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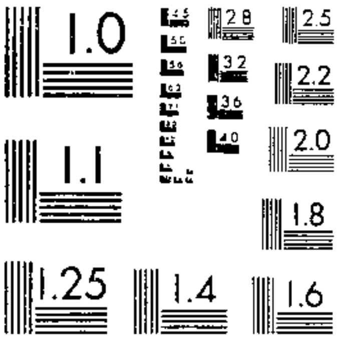

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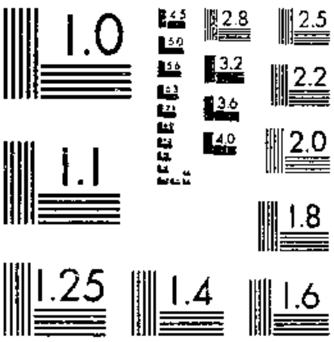

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TECHNICAL BULLETIN No. 245 — JUNE, 1931

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ARSENICAL AND OTHER FRUIT INJURIES OF APPLES RESULTING FROM WASHING OPERATIONS

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INTRODUCTION

The susceptibility of apples to arsenical-spray injury has been recognized for many years. Its cause and prevention have furnished the basis for a long series of investigations, most of which, however, have dealt primarily with foliage injury.

The experimental work previously reported has established the fact that arsenical-spray injury is due primarily either to the original content of water-soluble arsenic, to interactions in the spray mixture which liberate water-soluble arsenic, or to reactions of leaf extractives with the spray material.

The investigation now reported is concerned particularly with arsenical injury of apples at harvest time or during storage and was conducted at the United States Fruit Disease Field Laboratory at Wenatchee, Wash.

Since 1927, when chemical solvents were first employed in commercial fruit-washing operations in the Pacific Northwest, injury at the calyx has been found frequently on washed apples. It was first described as "calyx scald," because it appeared most frequently in the calyx region, although it occasionally occurred in the stem cavity as well (*2*).[1] The injury shows as a black or brown ring surrounding the calyx, or less frequently as dark patches of dead skin

[1] Italic numbers in parentheses refer to Literature Cited, p. 12.

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on the sides of the calyx cavity. At first the injury is very superficial, but in advanced stages it becomes depressed and extends one-eighth of an inch or more into the flesh, which becomes brown and dry. (Pl. 1.)

The particular type of injury concerned in the present discussion first came to general notice in 1927, on apples that had been washed in dilute hydrochloric acid. This association of the injury with acid washing led to a popular belief that it was caused by hydrochloric acid and possibly resulted from the rinse water having become too acid. However, elimination of traces of acid in the rinse water and even the use of sodium bicarbonate to neutralize acidified rinse solutions did not entirely prevent the injury.

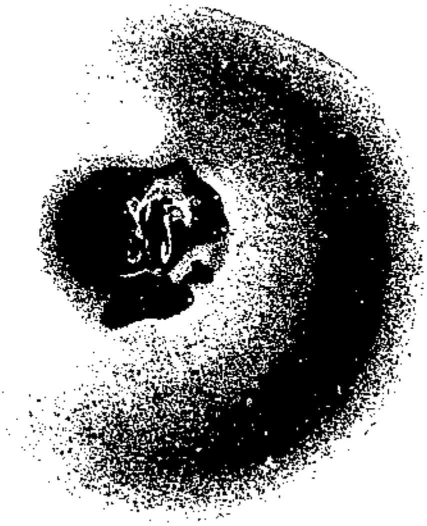
Calyx scald was frequently followed by rot invasion. (Pl. 2, A.) The fungi most frequently encountered in these calyx rots were *Penicillium expansum*, *Macrosporium* sp., and *Cladosporium* sp. With certain methods of washing and types of equipment that were discarded as soon as their objectionable features were discovered, the losses sometimes reached 60 per cent within three or four weeks after washing (*3*). Confidence in the commercial value of washed apples was almost destroyed, and fruit growers and shippers of the Northwest experienced a period of extreme anxiety verging almost on panic. The fruit industry faced the necessity of removing spray residue in order to market the apple crop, and where this could only be accomplished by washing, it appeared that the keeping quality of the apples might be destroyed.

