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Washing Fruits and Vegetables to Remove Residues

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INTRODUCTION

Quality of processed foods depends upon quality of the raw products. Raw material quality, in turn, is dependent upon many environmental and inherent factors. Insect and disease problems are often classed as the most serious problems facing the fruit and/or vegetable producer. Recently many new chemicals have become available for control of pests.

The use of pesticide chemicals is necessary for control of pests to prevent direct crop losses, to maintain quality, and to lower production costs. Hayes (4) stated that it should be apparent that the use of pesticides promotes health directly by control of pest-borne diseases and indirectly by increased and improved agricultural production.

The United States has taken the lead in legislating the use of pesticide chemicals and additives in food. This began with the Pure Food Act in 1906 which was followed by the Federal Food, Drug and Cosmetic Act of 1938. Since then, several amendments have been made to the latter Act. One of the most important was the Miller Amendment in 1954. It dealt primarily with the regulation of the safe use of pesticides for the production of raw agricultural commodities. The Miller Amendment was followed in 1958 by the Food Additives Amendment and in 1959 by the Colley Amendment, which covered such chemicals as plant growth regulators, nematocides, and herbicides.

Today all pesticides, food additives, and related chemicals may be considered unsafe unless sufficient evidence is presented demonstrating their safety at recommended levels. These regulations may prohibit the presence of certain chemicals in the finished product or establish limits for the amounts of chemicals which may be in the commodity. With the myriad of chemicals available for use in production of a food crop, there is a possibility that, by misuse, a residue could be present in the finished product.

It would seem desirable to determine whether residues could be reduced by processing fruits and vegetables. Therefore, a study was undertaken with the following objectives in mind:

- To determine pesticide and herbicide residues on fruits and vegetables during preparation and processing, using radioactive tracer techniques.

- To determine whether detergents and related chemical compounds used in washing fruits and vegetables contributed an additional residue.

REVIEW OF LITERATURE

Washing

A review of the literature revealed that until 1959, little information had been published concerning the role of the unit operation of washing in reducing extraneous material on fruits and vegetables to be processed. