BULLETIN No. 575 OCTOBER, 1929

New York State Agricultural Experiment Station

Geneva, N. Y.

WASHING FRUIT TO REMOVE SPRAY RESIDUE IN THE HUDSON VALLEY

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PUBLISHED BY THE STATION
UNDER AUTHORITY OF CORNELL UNIVERSITY

CORNELL UNIVERSITY
NEW YORK STATE AGRICULTURAL EXPERIMENT STATION, GENEVA, N. Y.

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WASHING FRUIT TO REMOVE SPRAY RESIDUE IN THE HUDSON VALLEY

E. V. SHEAR[1]

ABSTRACT

Altho spray residue on apples and pears in the Hudson Valley rarely contains an amount of arsenic which makes it injurious to the health of consumers, it is unsightly and often injures the sale of the fruit. In this investigation an effort was made to find the best method of removing spray residue and other adhering impurities, such as dust and sooty fungus. Various materials and methods were tested and studies made of several factors which enter into the problem. The keeping quality and appearance of treated and untreated fruit in storage was compared.

Everything considered, the best results were obtained by giving the fruit a brief bath in very dilute hydrochloric acid and rinsing immediately in water. The concentration of acid and length of treatment need to be varied according to conditions. A bath of one minute in acid concentrations of from 1 to 100 to 1 to 500 meets the requirements in most cases, so far as spray residue is concerned.

Properly managed, the acid washing of fruit is rapid, cheap, safe, and effective.

INTRODUCTION

In August 1926, it became apparent that visible spray residue would make it difficult to market the fruit of a Greening apple orchard at Highland, N. Y., which had received late summer sprays for bitter-rot control. Buyers who inspected the fruit on the trees told the owner that they would not handle the fruit unless he would furnish a certificate that it did not carry an excess of arsenic. This prejudice against spray residue had its origin in the rejection of American fruit

[1]The writer is indebted to W. D. Mills, Instructor in Plant Pathology at Cornell University, for advice and assistance in the early part of the work here reported.

in British markets the previous season because of residue containing arsenic.

The last sprays used on this orchard had been composed of copper and lime, so it was thought that the residue contained little arsenic. Samples of the fruit were sent to the New York State Department of Agriculture and Markets, and analyses reported back showed that most of the fruit carried only small amounts of arsenic, the maximum amount found being 0.0078 grain per pound of fruit. This is about three-fourths of the maximum amount of arsenic allowed by the British arsenic tolerance act which specifies that no more than 0.01 grain of arsenic shall be allowed per pound of fruit.

An examination of available publications was made to learn whether such a difficulty had been adequately met in the past. At that time there were numerous recent reports of methods developed in other fruit-growing districts for removing arsenic from fruit, but these methods did not appear to meet the requirements of this Hudson Valley problem which demanded cleaning bordeaux residue from the fruit so it could be sold on a market that was aroused against all forms of residue.

Subsequently, the scope of the investigation was extended to include various kinds of spray residue and adhering impurities. Many materials and several methods have been tried during two and one-half years that the fruit cleaning experiments have continued, but not all of the ineffectual work will be described. A method of cleaning fruit with hydrochloric acid proved successful for general use. This will be described in detail. Certain other methods proved harmful or without benefit. Some of these latter have been and still are advocated, and experience suggests that other unsuitable treatments will turn up for trial, so the evidence against a few unsatisfactory cleaning treatments will be given.

TRIALS OF MATERIALS FOR CLEANING FRUIT

ALKALIES AS CHEMICAL CLEANERS

The materials most often recommended for use in removing residue at the beginning of this work were various alkalies. It seemed doubtful whether these would give good results where the main residue was of a basic nature, so early in the work the use of acids received principal attention. Even after it appeared probable that acid solutions would effect cleaning, there were so many unanswered questions about the effect of acids on fruit that work with alkalies was continued.

Two considerations particularly favored the use of alkalies. They were in use commercially and considerable information was available regarding the materials of this type and the concentration of these materials suitable for use on fruit, so their use was not an adventure into a field that was wholly unknown. Also alkalies are good wax solvents. It was believed that even tho they would not remove the basic bordeaux residue chemically they might remove enough of the wax to allow the residue to be easily rinsed or wiped off.

All of the work with alkaline materials was disappointing, strongly indicating that chemicals of this group are not suitable for use in eastern fruit-growing sections where fungicides are used thruout the season and form the major part of spray residue. Bordeaux mixture, lime-sulfur solution, and Jersey dry-mix all form residue of strongly basic types on fruit, and such residues are dissolved only by acids.

Alkalies did not satisfactorily remove these residues. The alkalies, when used at sufficient concentrations, dissolved the wax from the surface of the fruit. This fruit went down rapidly in storage because of wilting due to excessive evaporation thru the unprotected skin of the fruit. Wilting of fruit treated with alkalies has recently been reported (12)[2] with fruit from other districts. The once popular and widespread use of this group of chemicals has been almost wholly abandoned in western fruit districts in favor of acid washing.

OILS AS AIDS IN SPRAY RESIDUE REMOVAL

Another type of material that offered some promise was oil. Considerable was known about the effect of oil as a spray or wash on trees, foliage, and fruit. Like alkalies, oils are good wax solvents. It seemed possible they would release the residue by removing the wax in which the residue was embedded. There was also the possibility that a coating of oil on residue particles would cause the particles to adhere to cloths and be more easily wiped from the fruit. These possible benefits from oils did not prove to be of practical importance.

The disadvantages of a coating of oil on fruit outweigh the good. Oils do cut the wax on the fruit and residue from oiled fruit sticks to cloths, leaving a better looking polished surface than results from wiping unoiled fruit by hand. However, hand wiping in itself proved poor economy without the added expense of previous treatment with oil. A disadvantage of oil was that it caused wipers (cloths or brushes)

[2]Refers to Literature Cited, page 33.

to become coated with a mixture of residue, oil, and fruit wax that very quickly made the wipers unsuitable for use, and it was difficult to clean the wipers of this dirt so they could be used again. Without subsequent hand wiping oils did no good. Where a residue problem exists, spraying fruit with oil or alkaline soap offers little prospect of removing the residue. Work during the past two years has indicated that such treatment increases the difficulty of removing residue.

HAND WIPING TO REMOVE RESIDUE

Various wiping methods were tried using dry cloths, cloths dampened with water, or with weak acid solutions, paper, and oiled paper, such as is used for preventing apple scald. Brushes and sponges were tried to secure better cleaning in the stem and calyx ends of apples. Hand wiping with cloths or other materials required 20 to 45 minutes per bushel of fruit. At Hudson Valley labor rates this cost is prohibitive, considering that about 1 or 2 bushels of fruit per minute can be cleaned in an acid bath.

No method of dry cleaning apples adequately removed the heavy residue in the stem and calyx ends. All wiping processes caused injury to calyx lobes and stems of fruit during the attempt to clean out the depressions in the ends of the apples.

Oiled paper, both wraps and shreds, are better than cloths for wiping fruit. These materials are cheap and there is no question about cleaning them as they can be thrown away when dirty. The shredded form of oiled paper is not ruined by wiping a few fruits with a handful and can be packed with the fruit.

Pears and the rounded cheeks of apples can be considerably improved in appearance by polishing with the shredded oiled paper containing 15 to 20 per cent of a mineral oil, which is generally used in storing late apples in the Hudson Valley. Much of the residue actually adheres to the oiled paper, but part of the apparent cleaning is simply the result of the residue being coated with oil and polished so that it becomes inconspicuous. Fruit packed in oiled paper is improved in appearance the longer it is stored, and the greater the amount of handling the more pronounced is the effect of this material. Fruit packed in oiled paper in the orchard and left in this material during the subsequent handling (storing, grading, and trucking to storage and market) comes out after several months' storage with the appearance of having much less residue.