ARSENICAL INJURY

OCCURRENCE IN THE ORCHARD

For many years arsenicals of various kinds have been used for spraying plants. One of the first experiments with soluble arsenic on apples to be reported was that of Gillette (*4*), who found that arsenious acid in dilutions as weak as 1 to 1,200 caused severe injury to the foliage. In later work he reported that the injury could be prevented entirely by the addition of milk of lime (*5*). Since then the use of lime with arsenical sprays has become an established procedure wherever tender foliage is sprayed or where there is danger of encountering much soluble arsenic in the spray mixture. Two types of lead arsenate are used for insecticidal purposes—basic lead arsenate and lead hydrogen arsenate, commonly known as acid lead arsenate. At the present time lead hydrogen arsenate has almost completely supplanted the earlier use of Paris green and other arsenicals for spraying apple trees, on account of its low content of water-soluble arsenic. Numerous investigations on the injurious effects of arsenical sprays have been conducted, and agreement has been reached in attributing the damage to soluble arsenic. In recognition of the danger from soluble arsenic, regulatory measures enforced by State and Federal authorities provide that lead arsenate offered for sale shall not contain more than 0.75 per cent of water-soluble arsenic pentoxide, As_2O_5 (on the basis of the paste form of lead arsenate, which contains 50 per cent water).

Although protected by law against the danger of purchasing lead arsenate that contains injurious quantities of soluble arsenic, the



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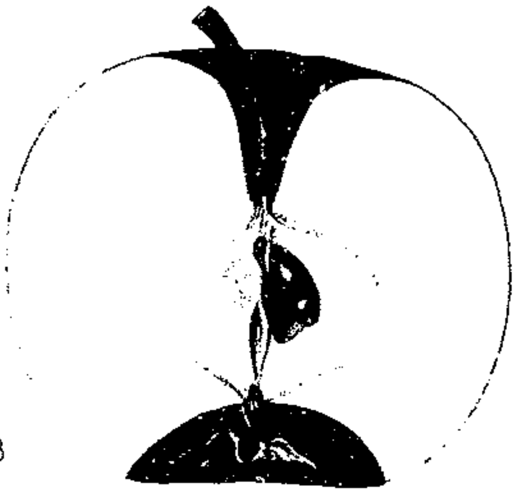
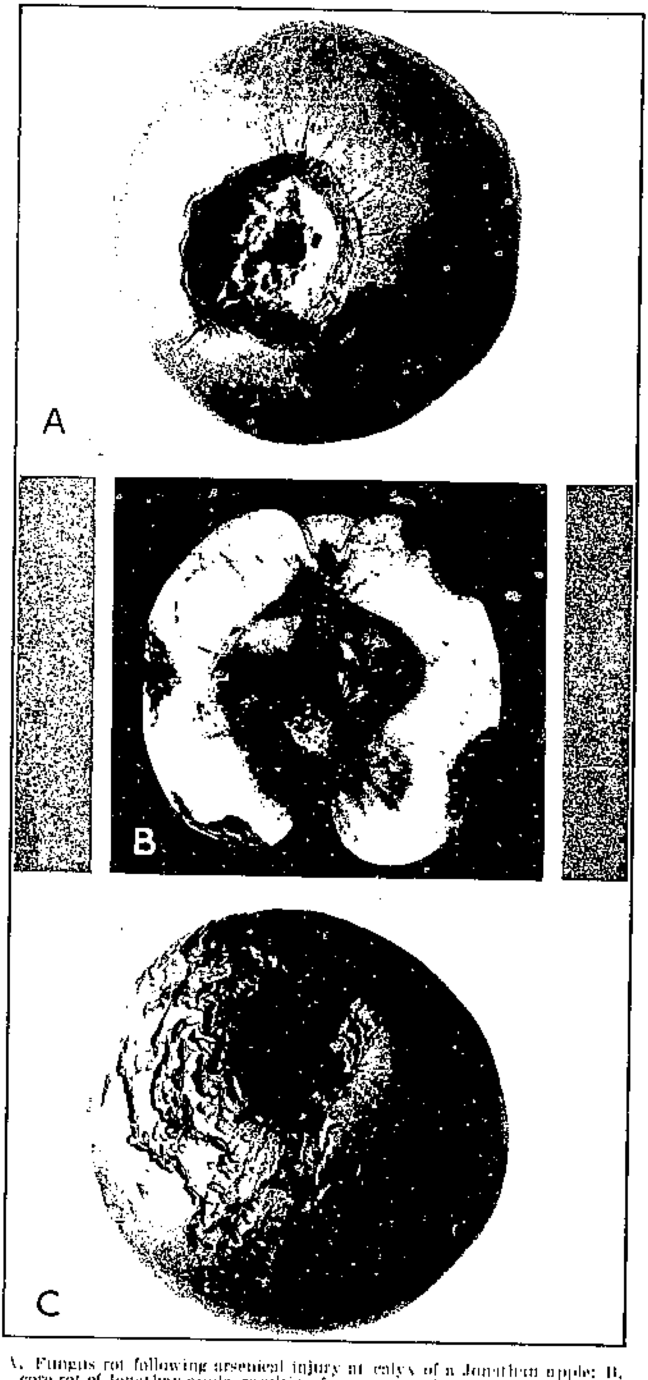


