shown that there are a number of important variables which may affect the quantity and character of the spray residue on the fruit at harvest time. Among them are the type and concentration of lead arsenate used, the materials used in combination with the lead arsenate, the method and dates of applying the sprays, and the weather conditions through the season.

The number of applications and the strength of arsenate of lead used should be reduced to the minimum required for the satisfactory control of the codling moth. In this connection, the attention of growers in Washington is referred to the spray recommendations prepared for that State in 1928 by the representatives of the Washington Agricultural Experiment Station, the United States Bureau of Entomology, and the Washington State Department of Agriculture. Growers in Oregon are referred to Extension Bulletin 403 (1928 revision) on the orchard-spray program for Oregon.[2]

In a general way, experience has shown that in the Pacific Northwest apples and pears sprayed more than three times with lead arsenate in concentrations of not over 2½ pounds to 100 gallons of water will usually require a washing treatment in order consistently to reduce the quantity of arsenic in the spray residue below the world tolerance for arsenic.

The greater the number of applications and the later in the season these applications are made the greater will be the quantity of spray residue on the fruit at harvest time and the more difficult will be the cleaning problem.

The use of spreaders with the lead arsenate in spraying has not resulted in making the residue more easily removed by washing methods unless the spreaders contained hydrated lime. Even then the results have not always been consistent. The dry cleaning of fruit seems to be slightly facilitated by the use of spreaders with the lead arsenate, mainly because of the smaller number of heavy blotches of residue on the fruit.

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 will generally interfere with cleaning. The proper use of the correct type of oil with the lead arsenate should prevent difficulty in satisfactorily washing fruit in

[2] MOTE, D. C., and ZELLER, S. M. ORCHARD SPRAY PROGRAM FOR OREGON. 1928 REVISION. Oreg. Agr. Col. Ext. Bul. 403, 22 p., illus. 1928.

efficient equipment. Dry cleaning is not generally facilitated by the use of combined lead-arsenate oil sprays. In some districts, however, through the use of oil the quantity of lead arsenate may be reduced sufficiently so that the arsenic of the residue on the fruit at harvest time will be below the required tolerance.

Definite recommendations can not be made at this time for the use of either hydrated lime or Bordeaux mixture in the sprays to facilitate the removal of residue at harvest time. There is a possibility, however, that the addition of 1 or 2 pounds of hydrated lime to each 100 gallons of spray in the last two spray applications will facilitate residue removal and may reduce the arsenical calyx injury that often occurs in some fruit districts owing to the formation of water-soluble arsenic on the fruit after the early fall rains.

It is assumed that in such cases the solvent used in the washing treatment will be hydrochloric acid, because it is questionable whether any other solvent than acid will remove the residue more effectively when lime or Bordeaux mixture have been used in combination sprays.

When commercial fruit-cleaning plans were first made, the opinion was that a grower could determine his cleaning procedure from the number of cover sprays applied to the fruit. Experience has shown that this is not possible, except in a very general way. Examination of the fruit by chemical means offers the only reliable basis for determining whether fruit sprayed with arsenicals requires cleaning to meet any tolerance that may be in force.

The maturity of the fruit has a marked influence upon the facility with which it can be cleaned by any method. The development of waxy or oily materials on the surface of the fruit which may make satisfactory cleaning difficult apparently takes place throughout the growing season, but it becomes very noticeable particularly after harvest on some varieties of apples, such as Winesap and Arkansas Black, as the fruit approaches a ripe condition. As the maturing fruit becomes softer it is also more subject to injury by mechanical means and provides a greater possibility for decay development. The suggestion to be made in this connection is a simple one: The sooner the fruit is cleaned after it is picked the more easily the cleaning can be done and the less risk of damage there is to the fruit. In any event, fruit should be cleaned before it has passed the firm stage of maturity. To accomplish this the following factors should be considered:

(1) Harvesting the fruit at the proper stage of maturity; (2) coordination of the picking and packing operations as much as possible, so that the harvested fruit will be subjected to a minimum of delay before it is cleaned and packed; and (3) holding the fruit in the coolest space available, preferably in cold storage, if cleaning and packing are unavoidably delayed after it has been picked.

Commercial experience has demonstrated that when proper precautions are taken fruit can be washed or dry cleaned in such a manner as to cause no commercially significant increase in decay or deterioration in storage. It has demonstrated that certain cleaning practices and certain types of equipment are not suitable for cleaning fruit. When these are avoided and sanitary conditions are provided

against the spread of decay, the cleaning becomes practical and desirable from the standpoint of marketing attractive fruit.

Not all varieties of apples can be cleaned with equal facility. In a general way, practical experience as well as experimental results have shown that the important apple varieties of the Pacific Northwest, when cleaned immediately after they have been picked, ranged themselves about as follows in the order of difficulty of cleaning: Esopus Spitzenburg, Arkansas Black, Winesap, King David, Delicious, Stayman Winesap, Jonathan, Yellow Newtown, Rome Beauty, and Winter Banana. The relative rank of different varieties with reference to ease of cleaning has been about the same for washing as for dry cleaning.

In order to be commercially practicable from a cleaning-efficiency standpoint, any type of equipment must have a considerable factor of safety. By this is meant that such equipment should be able to clean fruit satisfactorily to the required tolerance, while operated at moderate speeds and without the necessity for frequent repairs and adjustments, and that it should do this with a minimum of rough handling and mechanical damage to the fruit. A thorough study of cleaning methods should be made before spray-residue removal is attempted.