The main function of oiled paper is to improve the keeping qualities of fruit in storage, and as such its use is amply justified. Much of the improvement of the appearance of fruit containing spray residue is simply due to coating the residue with oil, unless hand wiping with the paper is practiced. Fruit should not be placed in oiled paper if it is planned to clean the fruit with hydrochloric acid as the oil coating impedes the action of the acid solution.

ACIDS AS CHEMICAL CLEANERS

The first test with an acid solution to remove spray residue successfully removed bordeaux residue, and incidentally, most of the arsenic, from Greening apples. Ten per cent hydrochloric acid (10 parts by volume of concentrated acid solution in 90 parts of water) was the solution used. A few hours after treatment the apples turned a rich cinnamon brown. Later tests showed that hydrochloric acid would remove this bordeaux residue in a solution as weak as 1 part of concentrated acid in 800 parts of water. At this dilution several minutes were required for the acid to do the work. At 1/800 dilution[3] the apples remained uninjured. The threshold of injury appeared to be at a dilution of 1 per cent (1 part of acid concentrate in 100 parts of water) with a one minute bath and immediate rinsing in fresh water.

Other acids were tried, but none were found as satisfactory as hydrochloric acid. Acetic acid, the acid ingredient in vinegar, gave good results but not as good as hydrochloric acid, and the cost of this acid is much higher than that of hydrochloric acid for washing. The cheapest form of acetic acid is vinegar which contains 3 to 5 per cent acetic acid. Iains (5) has found that 5 per cent acetic acid removes bordeaux residue from fruit, which suggests that good strong vinegar used full strength will make an effective wash. However, its cost would be 25 to 50 cents per gallon compared with about one-fifth of a cent per gallon for a 1/500 hydrochloric acid bath. During the past three years hydrochloric acid has cost from 65 cents to a dollar per gallon when bought in small lots in the Hudson Valley drugstores.

ATTEMPTS TO REMOVE RESIDUE BY SPRAYING

In the beginning it was thought that the preparation of special apparatus for washing fruit would entail considerable trouble and expense

[3]Thruout this article, the composition of acid wash solutions is given as 1/100, 1/500, etc. The first number is the volume of the concentrated acid, the second number is the volume of water used in making the wash solution.

so acid solutions were prepared in various concentrations and sprayed on the trees. (See Table 1). The solutions did not spread well and the percentage of fruit surface actually wet by the sprays was far from satisfactory, only 80 to 90 per cent being wet after a thoro drenching.

TABLE 1.—EFFECT OF HYDROCHLORIC ACID WHEN SPRAYED ON APPLES ON THE TREE.

	DILUTION					
	1/500	1/400	1/200	1/100	1/50	1/10
Injury to foliage..	trace	trace	slight	severe	severe	ruined
Injury to fruit.....	none	none	slight	severe	ruined	ruined
Effect on residue..	little	little	little	fair	fair	fair

The relatively small percentage of fruit surface not wetted by the acid spray contained a large part of the total residue. This was due to the tendency of apples to hang down among surrounding branches where they were partially covered. An apple may be well exposed to receive a good cover of spray material in early August and shortly after bend down into the protection of surrounding foliage so that dew and rain cannot weather away the spray residue. Frequently, apples that show no residue as they hang on the tree will have a heavy deposit of residue, corresponding to the outline of each protecting leaf. These areas are protected from late spray applications used for removal of residue.

In 1928, materials appeared on the market that were recommended for use as sprays for removing spray residue. It appears that this is a recent development in fruit-growing areas where residue removal is especially important because of the presence of toxic material in the spray deposit. The results obtained in the Hudson Valley do not commend the practice of spraying fruit while on the trees to dissolve spray residue. Even hydrochloric acid, the best residue solvent known, is not successfully used in this way.

In addition to the difficulty in securing adequate coverage and wetting, there were other unsatisfactory aspects to spraying for residue removal. All acids used as direct sprays on trees proved injurious to foliage, even at dilutions considerably weaker than were required to remove spray residue. Hydrochloric acid burned both foliage and fruit on the tree when used at the rate of 1 part of concentrated acid solution to 200 parts of water. This concentration was about the threshold of acid injury to fruit in spray tests, the fruit showing very few small

translucent tan-colored burns two days after spraying. Only a few fruits showed this injury, which centered mostly about lenticels and limb-rub scars. A few leaves showed scattered areas of brown tissue bordered by leaf veins. Slight foliage injury resulted from applying a 1/500 solution as a spray on a sunny day with an air temperature of 82°F.

When sprayed on the fruit on the tree, acid had little effect on residue at a dilution of 1/200 or greater. At 1/100 there was the first noticeable effect in residue removal. At 1/50 acid concentration all but the thickest residue spots were dissolved when well wetted by the solution. A few hours after spraying the fruit was seriously mottled with small water-soaked, tan depressions centering about lenticels. During the next few days the burned flesh collapsed so that four days after spraying the fruit looked much like golf balls, the surface consisting of light brown dimples separated by ridges of green skin. Foliage was generally killed wherever spray drops dried. The 1/10 acid solution acted like the 1/50 dilution with quicker effect.

Fruit sprayed with 1 per cent and 2 per cent emulsions of light lubricating oil just before picking was taken to the laboratory and washed the following day with hydrochloric acid solution. The 1/800 acid solution attacked the oil-coated deposit so slowly on fruit sprayed with 2 per cent oil that 15 minutes' treatment did not give complete removal. Unoiled fruit was cleaned in three minutes. A 1/100 acid solution cleaned the oiled fruit well in three minutes. This strength of acid cleaned unoiled fruit in 15 seconds.

TESTS WITH ACID BATH

WASHING FRUIT IMMEDIATELY AFTER PICKING

Laboratory work showed that spray residue, chiefly bordeaux mixture, on Greening fruit in 1926 was effectively removed in acid solution as weak as 1 part of hydrochloric acid concentrate in 800 parts of water. Fruit washed in this solution, without rinsing, was kept for several days at room temperature (65° to 80°F) with no difference appearing between treated fruit and unwashed fruit. With so low an acid concentration, it was necessary to prolong the period of washing for 3 to 5 minutes to insure the dissolving of heavier residue spots. This slowed down the process. All higher acid concentrations cleaned this residue from fruit equally well and more quickly. Acid burning on the fruit occurred when a bath of 1 per cent or more of concen-

trated acid was used unless the fruit was immediately rinsed in water to remove the acid.

An acid bath consisting of 1 part of hydrochloric acid concentrate in 500 parts of water was tried for cleaning Greening fruit heavily coated with bordeaux spray residue. Fruit remained in the acid bath about one-half minute and was immediately rinsed in a tub of running water. The visible bordeaux was satisfactorily removed and the arsenic load of the fruit reduced from 0.0064 to 0.0017 grain of arsenic per pound of fruit.[4] About 10 per cent of the apples showed traces of residue remaining, practically all of which was around the bases of stems and close to the calyx lobes.

Large wooden tubs were used, made by sawing in two a 200-gallon cask. Acid solution was made up in one tub by pouring into the tub 75 gallons of water and adding 19 fluid ounces of hydrochloric acid concentrate.[5]

A line of spray hose was run into the other tub to supply rinsing water. Village water was available. Running water should be used in the rinsing tank if possible. A spray rig will do this very acceptably if no easier means is available.

The acid bath and rinse water were frequently tested for acid to learn how much the very heavy residue reduced the strength of the acid bath and how high an acid concentration was built up in the rinsing bath. This fruit was more heavily coated with spray residue than would

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[4]This record should not be taken to indicate that a brief treatment in 1/500 hydrochloric acid solution can be depended upon to remove heavy arsenical residue. This solution has not been tested against heavy arsenical residue in this work as none of the Hudson Valley fruit analyzed for arsenic has contained more than 0.0078 grain of arsenic per pound of fruit. Most of the fruit contained only traces of arsenic.

[5]All measurements refer to volume. Nineteen fluid ounces mean 19 ounces liquid measure. A glass quart measure is necessary for measuring small quantities of acid. These measures (graduates) as supplied for household and pharmaceutic use are commonly marked in ounces, half pints (teacupful or 8 ounces), pints (16 ounces), and quarts (32 ounces).

To determine the amount of acid to use in 75 gallons of water to make a 1/500 solution, multiply 75 gallons by 4. This gives 300 quarts of water. Divide the quantity of water by the dilution of acid, i. e., $300 \div 500 = 3/5$ quart of acid needed. $3/5$ quart $= 3/5$ of 32 ounces $= 19$ ounces of acid.

If acid is to be used at the rate of 1 gallon of concentrated hydrochloric acid to 100 gallons of water, a 75-gallon tank (containing 300 quarts) would require 3 quarts of acid concentrate. Metal, especially tin, containers should never be used with hydrochloric acid. Wooden tanks are the only suitable containers likely to be available for use as washing tanks. Other materials may be used for rinsing tanks, if running water is used for rinsing. Cement tanks cannot be used for the washing solution. Hydrochloric acid is injurious to clothing, tho much less harmful than sulfuric and nitric acids.

ever be the case under normal orchard conditions where bitter-rot control is not the main concern of spraying. Three weeks before the fruit was picked and washed it had received a heavy cover of bordeaux-spray consisting of 6 pounds of copper sulfate, 10 pounds of hydrated lime, and 100 gallons of water.

A previous cover of this material had also been made in late July, six weeks previous to picking. Some of the fruit was covered with the spray residue.

It was suspected that this very heavy residue when passed thru acid as weak as 1/500 in a small tank would rapidly eliminate the acid. In the beginning the acid was tested after washing every 10 or 15 bushels of fruit. Such quantities of fruit did not measurably reduce the acid concentration. Washing 100 bushels of fruit reduced the acid 5 to 8 per cent. Three hundred bushels of fruit reduced the acid strength 20 per cent.

The flow of rinse water was about 2 1/3 gallons per minute. Even with this slow rate of change the accumulation of acid in the rinse tank was scarcely measurable and was estimated at 1/20,000 acid concentration with about 2 bushels of fruit per minute passing thru.

The fruit was picked and placed in barrels, and washing was done within 48 hours after picking. The fruit was transferred to baskets which were lowered into the top of the acid solution and the fruit turned out into the liquid. The fruit was then rolled around in the liquid by hand to insure that all surfaces, especially stem and calyx ends, were submerged in the bath. About one-half minute was allowed for washing, then the fruit was gathered into a basket and lifted out of the acid. The basket was rested on the edge of the tub a few seconds to allow excess acid solution to drain back into the bath. Draining the fruit reduces the loss of acid and prevents the carrying over of an excessive amount of acid into the rinse water. The more closely fruit is drained the less debris, fungous spores, etc., pollute the rinse water.

In the rinsing bath the fruit was handled the same as in the acid bath. On removal from the bath most of the fruit was stacked in baskets in a packing shed for a few hours to dry, then it was barreled. Some of the fruit was packed directly into barrels from the rinsing bath and the barrels headed up.

ACID INJURY

None of this fruit showed injury from acid burn immediately after it came out of the bath. When examined a week later no injury was

found, tho after about five weeks' storage slight acid burns began to appear in the lots stored wet without rinsing. This injury was so slight it could be discovered only by very close inspection of the fruit. It consisted of light tan water-soaked areas bordering cuts, stem punctures, and other bruises on the fruit. These injuries slowly turned brown and dried, forming slight pits after several months' storage. Some of these injuries formed centers for decay, but most of them remained free from infection by rot fungi.

Unwashed fruit, fruit barreled directly from the acid bath (without rinsing), and fruit packed wet and dry after being rinsed was stored for a study of its keeping qualities. Latent development of acid injury was observed on the unrinsed fruit, but was not serious. Table 2 shows that washed fruit which was not rinsed developed much more rot than untreated fruit.

TABLE 2.—DECAY OF ACID WASHED AND UNWASHED GREENING APPLES.

LOT NO.	NUMBER OF APPLES	TREATMENT	PERCENTAGE DECAYED FRUIT	PERCENTAGE SCALDED FRUIT
1	520	washed, but not rinsed	17	3
2	490	washed and rinsed	5	5
3	497	untreated	8	15

Three factors may be considered to have influenced the comparative amounts of decay in these two lots of fruit as follows:

1. The unrinsed fruit was slightly burned by acid, altho storage observations showed that most decay spots could not be traced to acid burns.

2. The untreated fruit thruout the storage period was protected from decay by a very heavy load of fungicidal spray residue. Practically all of this had been removed from the washed fruit.

3. The fruit which was packed wet directly from the acid bath was washed in 75 gallons of acid solution thru which about 700 bushels of apples had previously passed. This fruit was exposed to an extremely heavy concentration of fungous spores in the acid bath. This, coupled with the removal of the fungicidal residue, is believed to account for most of the rotting in this lot of fruit.

In Tables 4 and 6 some of the fruit showed considerably more acid injury than this Greening fruit. However, decay is not closely correlated with amount of injury but with rinsing. Fruit treated in weak acid

and not rinsed decayed, tho there was practically no acid injury. Fruit treated in strong acid and rinsed showed more acid injury but less decay. Samples of all these lots of Greenings kept satisfactorily in cold storage until the following August (11 months).

There was a scanty development of sterile white mycelium in acid burns on the fruit of lot 1 in Table 2, and similar fruit listed in Table 4 which was stored wet from the acid bath without rinsing. This fungus does not appear to be a virulent rot-forming fungus, as only a small percentage of these injuries served as centers of active decay areas. The most frequent fate of these lesions is a slow discoloration from light tan to brown, accompanied by drying and shriveling of the surrounding flesh of the fruit, forming a brown pit in the surface of the fruit after a month's storage.

Table 2 shows a small reduction in scald on washed fruit which was not rinsed. However, this effect has not uniformly followed the washing of the fruit. In the case of this Greening fruit some difference in condition of the various lots of fruit may account for the result or it may be due to acid action.

Delayed acid injury is considerably more pronounced in wounds that have dried. In fruit that is bruised at picking time and stored for some time, the wounds dry and shriveled areas appear around the injuries. If such fruit is subjected to an acid bath, the acid is absorbed by this dry flesh and rinse water does not remove the acid. During three months' storage such acid washed fruit has developed acid burn extending a quarter of an inch from the border of the wound at the time of washing. This delayed injury occurred on badly bruised Baldwin fruit washed in 1/200 acid solution and rinsed in running water, the washing being done in January after 15 weeks' storage. After four months' additional storage, wilting was so severe that one-fourth of the surface of the fruit was crinkled about some of the injuries.

Fruit which is to be washed in an acid bath should not be roughly handled as acid will cause burning of wounds at 1/200 concentration. If bruising has occurred the washing should be done as soon as possible after picking. The Baldwin fruit shown in Table 3 had been roughly handled, but was washed before the wounds dried and there was only slight injury with 1/50 acid solution on the fruit that was rinsed. A lot of bruised Baldwins washed in 1/100 acid solution in January 1928, about four months after picking, appeared to be only slightly injured by the acid and the fruit was marketed in good condition. Two bushels which were stored until April were only fit for cooking fruit

because of the excessive wilting that had occurred around the bruised and dried out spots which had been burned by acid.

DELAYED WASHING OF FRUIT

During October and November 1926, and in January 1927, further tests were made of acid washes. This work was designed particularly to learn the amount of injury that would result from washing commercial varieties of apples other than Greenings with hydrochloric acid at various concentrations. It was considered possible that washing might become a fixed and necessary operation to fit fruit for sale because of the aversion with which all forms of residue were viewed by the handlers of fruit. Moreover, when it became known that a practicable way of cleaning fruit had been developed, requests were received for information about removing other types of residue than bordeaux from fruit.

Fruit which had been stored for an extended period was not as easily cleaned as the Greenings which were cleaned at picking time. Acid as weak as 1/500 did not clean some varieties well after as short a storage period as three to five weeks. Increasing the strength of the acid increased the liability of injury to the fruit. This injury was further increased as the storage season lengthened. The fruit gradually ripened, became softer, and was more easily cut and bruised, furnishing holes for the acid to attack the flesh. The failure of the acid to clean the fruit was due to the formation of wax which coated the residue, protecting it from the acid.

Tables 3 and 4 show the results in October 1926, of using several different acid concentrations with various important commercial apple varieties. Some of the apples were recently picked, while others had been in cold storage the number of days indicated. Table 5 gives the result of a similar test with Greening and Baldwin fruit in October 1927.

The McIntosh and Jonathan apples in Table 3 were stored for several weeks before washing and had considerable wax, consequently the 1/500 acid solution did not remove all of the residue. The other five varieties which had not passed thru an after-ripening storage period were cleaned by all concentrations of acid used. Greening fruit was cleaned rapidly and thoroly in 1926 with 1/500 acid immediately after picking. In 1927 after 29 days storage, 1/100 acid was required to clean Greening apples well. (See Table 5). Some of the Greening and

TABLE 3.—EFFECT OF CLEANING AND AMOUNT OF INJURY UPON TREATING SEVERAL VARIETIES OF APPLES WITH VARIOUS CONCENTRATIONS OF HYDROCHLORIC ACID.*

VARIETY	NUMBER OF DAYS STORAGE PREVIOUS TO TREATMENT	DEGREE OF CLEANING IN ACID CONCENTRATIONS OF				AMOUNT OF INJURY IN ACID CONCENTRATIONS OF			
		1/500	1/100	1/75	1/50	1/500	1/100	1/75	1/50
McIntosh	38	fair	fair	good	good	none	none	none	slight
Jonathan	18	fair	good	good	good	none	none	trace	trace
Stayman	8	good	good	good	good	none	none	trace	slight
Baldwin	7	good	good	good	good	none	trace	trace	slight
Newtown	4	good	good	good	good	none	none	trace	trace
Stark	4	good	good	good	good	none	trace	slight	slight
Spy	4	good	good	good	good	none	none	none	none

*Fruit treated in acid bath for one-half to one minute. Temperature of bath 40° to 50° F. Temperature of fruit 31° F. Fruit rinsed in running water immediately after the bath.

TABLE 4.—EFFECT ON APPLES TREATED IN HYDROCHLORIC ACID BATH BUT NOT RINSED; TREATMENT OTHERWISE THE SAME AS IN TABLE 3.

VARIETY	NUMBER OF DAYS STORAGE PREVIOUS TO TREATMENT	DEGREE OF CLEANING IN ACID CONCENTRATIONS OF				AMOUNT OF INJURY IN ACID CONCENTRATIONS OF			
		1/500	1/100	1/75	1/50	1/500	1/100	1/75	1/50
McIntosh	38	fair	good	good	good	trace	slight	slight	moderate
Jonathan	18	fair	good	good	good	none	slight	moderate	slight
Stayman	8	good	good	good	good	none	slight	moderate	moderate
Baldwin	7	good	good	good	good	none	slight	moderate	moderate
Newtown	4	good	good	good	good	none	slight	slight	moderate
Stark	4	good	good	good	good	trace	slight	moderate	moderate
Spy	4	good	good	good	good	none	trace	trace	slight

TABLE 5.—EFFECT ON APPLES TREATED IN HYDROCHLORIC ACID BATH ON OCTOBER 12 AND 13, 1927.

VARIETY	NUMBER OF DAYS STORAGE PREVIOUS TO TREATMENT	EFFECT ON REMOVING RESIDUE WITH ACID CONCENTRATIONS OF			AMOUNT OF INJURY AT DIFFERENT ACID CONCENTRATIONS		
		1/500	1/100	1/50	1/500	1/100	1/50
Greening	29	fair	good	good	none	trace	slight
Baldwin	0	good	good	good	none	trace	slight

Baldwin fruit was brought to the laboratory and the washing repeated at a temperature of 80°F, but 1/500 hydrochloric acid did not clean the Greening fruit quickly or completely at this temperature, which was as high as prevailed when Greenings were successfully cleaned with acid solution in 1926. The poorer results were due to the delay in cleaning and the accompanying secretion of wax by the fruit, causing the residue to be coated by wax and protected from the acid.

Fruit listed in Table 4 represents duplicate lots of the varieties listed in Table 3. This fruit was not rinsed in water but was stored directly after treatment with acid, otherwise both lots of fruit received the same treatment. None of the rinsed fruit was sufficiently injured to harm its appearance or keeping quality. Injury was greater on the fruit which was not rinsed, the injuries marked "slight" being of the degree which were considered not to be serious on fruit which would be immediately consumed. Shrinkage from burns and decay prevented further extended storage of the unrinsed fruit which was injured to the degree marked "moderate".

Baldwin and Stark fruit was more injured than other varieties. The Baldwin fruit had been roughly handled in picking. The Stark fruit was russeted considerably at the stem and calyx ends, and a few days after acid treatment lines of acid burns slowly developed in the russeted areas.

In January 1928, Baldwin apples which had been in storage three months and McIntosh which had been stored four months were washed. The Baldwins were satisfactorily cleaned with 1/200 hydrochloric acid solution, but a concentration of 1/100 was required for the McIntosh. Weaker acid baths did not remove all of the residue and slowed down the work. Experience so far shows that apples are not satisfactorily cleaned by acid weaker than 1/200 after extended storage, partly because of changes in the surface character of the fruit and

partly because acid action is lessened by the low temperature necessary in storage washing.

BEHAVIOR OF DIFFERENT SORTS OF SPRAY DEPOSITS IN ACID BATHS

Our earliest work on removal of spray residue with acid dealt with a spray residue consisting of bordeaux mixture and lead arsenate. This residue has proved the easiest to remove of all forms met with in this work.

The objectionable deposit left by Jersey dry mix has been the form of spray residue most commonly met in later work. This residue is very actively attacked by acid, but the greater thickness of deposits left by the dry-mix spray makes removal slower and less certain by very weak acid solutions. The 1/500 acid has repeatedly given satisfactory results, cleaning this material from freshly picked fruit. It is desirable to use as weak acid as possible in washing fruit, and 1/500 appears to be the best strength in some cases. If it is found that treatment is too slow with this dilution more acid may be added.

Lime-sulfur solution plus a small amount of lime to reduce arsenic burn is another widely used fungicide for summer spraying in the Hudson Valley. This spray leaves less residue than either bordeaux mixture or dry mix and is less apt to necessitate acid treatment. The residue behaves very much like dry mix residue in an acid bath. The spots on the fruit are not spread as evenly over the fruit surface as bordeaux deposits, but they are thicker and less rapidly dissolved. The 1/500 hydrochloric acid has been used in two cases to remove lime-sulfur residue with good results. Stronger acid may sometimes be needed. We have not had much experience with this residue.

Oil and soap in late sprays form residues which are not removed by weak acid and are only slowly attacked by acid as strong as 1/100 when washing is done immediately after picking.

Heavy lime wash used for late sprays on pears to reduce psylla damage leaves a deposit that yields readily to acid treatment. The sooty fungus which often follows psylla attack is not removed by acid.

DIFFICULTIES ENCOUNTERED IN WASHING FRUIT IN STORAGE

Wax formation.—Apples secrete wax in storage and the residue becomes embedded in this wax with the result that cleaning is more difficult. The length of treatment must be increased or the acid strength stepped up. Both of these factors increase the liability of injuring the fruit.

Softening of fruit bruises.—Fruit gradually ripens in storage and becomes softer and more easily injured. Acid burns result from mechanical injuries and this burning is more serious because of the stronger treatment necessary in delayed washing. Picking bruises become dry during storage and these dry wounds absorb acid solution, retaining it in spite of subsequent rinsing. Deep and wide acid burning results around dry wounds.

Temperature.—Fruit comes from storage at a temperature of 31° to 32° F. This slows down the action of the acid bath. The temperatures at which acid washing is done must be carefully regulated or sweating occurs. Sweating injures fruit. Moreover, fruit carrying a heavy load of condensed water rapidly dilutes acid baths and necessitates more frequent renewal of the acid. Sweating has been observed at packing room temperature of 55° to 65°F, depending on the humidity of the atmosphere. Air temperature of 50° F is about as high as can be used in washing fruit in winter. The temperature of the bath should be no higher than this. Little is known of the effect of washing fruit at 31° F in a high temperature bath. Until more is learned, high temperatures should not be used.

The low temperatures necessary in this work require increased acid concentration or lengthened period of washing. In a room temperature of 50° F, passing 160 bushels of ice cold fruit thru 50 gallons of acid solution lowered the temperature of the bath from 48° to 38° F. Fruit at 30° to 32° F rapidly cools the bath. If there are no arrangements for heating the bath, it is better to change the solution rather than accept the delay of giving the fruit extra long periods of washing.

DILUTION OF ACID BATH BY WATER ON FRUIT

Fruit may carry considerable water into the acid bath if it has become wet by rain or dew in the open or by condensation from the air when brought from storage into a warm packing room for washing. Fruit wet with rainwater, in one instance, reduced the strength of the acid bath about twice as fast as other fruit from the same orchard picked the day before and stored dry in a packing shed.

Several bushels of fruit were sprayed with known amounts of water and the amount that ran off measured. Eighty to 190 cc of water remained on a bushel of fruit, the stem and calyx cavities holding a large part of the water. Fruit carrying 100 cc of water per bushel would add 10 liters, approximately 2½ gallons, of water to the bath.

for every 100 bushels washed. In a 50-gallon tank this would represent a 5 per cent dilution. This is about the rate that very heavy spray residue removes acid by chemical action. When washing wet fruit the acid bath should be frequently tested and acid added as needed or the solution should be changed frequently.

INCREASING THE WETTING PROPERTY OF THE ACID SOLUTION

From the beginning trouble was experienced because the acid solution did not thoroly wet the residue on fruit. This difficulty was experienced with some fruit at picking time. The trouble was increased by delay in washing. There are three causes recognized as retarding the action of acid in wetting residue, *viz.*, (a) wax coating over the residue, (b) wind-blown dust coating the residue, and (c) air bubbles persisting in the stem and calyx ends of apples.

Dust and wax, in addition to being hard to wet, are not attacked by hydrochloric acid and serve as barriers between the solution and the spray deposit. Stem cavities sometimes are not cleaned at all because of air filling the cavities.

Oils of the light lubricating type, somewhat heavier than kerosene, were emulsified with various concentrations of acid in attempts to decrease the surface tension of the acid bath and secure better wetting. One and 2 per cent oil emulsions did not greatly modify the physical properties of the solution. Results with these percentages of oil were no better than with acid alone. Cleaning was impeded by 5 per cent oil emulsion. Probably, oil coated the residue and protected it from acid action.

RINSING WASHED FRUIT REDUCES DECAY

Rinsing fruit after washing in an acid bath reduces the acid injury even when very dilute acid solution is used. In general, the less fruit is injured the less decay occurs. This is true for acid injury as well as for bruises and stem punctures, altho smaller percentages of acid burns serve as infection centers for rot fungi. The principal reason why rinsing reduces decay is because the rinsing bath really cleans the fruit.

The rinsing bath does not remove much of the alkaline residues on Hudson Valley fruit. Tables 3 and 4 for rinsed fruit and unrinsed fruit show that the residue remained after rinsing where the acid had not done good work. The rinse bath removes from the fruit the accumulation of debris in the wash water. Along with insoluble dirt

large quantities of bacteria and fungous spores are washed from each lot of fruit as it passes thru the acid bath and remain suspended in the solution until picked up by fruit that is later washed. This accumulated dirt makes the acid solution turbid after a large volume of fruit has passed thru. If the fruit is not rinsed after washing in this dirty solution, the adhering drops of solution dry on the skin and leave rings of dirt. The importance of the rinse water in removing insoluble dirt and spores from fruit emphasizes the desirability of providing flowing rinse water or changing this water very often.

Table 2 shows that the amount of rot was doubled by passing fruit thru a dirty acid bath and storing a long time without rinsing. Rinsed fruit decayed less than unwashed fruit and less than a third as badly as fruit which was not rinsed.

Table 6 lists the same fruit which is listed in Tables 3 and 4 and is typical of results frequently observed in the decay of washed fruit. The decay of untreated fruit averaged 5 per cent. Fruit that was washed and rinsed averaged 4.4 per cent decay, while fruit that was washed and not rinsed averaged 7.9 per cent.

It is difficult to get away from the factor of increased acid injury on unrinsed fruit when comparing it with rinsed fruit. Comparing Tables 3 and 4 showing the amount of acid injury on this fruit with Table 6 showing the amount of decay, it is evident that the degree of injury and amount of decay are not closely correlated. In the case of unrinsed fruit there is a slight tendency for decay to be greater with the stronger acid treatment, but the amount of decay following 1/50 acid wash is not in proportion to the increased acid injury of this treatment compared with 1/500 acid wash which gave no acid injury. All varieties, except Spy, showed some injury when washed in 1/50 acid bath and immediately rinsed (Table 3). The percentage of decay in this fruit was 4.1 (Table 6). The unrinsed fruit (Table 4), after washing in 1/500, showed the merest trace of injury on two varieties and all the other fruit was uninjured, yet there was 7 per cent of decay in this fruit. Except in the case of the Baldwin fruit, which showed serious injury and later decayed very badly, there is no pronounced agreement between the amount of injury observed at washing time and the amount of decay which developed later.

Tables 3, 4, and 6 indicate what has generally been found in washing fruit namely, the more the fruit is injured, either in the bath or previously, the greater the amount of decay. However, when the rinse bath is omitted, whether fruit is much injured or not, decay becomes an im-

TABLE 6.—PERCENTAGE OF DECAY OF FRUIT LISTED IN TABLES 3 AND 4, COMPARING FRUIT RINSED AFTER TREATMENT WITH FRUIT NOT RINSED AND WITH UNTREATED FRUIT.

VARIETY	NOT TREATED, PERCENTAGE OF DECAY	TREATED, PERCENTAGE OF DECAY									
		Rinsed					Not rinsed				
		Acid concentration				Average each variety	Acid concentration				Average each variety
		1/500	1/100	1/75	1/50		1/500	1/100	1/75	1/50	
McIntosh	3	2	3	5	3	3	5	7	7	8	7
Jonathan	4	2	5	4	4	4	4	7	8	6	6
Stayman	7	4	3	9	4	5	6	9	9	8	8
Baldwin	9	6	8	7	7	7	9	6	12	12	10
Newtown	3	5	3	0	2	2.5	11	4	4	6	6
Stark	5	3	4	4	4	4	6	6	7	11	7.5
Spy	7	2	6	7	5	5	9	9	11	10	10
Average percentage decay	5.4	3.4	4.6	5.1	4.1	4.4	7.1	6.9	8.3	8.7	7.9

portant loss factor. In the unrinsed fruit in Table 6 the Spies were the last apples washed and they decayed very badly, tho this fruit suffered the least injury of any variety of the unrinsed lot (Table 4).

Sound Hudson Valley apples that have been carefully handled will store well after washing in acid solutions as strong as 1/100. This solution contains approximately 30 per cent of actual hydrochloric acid by weight. Acid concentrations of 1/75, 1/50, and 1/30 may be needed where arsenic removal is important and can be used without immediate damage to the fruit if the treatment is limited to a minute or less and is followed by thoro rinsing in fresh water. Until more is learned about the tolerance of eastern fruit for hydrochloric acid wash, extended storage of fruit washed in strong solutions is not recommended. 1/30 acid solution, containing 1 per cent of hydrochloric acid by weight, is the strongest solution that can be regarded as safe. Streeter[6] has stored fruit washed in this strength of acid for two months without injury. Hydrochloric acid as strong as 1/10 has been recommended in other districts for washing fruit. Eastern fruit will not tolerate this high concentration of acid.

Fruit which is russeted and varieties which develop little wax should not be washed in acid solution stronger than 1/100 if extended storage is desired. Bruised fruit may be expected to show some injury from washing with 1/200 acid solution, and more injury at higher concentrations.

EFFECT OF STORAGE HUMIDITY ON WASHED FRUIT

Fruit washed with hydrochloric acid behaves so much like untreated fruit that under various storage conditions no differences could be found in most cases. There is not enough known about desirable humidity conditions in fruit storages to warrant positive conclusions. In the Hudson Valley work several storage systems have been used for storing both treated and untreated fruit at humidities varying from 60 to 100 per cent of absolute atmospheric saturation. Storages maintaining a relative humidity of 80 to 90 per cent held fruit without excessive wilting. Drying was much more rapid at 60 to 70 per cent relative humidity.

There is a possible objection to very high relative humidity, over 90 per cent, in that if the temperature is lowered even slightly condensation of moisture on the fruit occurs. Theoretically this should favor

[6]Unpublished data from L. R. Streeter, Associate in Research (Chemistry) at this Station.

decay fungi. Practically, this effect has not been determined as important. This matter merits attention. So far as the question can be answered, it seems wiser to advise that fruit storage atmosphere should be maintained at a high relative humidity. Error in the direction of excessive moisture appears less costly than too low humidity with its accompanying wilt of fruit. The Greening fruit in Table 2 was stored in very high humidity and decay was low during the eleven months' storage period. During the season of 1928-29, storage space with controlled humidity has been available for the first time.

ADDING ALKALIES AND DISINFECTANTS TO RINSE WATER

Early in the work there was some question as to whether addition of alkali to the rinse water might be warranted to effect chemical removal of the hydrochloric acid carried over into the rinsing bath. It also seemed possible that a disinfectant in the rinse water might provide complete insurance against decay. Table 7 gives the result of treating 3 bushels of Baldwin and McIntosh fruit in 1/100 hydrochloric acid bath and then rinsing in various solutions. The alkalies and disinfectant did not improve the keeping quality of the fruit.

TABLE 7.—EFFECT OF VARIOUS RINSING BATH SOLUTIONS ON THE KEEPING QUALITY OF APPLES WASHED IN 1/100 HYDROCHLORIC ACID SOLUTION FOR THE REMOVAL OF SPRAY RESIDUE.

VARIETY	COMPOSITION OF RINSING BATH	PERCENTAGE OF ROT AFTER THREE MONTHS' STORAGE
Baldwin	1 pound hydrated lime in 100 gallons water	7
McIntosh		1
Baldwin	1 pound bicarbonate of soda in 100 gallons water	3
McIntosh		4
Baldwin	Formaldehyde 1 to 800	4
McIntosh		2
Baldwin	Water	5
McIntosh		2
Baldwin	Untreated	6
McIntosh		4

The fruit in Table 7 was washed in 1/100 dilution of hydrochloric concentrate and immediately rinsed in one of four solutions to remove acid or, in the case of the formaldehyde solution, to remove acid and disinfect the surface. The failure of neutralizing agents to reduce rot as compared to a fresh water rinse is probably due to the fact that the

water removed the acid carried over from the acid bath very effectively and infection of burns did not occur. Neutralizing agents were no more effective. The fruit was exposed to formaldehyde less than one minute in the rinsing bath. Probably this time was insufficient to permit sterilization. In practice it would be impractical to leave fruit in a rinse bath for an extended time unless the tank was of very large capacity.

The McIntosh apples used in this experiment, in spite of efforts to avoid injury, suffered considerably from handling. Many of the bruises were slightly burned by the acid and one month after treatment the McIntosh fruit did not appear at all attractive. It was expected that these bruises would cause excessive rotting of the treated fruit as compared with untreated McIntosh, but this did not occur.

As fruit washing has been practiced during the past three years in the Hudson Valley, fresh water has appeared to be a better rinsing bath than any other material. It removes excess hydrochloric acid satisfactorily and cleans the fruit of enough spores so that carefully washed fruit usually shows less rot than untreated fruit. No disinfectant has been found that will kill spores in the brief time fruit is in the rinsing bath without injuring the fruit.

One part of formaldehyde to 150 parts of water is suggested by the Oregon Agricultural Experiment Station as a desirable rinsing solution. This strength of formaldehyde might cause discomfort for workers in a small room, but it should be superior to plain water where running water cannot be provided. There is one advantage inherent to running water compared with disinfecting or neutralizing baths, and that is that running water prevents the accumulation of insoluble dirt to stick and dry on the fruit.

WASHING FRUIT TO REMOVE DIRT AND FUNGOUS DEPOSITS

Field dust.—Spray residue is frequently coated with dust blown by the wind from nearby roads and from the soil in clean-cultivated orchards. This dirt is found chiefly in the stem cavities of apples, where it frequently forms such a heavy deposit that spray residue and the skin of the fruit are entirely covered. Pears do not collect such quantities of wind-blown dirt.

Most Hudson Valley soils are not residual soils but are alluvial or glacial materials transported to their present locations by glacial action or water. The residual soils, derived from country sandstones and shales, are insoluble in hydrochloric acid (11). The greater part of the soils,

alluvial or glacial types, contain a high proportion of inert matter, altho some of the finer soils contain enough calcareous material to effervesce in hydrochloric acid solution (6). Wind-blown dust from soil is more difficult to remove with acid than any form of spray material used in the Hudson Valley.

Solutions containing 1/500 to 1/50 hydrochloric acid have been used on dust-coated fruit. The cleaning of stem cavities is not satisfactory, but acid concentrations of 1/50 or 1/100 adequately clean the cheeks of apples, except where all the residue is inert dust.

Road dust.—Road dust may not be as serious a complication as field dust in acid washing. Frequently, country limestone is used for road metal in constructing Hudson Valley roads. This forms a dust which, except for its extreme fineness, offers little difficulty in acid treatment. Heavy residue of lime-sulfur and road dust has been satisfactorily removed with 1/200 hydrochloric acid solution. In one case road dust was not well eliminated by washing in 1/100 acid bath.

Cement dust.—The effects of cement dust on fruit are forcefully shown in those parts of the Hudson Valley where the cement industry has completely eliminated fruit growing. Cement being a mixture of limestone and clay, there is a possibility that a hydrochloric acid wash, in which limestone is highly soluble, may have some value in removing cement dust from fruit. It is hoped that this matter can be studied further.

There have been some trials with hydrochloric acid solutions for washing cement dust from fruit. This dust does not yield to acid treatment as readily as alkaline spray residues.. A one-minute bath in 1/200 acid solution, and in another trial, one-minute treatment in 1/100 acid, cleaned pears of cement dust without injury to the fruit. Long or short treatment in acid did not satisfactorily clean apples which had caked deposits of cement dust in the stem cavities. The acid dilutions used were 1/50 and 1/200.

Sooty fungus and black mold.—It would be highly desirable to find a material that would remove the deposits of black mold that follows aphis attacks on apple and pear psylla attacks on pear. There is probably no form of dirt that depreciates fruit more than this fungous growth. Many materials have been tried against this fungus deposit; but no satisfactory means of removing it has been found.

Bleaching agents and materials which will dissolve the black mycelium without injuring the underlying skin of the fruit seem to offer

the best hope of solving this problem. Sulfur fumes and chlorine compounds, the commonest bleaches, cause immediate injury to the skin of both apples and pears. Alkalies dissolve the wax from fruit, permitting the fungus to be easily removed by hand wiping. This is a slow, expensive treatment and fruit so handled does not keep well in storage. Pears washed in alkali developed browning of subepidermal tissue and wilted seriously when stored for two or three months after washing.

Javelle water, containing both alkali and free chlorine, has been recommended for removing sooty fungus. It possesses the virtues of both alkalies and bleaching agents. However, it also possesses the disadvantages of both these materials. Treated fruit wilts if stored, and pears also develop brown spots beneath the skin.

FORMATION OF WAX ON FRUIT AND ITS RELATION TO THE SPRAY RESIDUE PROBLEM

Wax formation on fruit is of great importance, and one factor which has recently received attention is the effect of wax in holding spray residue on the fruit. Previous to the beginning of spray residue work, this very important matter was overlooked. At present fruit wax is under some scrutiny as a handicap to efficient residue removal, and such interest largely obscures the vital function fruit wax performs in fitting fruit for storage.

The fruit industry has suddenly become conscious of fruit wax, because wax and spray residue become mixed, and residue mixed with wax does not readily dissolve in hydrochloric acid or other solvents. This matter has been mentioned earlier in this bulletin in connection with the delayed washing of fruit. Fruit on the tree develops wax. This wax protects residue from weathering, accounting for the retention of residue until picking time. McIntosh, Northern Spy, and Jonathan fruits secrete considerable wax on the trees and are much more apt to retain residue than Rome Beauty or Ben Davis which secrete little or no wax. Baldwin, Greening, King, Stark, and Newtown are intermediate. Baldwin and Stark often secrete very little wax.

Variety of fruit is only one variable in determining the amount of wax on fruit. Culture influences wax secretion in that early maturing apples of a variety form more wax than later maturing fruit. Comparison shows that Jonathan, Rome, Winesap, and Delicious generally develop considerably more wax as grown in the Northwest than they do in the Hudson Valley. This comparison explains in some measure the

difference in the severity of the spray residue problem in different districts. Virginia-grown fruit has somewhat thicker wax, and western New York fruit possibly has somewhat less wax than Hudson Valley fruit. The simplest way of determining waxiness of fruit is scraping the skin of the fruit with a knife.

The obvious advantages of wax on the surface of fruit are three, *viz.*, (a) it cuts down evaporation, (b) forms a barrier against decay organisms, and (c) enhances the appearance of fruit. Much of the better color ascribed to western fruit is simply due to the higher gloss imparted to it by its waxy coat.

During the past two years it has become evident that wax has an additional very important relation to keeping quality and appearance of fruit. A close connection is indicated between the tendency of fruit to form wax and susceptibility to russeting. McIntosh, Wealthy, Jonathan, and Northern Spy form much wax under Hudson Valley conditions, rarely russet, and are difficult to wash after extended storage. Rome Beauty and Ben Davis form wax sparingly, often russet, and residue can be washed off after several weeks or even months of storage. Baldwin, Greening, and Delicious vary considerably in waxiness. They sometimes have a moderate coating of hard wax possessing a good gloss, or they may have but a thin coat of soft wax that makes the fruit surface appear greasy or oily. There is also great variation in the amount of russeting of these varieties, russeting sometimes being very severe.

Early picking of fruit of the wax-forming varieties facilitates residue removal, but it is not justified under Hudson Valley conditions. Normally ripened fruit can be washed satisfactorily at picking time, keeps in storage much better and is much more attractive than fruit picked before adequate color and wax have developed. Varieties that form heavy wax are mostly thin skinned. They need wax for protection. This is particularly true of the Northern Spy and Wealthy.

There has been a tendency during the past three years to let fruit hang late so that the residue might weather from fruit. Where wax has formed on fruit, rains wash off residue very slowly. There is loss from dropping and the fruit suffers in quality and shortening of its storage life from this treatment. When residue demands attention, it is better to treat the fruit in the best way to preserve its quality and use a cleaning process to remove the residue. Fruit can be washed at a cost of 2 to 5 cents a bushel. Properly done, acid washing does not affect the storage of apples adversely and improves their appearance.

RETENTION OF RESIDUE FROM COMBINED SPRAYS CONTAINING OIL

One or 2 per cent oil sprays are sometimes used against red mite in midsummer because of lack of control early in the season or heavy mite infestation from surrounding trees. There is strong temptation to add lead arsenate to this oil for controlling maggot, and, in addition, a fungicide to reduce scab and sooty fungus. The combination of these materials makes a very heavy spray with consequent very thick residue. The oil serves as a binder and waterproofs the deposits against weathering or action of acid.

A block of Greenings and Baldwins was sprayed with dry-mix and lead arsenate seven weeks before the Greenings were picked. Oil was not used on the Greenings because this variety normally escapes red mite injury. One per cent oil was added to the mixture for the Baldwins to reduce mite injury. In the seven weeks' interval before harvesting the residue was reduced on the Greenings enough to be unobjectionable. The Baldwin fruit was harvested 12 weeks after spraying and there was considerable residue still remaining on it. Washing with 1/200 hydrochloric acid solution cleaned the faces of the apples, but it did not remove all of the deposit from the stem cavities and calyx basins. Normally, Baldwin apples contain less residue than Greenings because they develop less wax on the tree before picking and are exposed to a long season of weathering. Streeter[7] has analyzed McIntosh, Greening, and Baldwin apples which received identical spray treatment. The McIntosh contained 0.022 grain, the Greening 0.019 grain, and the Baldwin 0.008 grain of arsenic per pound of fruit.

This fruit received the regular sprays recommended for western New York apples, but the material was applied in excessive amount for experimental work. The Greening and McIntosh fruit should have shown the same amount of residue as they were exposed to the same amount of weathering, these varieties ripening together. Heavy wax secretion on the McIntosh during the ripening period probably accounts for the difference.

SPRAY RESIDUE CONTENT OF FRUIT

The Hudson Valley is more fortunately situated than most fruit-growing sections in receiving assistance from rain in removing spray residue. The mid-Hudson region receives about 26 inches of rain during the growing season, approximately 12 inches fall during the

[7]Unpublished work.

months of July, August, and September (9). This may be considered the approximate amount of rain effective in weathering away residue. The Lake Shore region of western New York receives 15 to 20 inches of rain during the growing season, with 9 or 10 inches during the three months when residue removal occurs. The Finger Lakes section receives about the maximum rainfall for the Lake Shore section and the Champlain district about the minimum for the Lake Shore section.

Rain and wind remove spray residue and wax retains the residue. These opposing factors account for much of the difference in the amount of residue found on fruit in various fruit sections of America. There is little likelihood that growers in the Hudson Valley, with present spray schedules, will be forced to remove spray residue because of present legal restrictions against toxic materials; but, as a means of improving the appearance of the fruit, washing may be useful.

Analyses of Hudson Valley fruit have shown a light content of arsenic (14). Analyses during two years by Hartzell and Wilcoxson (3, 4) of apples grown at Yonkers, N. Y., agree with these findings on Hudson Valley grown apples. Work in New Hampshire (13) and in Pennsylvania (8) has shown that the routine operations of picking, packing, and handling fruit reduces the arsenic load. Hamilton (2) has shown that heavy overspraying of apples is not necessary in New Jersey for the fruit to retain more lead arsenate than is allowed by present legal tolerance regulations. Fruit in the lower interior of trees carries much more residue than fruit on upper branches. Low fruit receives the drip from upper sprayed parts and the residue is protected from dashing rain and from wind which causes outside fruit to be wiped by leaves and branches. MacLean and Weber (7) also show that low-growing fruit carries much heavier residue and that small apples have much more residue per pound than large ones.

When doubt exists about the amount of arsenical residue on fruit and it is desired to collect samples for analysis, the smaller fruit on the lower inside branches should be picked without excessive rubbing or handling. Visible residue is not a certain indicator of arsenical residue, fruit showing heavy residue often analyzing low in arsenic. However, heavy visible residue is the criterion apt to be used in sampling on the market, and fruit with this form of residue is more apt to have arsenical residue also. When fruit is collected on the market, it is the worst sample of residue that can be found which forms the basis for judgment. This should be considered and every effort made to prevent any fruit reaching market containing excessive residue. Fruit which needs

washing should be washed and not sold into channels where analyses will result in prolonging and increasing the present concern over spray residue.

EFFECT OF LATE SPRAYS ON ARSENIC CONTENT OF FRUIT

It would be most unfortunate if this bulletin were to leave fruit growers with the impression that eastern fruit, because it generally carries small amounts of toxic residues, can be carelessly sprayed with arsenic solutions without danger of such fruit exceeding the legal tolerance or injuring consumers. It is implicitly recognized that lead arsenate spray leaves a most undesirable residue on fruit when most care is used in applying the material. Entomologists recognize this and are seeking for less toxic substitutes that will give insect control.

The work of Streeter (page 28) and that of McLean and Weber (7) clearly shows that overspraying and late applications of arsenic may result in eastern fruit carrying an excessive amount of arsenic. Western fruit districts by great effort and refined methods have largely eliminated the chief cause for complaint against spray residue. It would be most unfortunate if an eastern fruit district should furnish an excuse for the revival of this critical situation.

Hudson Valley apple and pear growers are justified in feeling special responsibility regarding spray residue. This district sends a large quantity of fruit to the foreign markets which are most critical of spray residue. The enforced use of late poison sprays on apples, because of apple maggot, adds considerable risk that some of this fruit may run over the tolerance limit. Mundinger (10) suggests that dust applications for apple maggot are satisfactory. If dust is substituted for spray in the second apple maggot application in late July, the risk of having heavy residue at picking time is greatly reduced.

EQUIPMENT FOR WASHING FRUIT

It is believed the methods and equipment which have been described will suffice for sporadic cases where residue must be washed from fruit. It is not intended that tub dipping should be considered for washing fruit where this work is to be done regularly. Several efficient machines for washing fruit without bruising or other handling injuries are now on the market. It is possible that the improved appearance of washed fruit may in itself be accepted as reason enough for washing all fruit. Western districts have accepted washing of fruit and there are sugges-

tions that they consider the enforced cleaning as a new advantage for their fruit. They claim that cleaned fruit sells for sufficient premium to justify washing simply to better the appearance of their pack. Inquiries among market men in New York, Albany, and Rochester lead to the conviction that this is true for western fruit. This merits study by those interested in eastern fruit production.

Better methods and equipment than those used in this preliminary work will be required where fruit washing is practiced on a large scale. The way the work has been done fruit is handled too much. Machines are now available for floating and dipping or spraying fruit with acid solution. These eliminate handling injury and speed up the work.

SUMMARY

The principal ingredients of spray residue in the Hudson Valley are largely or wholly non-toxic. Cleaning methods have been principally concerned with the removal of unsightly deposits, tho it has been found that arsenic, the root of the residue problem, is also eliminated when other residues are removed.

Hydrochloric acid is the only cleaning agent that has given satisfactory results. Alkalies and oils are unsatisfactory. Fruit treated with alkali wilts in storage and pears are discolored.

Hand wiping of fruit increases decay, causes excessive wilting in storage, and injures the appearance of some varieties of apples and most varieties of pears. It is very expensive compared with acid washing. Shredded oiled paper was the best mechanical cleaner tried, but hand wiping with this material is costly. Packing fruit with one-half pound per bushel of paper containing 20 per cent of oil results in an improved appearance of the fruit. Residue in contact with oiled paper absorbs oil, and acid washing is difficult where fruit has been stored in oiled paper.

The application of late sprays to help remove residue has been without value. Even hydrochloric acid, the best residue solvent in use, does not function well when used as a spray for fruit hanging on the tree. Mature fruit is protected from late sprays by foliage. Late sprays with alkalies injured fruit and foliage. Oil sprays made acid washing slow and uncertain.

Arsenic and fungicides containing lime are readily removed when fruit is floated in a solution of hydrochloric acid. The residue of sulfur sprays and oil sprays is more difficult to remove. Weaker acid can be used and less injury results if fruit is washed at picking time.

Acid action is impeded by low temperature, wax, oil, and dirt. No method or material has been found for increasing the action of hydrochloric acid on residue.

The rinsing of washed fruit is necessary. Flowing water is the best rinse material that has been tried. Unrinsed fruit decays badly.

Washed fruit stores as well as unwashed fruit except where the fruit has been bruised and allowed to dry before washing. Such fruit is burned by acid and wilts in storage. Sound washed fruit comes out of storage in better condition than unwashed fruit. Moist storage air, over 80 per cent relative humidity, is desirable for all fruit. The longer fruit is stored before washing, the more difficult it is to wash. Wax secretion, low temperature, sweating, and softening of fruit complicate the work.

Wet fruit markedly increases the rate of dilution of an acid bath. A 50-gallon bath should be tested for every 50 bushels of fruit when washing wet fruit. Testing the bath after every 100 or 200 bushels of fruit is sufficiently frequent for dry fruit.

Acid solutions of 1/100 to 1/500 will probably be found suitable for most fruit washing work. It is safe to treat fruit in 1/30 acid solution when arsenic removal is required; but acid concentrations greater than 1/30 (approximately 1 per cent actual acid) are not safe. Sound, well finished apples tolerate strong acid, up to 1 per cent actual acid, much better than russeted or bruised fruit. One minute or less is preferable to longer treatment. Wooden containers should be used for the acid bath.

Wind-blown dust from cultivated soil, roads, and cement factories is hard to wash from fruit, tho sometimes hydrochloric acid will attack and remove such material. Dust particles vary in chemical composition and fineness. On pears and on the cheeks of apples, acid cleaning has been satisfactory. Caked deposits in stem cavities of apples often do not dissolve in acid.

No method has been found suitable for removing deposits of sooty fungus or black mold from fruit.

Wax secretion on the skin of fruit is a vital function in improving the keeping quality and attractiveness of fruit Waxy fruit does not russet. Residue covered by wax is protected from weathering and acid. Waxy varieties are more apt to have residue and should be washed right after picking.

Rain is an important weathering agent in reducing spray residue.

Most of New York State receives considerable rain late in the season, the lower Hudson Valley being the most fortunate part of the State in this respect. In this climate fruit normally carries very little toxic residue resulting from the spraying system practiced by commercial growers. However, care should be taken to avoid the use of excessive amounts of residue-forming materials late in the season.

Sample fruit for residue analysis should be selected from that part of the crop most likely to carry heavy residue. Otherwise, an analysis will simply fool the man who has done the sampling. In the market, the heaviest residue which can be proved forms the basis of judgment.

It is better to spend a few cents per bushel to wash fruit unnecessarily than to sell fruit which should be washed.

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