B

A. Hoen & Co., Inc.

A.—Injury from soluble arsenic around calyx of a Grimes Golden apple

B.—Section of a Jonathan apple showing injury from soluble arsenic to tissue at both calyx and stem end



A, Fungus rot following arsenical injury at calyx of a Jonathan apple; B, core rot of Jonathan apple, resulting from penetration of washing solution contaminated with fungus spores through open calyx tube; C, heat injury to Jonathan apple caused by exposure for three minutes in hydrochloric-acid washing solution heated to 110° F.

fruit grower is still confronted with the injurious effects of arsenic rendered soluble after the spray is applied. Headden (*7*), Haywood and McDonnell (*6*), and others have shown that in many cases soluble arsenic is formed by dissolved salts in the water used. Volck (*11*) found that lead hydrogen arsenate is unstable in the presence of meteoric water, forming basic lead arsenate and arsenic acid. This was confirmed by McDonnell and Graham (*8*), who studied the decomposition of dilead arsenate in pure water. Mogendorff (*9*) found that the decomposition of lead arsenate, with formation of soluble arsenic, is favored by an alkaline medium either formed from salts present in the spraying water or produced by the leaves. He found, moreover, that injury is caused only after the arsenic has accumulated in the leaf tissues. All these investigations have been concerned with foliage injury.

The type of arsenical injury discussed in this bulletin is known to occur in eastern districts, but apparently it has affected the market value of the fruit but little, if at all. Although this fruit injury was observed by the writers in the Wenatchee Valley from time to time long before apple washing became part of the ordinary packing procedure, it occurred so rarely in the orchard as to escape general attention. However, with the rise of fruit-cleaning problems in the last few years, it has assumed importance on packed apples in storage (*2*, *3*).

During rainy fall weather this injury has been observed on heavily sprayed apples before harvest, but more commonly it has been found on picked apples that were allowed to stand unprotected through rainy weather. Its greater prevalence in the latter case may doubtless be explained by the fact that apples in boxes are slower to dry than when they are on the tree, and the quantity of soluble arsenic increases with the length of time the apples remain wet.

In the irrigated apple-growing districts of the Pacific Northwest it is often necessary to apply six or seven sprays of lead arsenate during the season in order to control the codling moth. The last spray is sometimes applied not more than a month before harvest. The growing season is practically rainless, and spray residue therefore is not markedly diminished by natural climatic factors as is the case in the more humid districts. On the contrary, there is a continual increase in the amount of lead arsenate on the fruit as a result of spray applied, so that the maximum load is found near harvest time. The apples of this region therefore often carry heavy loads of arsenical spray residue when picked from the tree, particularly in the case of varieties like the Winter Banana, Grimes Golden, and Jonathan, which are picked early in the season. Arsenical residues, calculated as As_2O_3, often reach 0.07 or more grains per pound of fruit. Foliage injury is usually negligible under northwestern conditions, and the fruit injury has seldom been severe enough to cause any serious loss, although occasionally 10 per cent or more of a crop has been culled on this account.

OCCURRENCE ON STORED APPLES

Before the removal of spray residue was attempted, injury of the arsenical type had been observed also on commercial lots of apples that were stored wet in poorly ventilated rooms. During the harvest rush apples are sometimes stored loose in orchard lug boxes before being packed. To prevent wilting, the stacked apples are sometimes kept wet for long periods by spraying them with water. Under these conditions apples appearing entirely normal when picked have developed serious arsenical injury within a short time. An example may be cited of a crop of Winesap packed wet during the latter part of October, 1926, and stored in a poorly ventilated basement. Seventeen per cent developed this arsenical injury by the middle of December, whereas only about 1 per cent of the fruit from the same lot, placed in cold storage at the same time, developed arsenical injury during the same period. The decreased injury was apparently due to the drier atmosphere of the cold-storage room.

Arsenical injury of this type has been repeatedly produced experimentally at the Wenatchee laboratory. Heavily sprayed apples were packed in 50-pound lard cans with tightly fitting covers that prevented ventilation or evaporation. These were held in cold storage under the same conditions as similar fruit packed in ordinary apple boxes. Typical results of these experiments are presented in Table 1.

TABLE 1.—*Arsenical injury produced on stored apples*

Lot No.	Variety and year	Condition when packed in—		Arsenical injury at calyx
		Tight can	Ordinary box	
				Per cent
1	Jonathan, 1919	Wet		81.5
2	do	Dry		25.4
3	do		Wet	0
4	do		Dry	0
5	Winter Banana, 1928	Dry		47.8
6	do		Dry	0

In the case of the Jonathans packed dry in tight cans in 1919, injury developed in storage only after they had become wet from condensation of transpired moisture. However, the injury was less than one-third that of the lots which were wet when packed. The marked increase in the amount and severity of injury noted in lot 1 over that shown for lot 2, where the only difference was in the amount of moisture, indicates that the presence of moisture rather than CO_2 is the deciding factor. This is in agreement with the findings of Haywood and McDonnell (*6*) and Patten and O'Meara (*10*), who investigated the influence of CO_2 on arsenical injury of foliage.

It has also been shown by various investigators (*6, 7, 9*) that in the presence of small quantities of alkaline materials the amount of soluble arsenic derived from lead arsenate sprays is greatly increased. An excess of lime is effective in preventing such injury, since it combines with the soluble arsenic to form calcium arsenate, which is relatively insoluble and nontoxic to plant tissue. Many of the soils of the arid apple-growing district of the Pacific Northwest are alkaline, and incrustations of various alkaline salts are often found along the irrigation furrows in the orchards. At harvest the apples carry deposits of soil dust as well as residue of lead arsenate spray. This undoubtedly contributes to the occurrence of arsenical injury at the calyx of the apples.

That this injury occurs only after penetration of soluble arsenic into the fruit tissues, as already shown by Mogendorff (*9*) to be the case in leaf injury, was demonstrated in a series of chemical studies conducted at this laboratory.

Representative lots of uncleaned apples direct from the orchard, all showing deep killing of tissues at the calyx, were selected. The injured parts were dissected out and carefully peeled to eliminate surface deposits. The sample was then weighed and leached for 24 hours with distilled water, after which calculations of arsenic as arsenic trioxide (As_2O_3) were made on the leachings by the Gutzeit method.[2] Typical results of such determinations are presented in Table 2.

TABLE 2.—*Soluble arsenic calculated as As_2O_3 in injured tissue of apples taken directly from the orchard, Wenatchee, Wash., 1928*

Lot No.	Variety	Arsenic in 1,000 grams of fresh tissue	
		Injured	Normal[1]
		Milligrams	*Milligrams*
1	Yellow Newtown	6.96	0
2	Rome Beauty	4.10	0
3	Winesap	2.63	0

[1] Adjacent to injured tissue.

Similar analyses were made to determine whether arsenic could likewise be found in the tissues of apples upon which the injury appeared after washing. The results are presented in Table 3.

TABLE 3.—*Soluble arsenic calculated as As_2O_3 in apple tissue injured after being subjected to various washing processes, Wenatchee, Wash., 1928*

Variety	Solution used in washing	Arsenic in 1,000 grams of fresh tissue	
		Injured	Normal[1]
		Milligrams	*Milligrams*
Jonathan	Hydrochloric acid, 0.35 per cent	9.41	0
Winesap	do	2.63	0
Do	A commercial preparation composed of borax, sodium hydroxide, and sodium carbonate.	1.96	0

[1] Adjacent to injured tissue.

Further evidence that dissolved arsenic causes injury on apples was obtained from experiments in which nonsprayed Winesap apples were dipped in solutions of arsenic pentoxide (As_2O_5) and packed without rinsing or drying. These were held in ordinary cool storage. The results of this experiment are presented in Table 4.

[2] The writers are indebted to C. D. Dolman, chemist of the Department of Agriculture of the State of Washington, for the analytical work reported herein.

TABLE 4.—*Injury produced on arsenic-free Winesap apples by dipping them in solutions of arsenic pentoxide calculated as As_2O_5*

Arsenic in 100 cubic centimeters of water	Apples affected
Milligrams	*Per cent*
100	40
40	30
20	16
10	4
0	0

The injury did not begin to appear until 10 days after treatment, but continued to increase for several weeks. No injury occurred except around the calyx or in the stem basin, but sometimes both regions were affected.

Most of the injury was quite typical of that produced as a result of the washing process or that which occurs on heavily sprayed unwashed apples that become wet. Some of the apples in this experiment, however, were more severely injured, and the flesh at the calyx end was killed to a depth of a half inch or more. In such cases it was possible to secure good material for chemical analysis, and the amount of arsenic present in the injured flesh tissue was determined in the manner already described. In a typical case of this sort, 5.5 milligrams of arsenic calculated as As_2O_3 were found in 1,000 grams of fresh flesh tissue from the injured calyx region, whereas a control analysis of adjacent uninjured tissue gave negative results for arsenic.

Many washed apples found in storage with severe arsenical injury in the calyx upon analysis yielded less than 0.01 grain of arsenic (As_2O_3) per pound. Apparently, therefore, apples may be satisfactorily cleaned, so far as compliance with legal regulations is concerned, and still retain sufficient arsenic in the calyx region to kill the skin and underlying flesh tissue. The arsenic apparently is not always completely removed in the washing process, or the apples may take up additional quantities of soluble arsenic in their passage through washing solutions heavily charged with dissolved arsenic.

In studying the latter possibility, the accumulation of dissolved arsenic in a continuously used washing solution was determined during a 10-hour run. During the day 1,250 boxes of Winesap apples were washed, and samples of the hydrochloric acid were taken at intervals. The results are shown in Table 5.

TABLE 5.—*Accumulation of dissolved arsenic calculated as As_2O_3 in 0.77 per cent hydrochloric acid solution during 10 hours' washing of 1,250 boxes of Winesap apples*

Time	Arsenic per 1,000 cubic centimeters
	Milligrams
7.00 a. m.	Trace.[1]
10.00 a. m.	172.5
12.00 m.	275.0
3.30 p. m.	402.5
6.00 p. m.	550.0

[1] Commercial hydrochloric acid was used in which traces of arsenic occur.

The extreme difficulty of rinsing solvent solutions from the calyx region is attested by all who have had any experience in the washing of apples. Since machines with solid jet sprays forced the solvent deep into the calyx, frequently causing excessive loss from arsenical injury, it was soon found necessary either to modify them or to abandon their use.

METHODS OF PREVENTION

When apples are thoroughly cleaned, arsenical injury may be almost entirely prevented by the use of copious quantities of fresh rinse water. If any of the rinse water has to be recirculated, fresh water, as a spray under pressure, should be applied to the apples just as they leave the machines. The commercial adoption of this practice has prevented a large percentage of arsenical injury in the major apple-growing districts of the Pacific Northwest.

Many operators do not have access to a water supply which provides adequate rinsing facilities. Experiments were conducted to determine the best way to meet this situation. Injury to apples submerged for three minutes in a 1 to 1,000 solution of arsenic pentoxide was compared with injury to comparable apples dipped in similar solutions neutralized by the addition of sodium bicarbonate, calcium carbonate, calcium hydroxide, and magnesium carbonate, respectively. The apples were not rinsed but were packed and sorted in the usual manner and examined after 10 weeks of storage.

When apples were submerged in arsenic pentoxide, 1 to 1,000, and not rinsed, 40 per cent showed injury. When sodium bicarbonate was used to neutralize the arsenic pentoxide, 22 per cent of the apples showed injury. When calcium carbonate, calcium hydroxide, or magnesium carbonate was used to neutralize the arsenic pentoxide, no injury appeared on any of the apples.

The reaction between arsenic pentoxide and sodium bicarbonate produces sodium arsenate, which is almost as toxic as the arsenic pentoxide itself. On the other hand, the reactions between arsenic pentoxide and lime and the other materials tested produce compounds that are relatively nontoxic to plant tissues.

The practical application of the principle demonstrated in this experiment has been proved repeatedly in commercial operations. The use of lime in the rinse water is now a standard procedure in packing houses where the water supply is curtailed or where extra precaution against injury is desired.

A number of experiments were conducted to determine how lime can be used in the rinse water without leaving an objectionable residue on the apples after they are dried. It was found that when commercial hydrated lime was used, 3 pounds to 100 gallons was as much as could be employed without leaving a residue. When quicklime was used it had to be completely slaked and prepared as milk of lime before adding to the rinse water in order to obtain satisfactory results. When employed in this manner, and in the proportion of 2 pounds to 100 gallons, it was found to be preferable to the commercial hydrated lime.

HYDROCHLORIC-ACID INJURY

With the general adoption of hydrochloric-acid washes for the removal of lead arsenate residue, it was anticipated that there would be more or less chemical injury to the fruit, especially at the hands of people inexperienced in the use of chemicals.

The character of hydrochloric-acid injury to apples was early determined in laboratory experiments. This injury causes a bleaching of the skin, frequently accompanied by a cracking through the center of the affected area. With age, the injured area becomes depressed but remains a light tan or yellowish color. If arsenic is present, the spots turn black.

Apples may be left in a 3 per cent solution of hydrochloric acid (9 gallons of the commercial acid made up to 100 gallons of water) for as long as 3 minutes at a temperature of 70° F. without injury, provided thorough rinsing in fresh water follows immediately; apples also can be left in a 0.33 per cent solution of hydrochloric acid for 9 or 10 minutes at 70° without injury, if thoroughly rinsed immediately after removal from the acid. Prolonged exposure to the acid invariably results in injury, as does neglect of rinsing. Traces of acid to the extent of even 0.05 per cent may remain in the rinse water without producing any symptoms of hydrochloric-acid injury. On the other hand, as already noted, the use of acidified rinse water markedly increases injury from any arsenic that may not be removed in the washing process.

The injury from hydrochloric acid, except when apples remain in it for prolonged periods, is limited to the location of the acid remaining on the fruit. The stem and calyx cavities are most frequently injured, but wherever drops of the acid solution are retained evaporation of the water causes the acid to become concentrated, and the injury usually results at such points. (Pl. 3.)

The severity and extent of typical hydrochloric acid injury apparently is not influenced by the temperature at which the washing solution is ordinarily used.

The hydrochloric acid injury described herein was encountered only occasionally and except for isolated cases was never found to be a factor of importance in commercial operations. This is in accord with the results of other investigations on washing methods, which have shown that when apples are properly washed and rinsed no acid injury was encountered (*7*).

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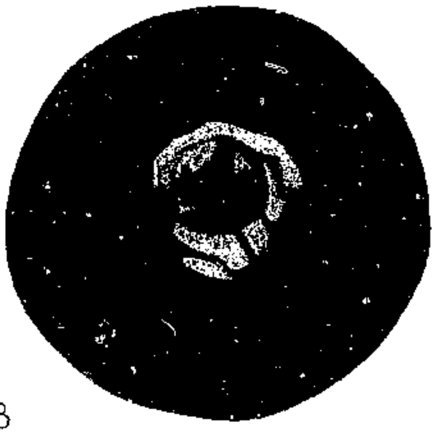

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Litho. A. Hoen & Co., Inc.

A.—Hydrochloric acid injury on Winesap apple

B.—Chemical injury on Jonathan apple from alkaline washing solution

INJURY FROM ALKALINE SOLVENTS

While hydrochloric acid is the solvent most commonly used for the removal of arsenical spray residue, a number of alkaline materials, including solutions or mixtures of sodium hydroxide, sodium carbonate, trisodium phosphate, borax, and other substances, are also employed. These solvents are sometimes used at a temperature of 100° F., or higher.

Arsenical injury, as already stated, occurs somewhat more commonly on apples washed in alkaline solvents than on those washed in hydrochloric acid. Because the alkaline solvents are much more difficult to rinse off than is the hydrochloric acid solution, apples washed in the former often retain some of the solvent in the calyx cavity, where it continues to react with residual lead arsenate, forming the injurious soluble arsenic.

Occasionally the alkaline solution itself causes chemical injury. Such injury is usually localized around the stem or calyx but is sometimes found at the lenticels as well. It is shown by the effect on the skin, which becomes dry and papery, tightly stretched, but seldom cracked, as in the case of hydrochloric acid injury, and is often torn loose from the underlying fleshy tissues. The color is yellowish or brownish yellow, except when a considerable quantity of arsenic is present, in which case the color becomes dark brown or black. (Pl. 3.)

INJURY AT THE CORE

In certain methods of washing some loss is caused by penetration of the washing solutions into the core through the open calyx tubes. This was especially true in early types of washing machinery in which the apples were submerged to a depth of several feet. It has also been found that submersion to a depth of 6 inches or more in washing solutions may result in core penetration. In other methods of washing, in which apples are not turned in their progress through the machine, those passing through with the calyx up so that it can be filled like a bottle are also likely to show some core penetration. The chemical injury to the core tissues is not in itself a matter of much importance, but the fungous spores introduced with the washing solutions cause core rot. (Pl. 2, B.)

Certain varieties of apples are commonly characterized by a rather large proportion of open calyx tubes. Among these may be mentioned Jonathan, Esopus Spitzenburg, Stayman Winesap, Ortley, and Delicious. On the other hand, such varieties as the Winesap, Yellow Newtown, Rome Beauty, and Winter Banana seldom have open calyx tubes. Varieties in the latter group may be washed with comparatively little danger from core rots, whereas with the former group due consideration should be given this factor in the selection of washing methods.

HEAT INJURY

It has been found that when apples are submerged in solutions heated to 100° F., or higher, for periods of three minutes or longer, there is considerable danger of injury to the fruit. The results of this injury usually appear within 10 days or two weeks in the development of latitudinal cracks around the calyx, often continuing lengthwise on to the cheek of the apple. (Pl. 2, C.) Only where considerable arsenic is dissolved in the washing solution does the cracked skin become blackened. Characteristically it is grayish or yellowish in color, resembling hydrochloric-acid injury, for which it might be mistaken. It may be produced, however, by the use of heated water alone.

Apples are somewhat more susceptible to this type of injury at the time of harvest than after being kept for several weeks. Fortunately, it is generally not necessary to use heated solutions at this time, unless unusual spray practices have been followed. Likewise, few washing methods or devices require exposure of the fruit for a period long enough to cause injury, even when heated solutions are used. Heat injury is a factor that must be considered chiefly in connection with dipping tanks or other homemade devices used in small-scale operations.

INFLUENCE OF WASHING ON STORAGE ROTS

Aside from rots due to penetration of washing solutions into the core region and those occurring at points of chemical injury, it has been found that loss from storage rots may be somewhat more prevalent on washed than on unwashed apples. The extent of this loss varies with the amount and character of the handling to which the fruit is subjected. The number of bruises and injuries is generally increased on apples during the washing process on account of the extra handling involved. The apples are never entirely dry when packed, and the moisture they hold also favors the development of rots by providing suitable conditions for the germination of fungus spores.

Large numbers of fungus spores are removed from the apples and accumulate in the solutions during the washing process. The washing solutions have little or no toxicity for these spores and may spread infection. This hazard can be greatly reduced by sorting out rotted apples before the fruit is washed.

No practical method has been found of disinfecting the apples during the washing process. The accumulation of spores in the washing machinery, however, can be reduced by discarding solutions after each day's run or after the washing of about a thousand bushels. The machines should then be thoroughly scrubbed out with clean water. Where live steam is available, it can be utilized effectively to disinfect the machines. Disinfection may also be accomplished by adding 1 pint of commercial formalin to each 100 gallons of washing or rinsing solution after each day's run. The formalin solution should be pumped through the machine for 5 or 10 minutes and allowed to stand overnight before being replaced by fresh washing solutions for the next day's operations.

However, the most important factor in the prevention of loss from storage rots is careful handling of the fruit to avoid bruising or puncturing the skin. This is imperative at all times. The hazard can also be reduced by drenching the apples as they leave the machine with copious quantities of fresh rinsing water under pressure.

CONCLUSION

The injuries herein described should not be understood to represent extreme hazards involved in all fruit-washing operations. This bulletin is rather an attempt to record the types of injuries that may be encountered and the experimental work which has been done to explain their nature as well as to determine methods of prevention. It is the general conclusion of all those familiar with the spray-residue problem that if washing is done with proper equipment and with due care under desirable sanitary conditions, neither the market value nor the keeping quality of the apples will be impaired; on the contrary, they may even be enhanced.

SUMMARY

Calyx scald is primarily caused by the presence of soluble arsenic on the apples. This was proved by producing the injury by application of soluble arsenic to the apples and by isolating soluble arsenic from the injured tissues.

This injury occurs on unpicked apples in the orchard and on uncleaned picked apples that have become wet, but most commonly on apples that have been subjected to washing processes. Its occurrence follows the use of either hydrochloric acid or alkaline solvents as washing materials.

Chemical injuries to apples from hydrochloric acid and alkaline solvents are described and differentiated from the injury caused by soluble arsenic. These injuries have been found only occasionally and rarely cause commercial losses.

The prevention of injury from soluble arsenic and from various chemical solvents commonly used in washing apples depends primarily on the adequate rinsing of the fruit with clean water. Where sufficient water is not available, the addition of lime to the rinse water is beneficial.

Core rots are increased by methods of washing that permit solutions contaminated with fungus spores to penetrate through open calyx tubes. Varieties commonly characterized by open calyx tubes, therefore, should be washed by methods that do not cause penetration.

Injury may result when apples are held in solutions heated to 100° F. or higher for periods of three minutes or longer. Apples are more susceptible to this injury at the time of harvest than after being kept for several weeks.

Loss from storage rots may be somewhat greater on washed apples, owing to the extra handling to which they are subjected. Careful handling to avoid bruising or puncturing the skin, and the use of copious quantities of fresh rinsing water under pressure are important factors in reducing losses from storage rots.

Where the washing is properly done, the market value and the keeping quality of apples are not impaired and may even be improved.

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