Decayed fruit should be sorted from sound fruit that is to be cleaned by any method. It is obviously unwise to risk a heavy contamination of the equipment by decay organisms.

Considering the elements of cost, relative cleaning efficiency, handling of the fruit, and tonnage capacity, it may be said that almost invariably the best dry-cleaning methods are neither so economical nor so satisfactory as suitable washing methods. Where fruit is cleaned primarily to improve its appearance, dry methods will be quite satisfactory.

## CLEANING FRUIT BY WIPING OR BRUSHING

The first commercial efforts to remove spray residue from apples and pears were made with dry-cleaning methods. These seemed to be the most simple and convenient and did not involve many changes in the methods of handling the fruit. During the past two seasons a comparative study has been made of the cleaning efficiency to be obtained with the dry-cleaning equipment in commercial use in the Pacific Northwest. The experimental results have been supplemented by observations made under many different packing-house conditions and covering practically all of the important varieties of apples and pears.

Special attention was devoted to four typical and relatively successful dry cleaners herein described.

### DRY-CLEANING APPARATUS

#### REVOLVING-BRUSH CLEANER

The fruit was carried along either on revolving brushes or upon a narrow belt conveyor while the cleaning was done by brushes rapidly revolving overhead in such a way that the bristle ends swept the surface of the fruit.

#### CLOTH WIPER

The fruit was carried forward on a roller conveyor which imparted a turning motion to the fruit as it passed under the rapidly moving cloth disks or flappers.

#### OSCILLATING-BRUSH CLEANER

The fruit was borne on a perforated-belt conveyor on which the individual fruits were kept from contact with each other. The oscillating motion of the long brushes on each side of the conveyor rapidly passed the fruit back and forth between them as it moved along and thus brought the surface of the fruit in contact with these brushes as well as with a similar brush overhead.

#### COMBINATION OF BRUSH CLEANER AND CLOTH WIPER

The fruit was first conveyed through a revolving-brush cleaner of the type described above. It was then carried forward on long rollers, spirally wound with rope, while cloth flappers were rotated rapidly above the fruit in contact with it and in a direction across its path.

### LIMITATIONS OF DRY-CLEANING METHODS

These observations and experiments have led to the following conclusions and suggestions with respect to the dry cleaning of apples and pears.

As a general conclusion it may be said that the methods of dry cleaning in commercial use, under the best conditions, can not consistently remove from apples more than about 30 per cent of the original quantity of spray residue on the fruit when the residue analysis on uncleaned fruit showed not more than 0.04 of a grain of arsenic trioxide per pound.

The average efficiency obtained for all varieties of apples with the four typical dry-cleaning methods under observation ranged from 15 to 35 per cent. This fact indicates that dry cleaning, as a rule, will not be satisfactory for apples having an original residue content above 0.015 of a grain per pound, even when there are no complicating factors involved in the cleaning.

With smooth-skinned pears, a slightly higher efficiency can generally be obtained. From a handling standpoint, however, dry cleaning is generally much less desirable than washing methods for pears. This statement is also true to a lesser degree for the more tender-skinned apples, such as the Winter Banana. Some types of dry-cleaning equipment are entirely unsuited for cleaning pears. In general, any method which subjects fruit to much rolling or moving about, so that it comes in frequent sudden contact with parts of the equipment or with other fruit is likely to cause mechanical injury. The use of roller conveyors with certain varieties of pears is also attended with danger. Brush cleaners have an element of danger in the possibility that the bristles may puncture the surface of the fruit and allow decay to start.

There was not much difference inherently between the cleaning efficiency obtained with the better dry cleaners. Variations in efficiency were almost invariably due to differences in the mode of operation of the equipment.

In many cases, dry-cleaning methods added more spray residue to the fruit than it originally bore. This was especially true for apples having relatively small quantities of residue on them before cleaning and when the equipment was not kept properly cleaned.

It is probable that one of the effects of dry cleaning is more or less to equalize the spray residue on different apples in a lot so that those with large quantities on their surfaces become cleaner, while those with lesser residue have more added. There is, however, only a small proportion of residue that is entirely removed from all of the fruit, even when the equipment is properly cared for.

Repeated dry cleaning of apples with the same equipment has not materially or consistently reduced the quantity of residue below that obtained with one cleaning treatment.

It was found, however, in the case of the cloth-roller type and the revolving-brush type of cleaners, that two such machines set in tandem arrangement were somewhat more efficient than one machine. The first machine then accomplished most of the cleaning and this made it necessary that the cleaning agents be changed more frequently on this machine.

Where an attempt has been made to increase the generally rather limited capacity of dry wipers by hastening the progress of the fruit through them, two undesirable conditions have generally resulted: (1) The fruit has often been improperly cleaned, and (2) the possibilities of injury to it have been increased. Each dry cleaner has an estimated capacity. Before this is exceeded the operator should satisfy himself that such action does not result in a lowering of cleaning efficiency or in damage to the fruit.

A very decided disadvantage of most dry-cleaning methods under commercial conditions has been the practical impossibility of constantly adjusting the equipment to the size of the fruit. Constant attention is necessary to provide even reasonably suitable conditions in this respect. In cases where the fruit sizes are extremely variable, the sorting out of the extremes, previous to dry cleaning, may be helpful in giving more uniform cleaning results with less damage to the large-sized fruit. In addition, in some types of dry-cleaning equipment, poor adjustment of the machine resulted in fruit being thrown entirely out of the machine. Although the actual losses from this cause were not important, the conditions under which they occurred could not be considered suitable for the proper handling of fruit.

Practically all of the relatively satisfactory dry cleaners polish the surface of the fruit and thus considerably improve its appearance. However, they frequently do not polish the stem and calyx ends of the fruit where often considerable quantities of dust and spray residue are left after the fruit has been given a dry-cleaning treatment. The oscillating-brush dry cleaner is somewhat more efficient than the others in cleaning the stem and calyx ends of apples.

The relative efficiency of cloth wipers is determined largely by the rate at which the fruit moves through the machine, by the cleanness and dryness of the cloths, and by the suitable adjustment of the cleaning agents.

Methods of cleaning cloths with solvents while they are in the machine are not satisfactory. Changing of the cloths at least every

two hours is essential under ordinary commercial conditions. Some packers discard the old cloths and replace them with new ones; others launder or steam clean the soiled cloths before using them again.

A suction arrangement by which loose dust and residue particles may be constantly removed from the machine will help materially in keeping the equipment clean.

The relative efficiency of brush cleaners is determined largely by the cleanness of the brushes, their ability to retain their original resiliency, their proper adjustment in the machine, and the rate at which the fruit moves through the machine.

With the oscillating-brush type the resiliency of the bristles is essential to efficient cleaning if injury to the fruit is to be avoided. The removal of particles of dust or residue by suction or by air blast is very helpful in prolonging the efficiency of relatively clean brushes. Brushes should be taken from the machine for cleaning several times a day. The use of some solvent on a sponge or cloth pressed against the brushes while they are in motion is not sufficient; soap and hot water or gasoline are usually available and are effective materials for cleaning the brushes, especially if applied with a scrubbing brush. At least one extra set of brushes for replacement while the used ones are being cleaned should be provided.

Under commercial handling and storage conditions there has been practically no loss from excessive wilting of apples following dry cleaning. However, there is a possibility of loss from slack packs if such apples are held in storage with a low air humidity. The best relative-humidity conditions for apple storage are found at about 85 per cent.

With pears there is considerably more danger of wilting after dry cleaning. This is especially true if the handling by the cleaner is rough and leads to some discoloration of the surface of the pears. Tender-skinned varieties, such as Anjou and Comice, are particularly susceptible.

## CLEANING FRUIT BY SOLVENT METHODS

The washing methods in commercial use during the past two seasons may be divided into two groups on the basis of the solvent employed: (1) Those using hydrochloric acid and (2) those using alkaline materials. Although the acid-solvent methods were used in most cases, the cleaning efficiency of both types have been studied. Observations have been made on seven typical methods using acid solution while cleaning all of the important commercial varieties of apples and pears. The fruit was obtained from a large number of orchards in the several districts where a variety of spray practices had prevailed during the growing season.

The solvent methods studied were the following: (1) Diffused spray, (2) forceful-jet spray, (3) flood washer, (4) flotation, (5) combination of overhead diffused spray and flotation, (6) tank dipping in boxes, (7) deep submersion, and (8) alkaline-solution washer.

The following is a brief description of the mode of operation of the various methods under observation:

### DIFFUSED-SPRAY WASHER

The fruit was carried forward on a rod conveyor while being sprayed with the cleaning solution from above and below by means

of fan-shaped diffused sprays. The period of exposure ranged generally from 30 to 50 seconds. The fruit was moved only slightly by the impact of the spray. Rinsing was done by fan-shaped sprays. The drying was done by air blasts directed against the fruit in a definite way so as to sweep the water from the fruit mechanically.

### FORCEFUL-JET SPRAY WASHER

A constant turning motion was imparted to the fruit as it moved forward in the machine on spirally wound rollers. The solution was sprayed from above by means of forceful jets. The exposure period varied from about 20 to 40 seconds. Rinsing was accomplished by similar means. Drying was done either by long rotating brushes overhead or by a cloth draper towel from which were suspended cloth flappers. In both these drying methods rapidly rotating disk-shaped brushes spaced at intervals between the rolls were also provided. The tips of the brushes touched the fruit as it rolled above on the conveyor.

### FLOOD WASHER

Two machines of the flood-washer type were observed under commercial conditions. In one machine the fruit was carried forward on spirally wound rollers while being subjected to a large volume of cleaning solution delivered through slits in a sort of overhead sluice box. The exposure period ranged generally from 30 to 50 seconds. The rinsing section was of similar character. The drying arrangements varied, but in most cases consisted of wipers of the type used for dry cleaning, with either cloths or brushes attached to the rolls. The other machine subjected the fruit to a large volume of cleaning solution, which was splashed over it as the fruit was carried forward on a perforated belt. The period of exposure varied usually from 50 to 90 seconds. The rinsing section was of similar character. The drying arrangements varied in different packing houses, but were often provided by wipers with either cloths or brushes on the rolls.

### FLOTATION

The fruit was floated, partly immersed, in the cleaning solution and was given occasional momentary shallow submersion and a slight turning motion by paddle wheels. The exposure period was about five minutes. Provision for rinsing was made in a short tank or by an overhead spray of fresh water, or by both. Various drying methods were in use under commercial conditions. In the machine under experimental observation, a wiper of the type used for dry cleaning was employed, with brushes in the place of cloths.

### COMBINATION OF OVERHEAD DIFFUSED SPRAY AND FLOTATION

The fruit was floated forward in the cleaning solution while being subjected to fan-shaped diffused sprays from above. These sprays had a tendency to impart a slight turning motion to the fruit, when space between fruits permitted. The period of exposure was not more than three minutes and in some cases only one minute. Rinsing was done by an overhead spray of fresh water. The drying arrangements provided under commercial conditions were of either a blower type or an evaporating-tunnel type, with several large fans or a wiper of the kind usually employed in dry cleaning.

### TANK DIPPING IN BOXES

Many variations of the tank type of apparatus existed, some involving the use of electric power for conveying the boxes of fruit. In one under experimental observation the fruit was immersed in the cleaning solution while in the boxes. The latter were pushed forward by hand, lifted from the cleaning solution for a short draining period, and then immersed in the rinsing tank, to which fresh water was supplied through overhead diffused sprays. The period of exposure to cleaning solution varied from three to five minutes. The boxes were then stacked for drying.

### DEEP SUBMERSION

The apples or pears were given a submersion treatment to the depth of about 5 feet by means of several conveyors, which very gently carried the fruit up and down in the cleaning solution. The rinsing was done by similar means, and the drying was accomplished either by means of a cloth draper towel with pendent cloths attached or by rotating brushes. The period of exposure to the cleaning solution was about five minutes.

### ALKALINE-SOLUTION WASHER

The essential cleaning feature of the most commonly used washer of the alkaline-solution type was a bath of warm solution which floated the fruit while it was subjected to overhead diffused sprays of warm solution. The rinsing was accomplished by sprays of fresh water. There was no drying arrangement, but under commercial operation the fruit was immediately subjected to a paraffin and oil coating treatment.

### INFLUENCE OF TEMPERATURE ON EFFECTIVENESS OF SOLUTION

By raising the temperature of the acid solution increased cleaning efficiency was obtained in washing apples from which the residue could not be otherwise satisfactorily removed. It can not be said, however, that all such lots were cleaned by this means to meet the world tolerance. In some cases it seemed that only a modification of the spraying practices would make the fruit capable of being washed satisfactorily, because even the best washing method has certain limitations.

The temperature of the solution should be at least 80° to 85° F. and preferably 90° to 100° if consistent cleaning is to be obtained. With such temperatures it was found that the acid concentration could be materially reduced below the quantity that was required when the solution was cold, without sacrificing cleaning efficiency. In many cases 1 or 2 gallons of acid to 100 gallons of water were sufficient if the solution was warm. In several cases the saving in acid consumption more than paid for the warming of the solution by steam coils or by electric heaters. These sources of heat can be obtained commercially and adapted to almost every washing machine that is now manufactured.

The higher temperature in the solution seems to increase to a certain degree the chemical reaction between the lead arsenate and the hydrochloric acid and to bring about a softening or melting of the

waxy or oily materials on the surface of the apple, so that the residue can be more effectively reached by the cleaning solution.

Winesap, Arkansas Black, Delicious, and Jonathan apples have been subjected to solution temperatures as high as 160° F. in commercial washers with the acid concentration as high as 3 per cent to determine the possibilities of injury from warm acid solution.

Some injury was manifest at temperatures above 120° F., and it must be emphasized that these extreme temperatures are not recommended but are mentioned merely to indicate that there is a sufficient factor of safety at temperatures ranging from 90° to 100°. At these temperatures no injury to the fruit or adverse effect was observed on apples held for considerable periods of time in common storage as well as in cold storage. There was no significant increase in fruit temperature during the time that it was commonly exposed to the warm solution in the washers.

It is not probable that warming the cleaning solution will be necessary in order to clean satisfactorily the average lots of fruit when this is done soon after they are picked, but it is suggested for fruit that is difficult to clean or in cases where consistent cleaning to the world tolerance can not be obtained by other means.

### ADJUSTMENT AND CARE OF EQUIPMENT

The proper adjustment of the washing equipment should not be overlooked at any time. All parts of it should be kept in proper condition to give maximum service. This applies especially to screens, spray openings, pipes, and pumping equipment. Each machine has an estimated capacity which should not be exceeded unless the operator is certain that the cleaning efficiency is not thereby jeopardized or the fruit subjected to danger of injury. No washing equipment will give satisfaction unless it has a chance to do its best work.

No fruit should be left in washing machines or dipping tanks during rest periods or when it is necessary to discontinue operations.

### METHODS OF RINSING

The rinsing of the fruit is a very important part of the washing process. Proper rinsing can do much toward eliminating the danger of injury to fruit from soluble arsenic and from decay.

Three methods of rinsing are available:

(1) The use of fresh water only for rinsing. This is perhaps the ideal condition, but it is not always possible where there is a scarcity of water.

(2) The recirculation of part of the rinse water. In this case the fresh water is best added as a final spray or flood over the fruit as it leaves the rinsing section. The first rinse water as the fruit enters the rinsing section should preferably be discarded. In this way the larger part of the acid solution and spores on the fruit will not be carried into the recirculated rinse water.

(3) The recirculation of the rinse water to which some substance like lime is added to neutralize the hydrochloric acid carried over on the fruit and to render insoluble the arsenic remaining on the fruit after washing. In this case it may not be necessary to provide a final fresh-water rinse, but one can be profitably provided for the fruit just as it enters the rinsing section, this water to be entirely

discarded, thereby keeping the recirculated rinse water relatively free from contamination. Mere rinsing of the fruit in boxes in a tank, even if some fresh water is added, is not generally so satisfactory as those methods heretofore mentioned. In any event, it is desirable to have at least 3 gallons of water available for each box of fruit washed.

In washing machines the exposure to the rinsing should generally be at least half as long as the exposure to the acid in the equipment commonly used. Constant attention should be given by the operator to keep the rinsing section in optimum operating condition.

### METHODS OF DRYING

Reasonable drying of the fruit seems essential to facilitate packing and to insure proper storage life to the fruit. The drying becomes of less importance with sound fruit as the washing and rinsing become more efficient and satisfactory.

The most successful drying method under observation in 1927 was the one employing forceful air blasts suitably directed to sweep the moisture from the fruit by mechanical pressure. The different types of cloth drying agents were fairly satisfactory, especially the draper-towel arrangement with pieces of toweling hanging down and passing over the fruit as it moved forward on the conveyor. These were continually passed through a wringer to remove excess moisture, and in this respect they were superior to the cloth roller wipers also commonly used for dry cleaning. The cloths on the rollers had to be frequently renewed if they were to function properly as drying agents.

The brush driers also under observation in 1927 were not generally efficient even when surrounded by heated air, especially when they were in tightly closed chambers.

Drying was more easily done early in the season or during the middle of the day when the relative humidity of the air was lower. This factor materially influences the drying of fruit in stacked boxes, as it is done in most dipping methods, and also affects the efficiency of any drying schemes designed to evaporate the moisture from the fruit. The space requirements of driers, if they are to be efficient, are also frequently difficult to provide under packing-house conditions in the Northwest.

The polishing of apples after drying is not generally essential if they are cleaned properly, although some packers express a preference for it. Any additional handling of the fruit, such as occurs when apples are passed through a polisher, simply increases the risks to the storage life and condition of the fruit and should be well justified before it is put into practice.

### APPARATUS AND METHODS FOR DETERMINING ACIDITY

A description of the apparatus and methods for the determination of acid strength is presented herewith.

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 0.1 c. c.); one 3-ounce bottle; standard sodium bicarbonate, 23 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 should be made up by dissolving the bicarbonate in 1 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 should not cost much more than $1 and if not available otherwise may be obtained from druggists.

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, and then allow the measured acid to drain into the 2-ounce bottle. Next fill the measuring pipette from the standard sodium bicarbonate solution. Adjust the level of the liquid with the 0 c. c. mark, and let it 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 the percentage of acid strength directly. 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 0.53 per cent.

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

## EFFECT OF CLEANING METHODS ON KEEPING QUALITY

In considering the capacity of any cleaning method to remove spray residue the question arises immediately as to the effect such a treatment may have on the keeping quality of the fruit and upon storage diseases. Perhaps no other factor has militated so strongly against the universal adoption of fruit-cleaning programs as has the uncertainty on these points, and the following suggestions summarize the best information now available.

The dry cleaning of apples can be done on a commercial scale in such a manner that there will be no exceptional loss from decay or deterioration in storage. This statement assumes that the proper sanitation precautions are taken, that the dry-cleaning equipment is properly adjusted and not overloaded, and that the cleaning agents are kept reasonably clean.

The dry cleaning of pears is less satisfactory mainly from a handling standpoint. Especially with the tender-skinned varieties such as Comice and Anjou, dry cleaning often results in skin scratches, abrasions, and stem punctures. Equipment employing rope-wound rolls for conveying the fruit as well as the oscillating-brush cleaners were found to give the most trouble. The smaller sized pears were generally most seriously affected, the character of the injury being a dark discoloration of the skin accompanied by excessive wilting.

The prevalence of rot was mainly dependent upon skin punctures, which in turn were determined by the character of the handling which the fruit received.

Mature apples and pears can be washed satisfactorily with dilute hydrochloric acid under commercial conditions without serious

injury to the fruit. This statement presupposes the proper operation of suitable equipment and assumes that certain precautions have been taken in order to avoid the injuries which may be induced by cleaning treatments and the consequent decay of the fruit.

These injuries, which are considered in greater detail in the following paragraphs, may be classified as follows: Arsenical injury at the calyx or stem, hydrochloric-acid burning, and chemical injury at the core.

### ARSENICAL INJURY

Arsenical injury is usually localized in the calyx region. It appears as a depressed black or dark-brown area surrounding the calyx or occasionally as dark patches of dead skin on the sides of the calyx cavity. In some cases or in advanced stages the injured area may extend one-eighth of an inch or more into the flesh, the affected tissue becoming brown and dry. Sometimes the same injury is found at the base of the stem. This injury opens the way for storage rots, especially when the fruit is stored wet.

This form of injury was prevalent on Jonathan apples washed in certain types of equipment, and its association with washing treatments employing hydrochloric acid led to a popular assumption that it was hydrochloric-acid burning, but it was equally prevalent on apples cleaned by alkaline solvents.

The same injury has also been of rather frequent occurrence on heavily sprayed apples in the orchards during rainy fall weather, and in former years it has been observed in storage on uncleaned apples that were packed wet. It was also produced experimentally by thoroughly wetting uncleaned apples after they had been picked and then packing and holding them in tight containers that would not permit the evaporation of the water.

Further evidence that the cause of the injury is soluble arsenic and not hydrochloric acid has been found in chemical analyses of injured flesh tissue taken after carefully peeling the affected area. Soluble arsenic has been found in all cases, whereas no traces of it could be found in adjacent normal tissue.

The occurrence of arsenical injury of this type on uncleaned apples may be explained by the accumulation of soluble arsenic from the sprays applied. This process is inaugurated when moisture is present and may be facilitated by the presence on the apples of small quantities of alkaline soil dust.

It has also been found that the same type of arsenical injury occurs when spray residue is incompletely removed from the calyx region. In such cases it appears that the disintegration of the lead arsenate begins in the washing process and continues under the influence of solvents or moisture retained on the apples when they are packed, and thus soluble arsenic is produced.

The prevalence of arsenical injury at the calyx was influenced by the manner in which the washing solution was employed, its strength, and the duration of exposure of apples to the solution. The injury was greatest where apples were dipped in boxes or submerged by other means. The stronger the cleaning solution the greater the injury developed. Prolongation of the time of exposure of the fruit to the cleaning solution increased the extent of damage. Washing

machines which applied the hydrochloric acid in solid jets with considerable pressure, forcing the acid deeply into the calyx, also caused considerable damage of this nature.

Frequent renewal of the washing solution to prevent the accumulation of toxic concentrations of soluble arsenic is a most important precautionary measure. It is significant that when the tanks were drained after each day's run, fresh washing solutions being provided daily or after washing about 1,000 boxes, no further serious trouble was experienced. The use of a final fresh-water rinse applied as a spray as the apples leave the machine is also desirable in connection with removing traces of soluble arsenic as well as spores of rot fungi.

A further precautionary procedure was indicated by experiments in which the injury was prevented by using a limewater rinse. In this case the lime reconverts the soluble arsenic found on the apples into a relatively insoluble and noninjurious form. The lime was added to the rinse water in the form of fresh stone lime, slaked and added in the concentration of 2 pounds to 50 gallons of water. If there is a conspicuous lime residue, a final fresh-water rinse may be employed to remove it. There is practically no need for the use of lime in the rinse water when pears are washed, and there is some question as to whether its use on russeted pears may not result in surface injury.

In some cases baking soda or sodium bicarbonate was added to the rinse water. While baking soda will neutralize the hydrochloric acid carried over on the fruit and thus prevent its further action upon unremoved spray residue, it is not entirely effective in the direct prevention of arsenical injury. Its reaction with arsenic acid produces sodium arsenate, which is almost as soluble and toxic as arsenic acid itself.

The alkaline solvents used also react with lead arsenate to produce sodium-arsenic compounds, which likewise produce injury when they become sufficiently concentrated.

In addition to arsenical injury, apples washed with alkaline solvents have shown a superficial brownish deposit in the calyx basin. This has been merely unsightly in most cases and apparently has been due to insufficient rinsing with fresh water.

### HYDROCHLORIC-ACID BURNING

Hydrochloric-acid injury is distinguished from arsenical injury primarily by its lighter color. The cases observed were due to insufficient rinsing, contact of the fruit with box boards soaked with acid solution during the washing process, and deep-submersion methods whereby fruit was held in contact with the acid for extended periods.

Most of the homemade washing devices have either submerged the apples in boxes or floated the fruit through long tanks with occasional submersion under paddle wheels. The low initial cost of such machinery and its simplicity of operation have made it generally adaptable to the average small orchard. A number of cases have come to attention, however, in which excessive losses from core rots occurred on apples washed by these methods. Likewise, very serious losses from core rots were experienced as a result of washing apples

in commercial machines which plunged the apples to a depth of 5 or 6 feet in hydrochloric acid for periods as long as five minutes.

### CHEMICAL INJURY AT THE CORE

The varieties most seriously affected by core injury were those with open calyx tubes which admit washing solutions and spores of rot fungi to the core region. Penetration of washing solutions may be detected even in the absence of core rots by the injury of the core tissues. This injury is characterized by a brownish discoloration and drying of the tissues.

The tendency to the production of open calyx tubes varies in different orchards and is greatly influenced by spring frosts. Where the apples were submerged in boxes, more than 50 per cent of those with open calyx tubes developed core injury, but where the apples were sprayed with washing solutions the core injury was negligible. The admittance of washing solutions to the core and the injury produced thereby is not so significant in itself, but when the spores of rot organisms may be introduced at the same time it becomes a matter of great importance.

The severity of the injury from core penetration is influenced to a considerable extent by the strength of the cleaning solution used. Hydrochloric acid used at the rate of 3 gallons per 100 gallons of water causes much more penetration injury with apples having open calyx tubes than when used at the rate of 1 gallon per 100.

It is apparent, therefore, that in using submersion methods some varieties of apples can be washed without serious danger, but indiscriminate use with varieties having open calyx tubes may result in considerable loss, particularly if the fruit is in motion or the exposure is prolonged. The deeper the submersion and the stronger the solution the greater the risk involved.

No great extent of penetration has been noted when the fruit was floated on the surface of the cleaning solution. When the flotation method is used, however, the fruit should travel through the machine in a single layer, and the duration of the treatment should not be extended beyond the time required for cleaning. Occasional shallow submersion just beneath the surface of the solution for a few seconds does not seem to cause much penetration to the core.

### ROT-PRODUCING SPORES AND MOISTURE

The accumulation of spores of rot-producing fungi in washing solutions was studied in a large number of machines throughout the season. The number of viable spores of the different organisms present in these solutions varied (1) with the quantity of fruit washed, (2) with the condition of the fruit (sound or infected), (3) with the manner of application of the washing solution, and (4) with the length of time the spores were in contact with the solution.

Hundreds of decay-producing spores are commonly found on a single sound apple as it comes from the orchard, whereas a rotted apple may bear enough infective material to destroy several carloads; hence the accumulation of spores in the washing solution is directly proportional to the number and condition of the apples washed. Decayed apples should be sorted out before they pass into the cleaning machines.

It was found that where apples were washed by spraying there was a greater accumulation of spores in the washing solution than where the apples were dipped or floated through the machines. Neither acid nor alkaline washing solution, however, had any apparent effect as sterilizing agents within the time that apples were exposed to them. Perennial canker spores were not killed by six days' exposure to either solution. No dependence could be had, therefore, on the chemicals commonly employed for washing to prevent rots by killing the spores.

A number of disinfectants have been tried for the purpose of killing spores of rot fungi in the washing solution. At present there is no practical suggestion to be given in this connection, and the use of disinfecting compounds in the washing solution or in the rinse water is not recommended.

Formalin appears to be useful in providing sterile machines at the beginning of the day's packing operation. At the end of each day's work 1 pint of formalin has been added to each 100 gallons of washing solution. The machines are then run for 5 to 10 minutes and allowed to stand overnight. The tanks may also be given a scrubbing with a broom. In the morning they are again run for a few minutes prior to the replacing of the used solutions with fresh acid and water. Where the machines can be thoroughly flushed out with clean water, practically as good results can be obtained without the use of formalin.

Although the most satisfactory results have been obtained when fruit has been dried before packing, no serious difficulties have resulted from the presence of traces of moisture on washed fruit. When the removal of the spray residue has been as thorough as possible and rinsing has been properly done no injury has occurred that could be attributed to the action of water.

Fruit packed with traces of moisture has dried quite readily both in cold storage and in common storage, providing the relative humidity has not been too high. Fruit in oiled or unoiled paper wraps has dried more quickly than fruit stored unwrapped.

When washed fruit is placed in storage in any large quantity it is probably desirable to avoid the addition of moisture to the storage air and to operate the storage at a somewhat lower relative humidity than is customary until the fruit is dried.

The opinion has been prevalent in some cases that the washing of fruit tends to hasten its ripening. Numerous tests have not indicated that such is a fact.

Some apprehension has existed over the possibility of injury to fruit handled while in a wet condition after the washing treatment. This fear has been based on the observation that apples which have stood in the rain tend to become turgid and are very susceptible to bruising. Injury of this nature has not been a factor in washed fruit. The length of time taken for the washing treatment is apparently so short that there is no effect on the turgidity of the fruit.

The washing of fruit, if done with proper equipment and under reasonably sanitary conditions, will not consistently increase the percentage of decay very materially and in some cases may not increase it at all or may even reduce it below the proportion found in unwashed fruit from the same lot. If there is an increase in decay it may be due to the additional handling and consequent rots at

punctures and cuts, to infections at the calyx following arsenical injury, or to infections at the core following penetration of the cleaning solution.

Anything which can be done on a commercial scale to reduce to a minimum these chances for trouble will make for improved washing conditions and satisfactory results.

## CONCLUSIONS AND SUGGESTIONS

The following conclusions and suggestions have been obtained from the results of the experimental work as well as from practical experience with the commercial operation of washing equipment during the packing season.

It is not safe to assume that any washing method will satisfactorily clean all fruit, regardless of its antecedent history, both as to spraying practices and method of harvesting. There are limitations to every cleaning method. The choice of materials for spraying as well as the manner of spraying the fruit in the orchard may materially modify the facility with which any method will remove spray residue. In other words, the spraying practices should be chosen with the purpose of making the cleaning of the fruit as easy as possible.

With proper operation of suitable equipment both apples and pears can be satisfactorily cleaned without serious injury to the fruit. Careless cleaning methods, however, may result in arsenical injury at the calyx or stem, hydrochloric-acid burning, or chemical injury at the core. Any of these injuries may open the way for storage rots.

The sooner the fruit is cleaned after it is picked the more easily the cleaning can be done and the less risk of damage there is to the fruit. In any event, fruit should be cleaned before it has passed the firm stage of maturity.

No matter what washing treatment is used, every precaution should be taken to keep decayed fruit out of the cleaning equipment. The sorting out of undesirable fruit generally requires additional sorters at the dumping table and should not be left for the dumper to attend to.

Any washing method which applies the solvent solution to the fruit by diffused spray, flood wash, flotation, or a combination of these should give satisfactory results for ordinary cleaning requirements. This statement presupposes that all desirable precautions in regard to proper washing have been taken.

The ultimate choice of any of these machines by a fruit packer will generally be influenced by such items as the initial cost of the equipment and its capacity, the cost of operation per box of fruit, the suitability for local requirements, the adaptability to the space available, and the general mechanical as well as cleaning efficiency of the machine.

Methods employing relatively deep submersion, especially when the fruit is in constant turning motion and the exposure is prolonged, should be avoided, especially with varieties frequently having open calyx tubes. The latter include particularly Jonathan, Gravenstein, Esopus Spitzenburg, Stayman Winesap, Ortley, White Pearmain, and sometimes Delicious. The large-sized apples of any variety may at times show this condition.

The submersion methods as well as the direct-jet spray method may cause the penetration of contaminated acid solution into the core of the fruit and thereby may bring about decay. Even in apples with closed calyx tubes deep submersion may lead to decay.

Dipping methods in which the fruit is immersed in a cleaning solution while in boxes are open to the same objection as submersion methods.

The method whereby warm alkaline solution was used was generally efficient with apples. Usually a solution of soda ash of about 2 per cent strength was used when the residue was not too difficult to remove. With heavily sprayed lots, the addition of caustic soda sufficient to make a 0.25 to 0.5 per cent solution was also added. In the commercial use of this method during 1927 borax was also added to the cleaning solution which was warmed to a temperature ranging from 80° to 110° F. Cleaning efficiency was greater at the higher temperature.

Since the alkaline solutions are solvents for the waxy materials on the surface of the apples, considerable care must be exercised in making the solution strong enough to be an efficient cleaning agent and yet not so caustic as to injure the fruit. A very thorough rinsing with an abundance of fresh water is also essential, since the alkaline materials are more difficult to wash off.

For pears having russeted surfaces, the use of an alkaline washing solution, especially when caustic soda is added, is attended with some danger of injury to the skin of the fruit.

The cleaning efficiency obtained with dipping methods as commonly operated was less than that obtained with washing machines which included some form of spray or flood wash when used under similar conditions. This was especially true with varieties of apples that are not easily cleaned or with fruit that has been subjected to spraying practices that make satisfactory cleaning difficult.

A certain degree of agitation is essential in the dipping methods, if they are to attain their greatest possible efficiency in cleaning fruit. A slight turning motion in the fruit is helpful in increasing the efficiency of cleaning in using most commercial washing machines of the spray or flood type, but this should not be of such a character as to bruise or injure the fruit. Pears are best handled by washing-machine conveyors which give them a minimum of individual fruit motion.

In the spray type of washer it has generally been found desirable to have 8 to 10 pounds of solution pressure in the delivery pipes. This pressure causes the solvent to flow more rapidly over the fruit, whereas the flood-wash methods accomplish a similar result by passing a large volume of liquid over it. The pressure of the liquid in the spray methods probably also removes some of the superficial dust and lead arsenate. It is probable, however, that the actual solution of the lead arsenate by the acid is determined largely by the constant removal of the products of the reaction and the constant renewal of the solvent against the surface of the fruit.

A prewash of the fruit with water or very dilute acid solution may assist slightly in removing some of the dust and residue from fruit and will remove some of the spores from its surface. With this procedure, however, there is a steady dilution of the actual cleaning solution in the washer from the water carried over on the

fruit, and constant care must be exercised to keep the cleaning solution at proper strength.

Where difficulty has been experienced in cleaning fruit, continuing its exposure to the washing treatment much longer than was the common practice in 1927 did not result in any marked improvement, although there was some increase in efficiency. In some cases soaking the fruit in the solution may result in slightly improved removal of the residue, owing to mechanical loosening of dust and residue particles, but the chemical reaction between hydrochloric acid and lead arsenate probably takes place very rapidly, as heretofore mentioned, and to prolong the exposure does not proportionately increase the reaction.

The proper washing of apples generally requires an acid concentration of at least 1 gallon to 100 gallons of water, although lightly sprayed apples and pears may often be satisfactorily cleaned with slightly less. With fruit that was difficult to clean, an increase in concentration up to 6 gallons of acid to 100 gallons of water resulted in increased cleaning efficiency, but the increases in efficiency have been proportionately less for each gallon added. Above 4 gallons to 100 the increase in efficiency has been relatively small. The use of high acid concentration is more costly, puts a greater burden on the rinsing section, and increases the danger of injury to the fruit from acid burning as well as from soluble arsenic due to the continued solvent action of the acid on poorly rinsed fruit. It should be possible to clean the general average of fruit soon after picking, in suitable equipment, with an acid concentration of not more than 3 gallons of acid to 100 gallons of water.

The acid strength should be watched carefully during the washing operation by means of the simple titration method described on page 11 of this circular. That is particularly true if wet fruit is put through the machine or if fruit is washed which has been sprayed with Bordeaux mixture or lime together with lead arsenate. A certain proportion of acid solution is carried away on the fruit as it passes through the washer. This loss should be replenished from time to time from a storage barrel of cleaning solution arranged to stand beside or over the washer. The acid tank of any washing machine should be emptied at least once a day. If tanks of the customary dimensions are used, the accumulation of soluble arsenic in the cleaning solution in one day's time will not be sufficient to interfere with the cleaning operation or unduly contaminate the rinsing section.

Certain precautions should be followed in the use of commercial-grade hydrochloric acid (also commonly called muriatic acid). It is usually shipped in glass carboys holding about 10 gallons of concentrated acid. The acid should test 20° Baumé, which is equivalent to about 32.1 per cent. A slight yellow tinge in the acid does not detract from its value as a cleaning agent.

Care should be exercised in handling the acid, since it will attack metal, cloth, and leather, unless neutralized by soda or lime. Either hydrated lime, carbonate of lime, or common baking soda will be satisfactory for neutralizing.

Some form of a carboy tipping frame will be found convenient as an aid in pouring the acid from the container. A nonmetallic gallon measure with quart divisions is a necessary utensil for properly measuring the required concentrated acid.

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January 1, 1929

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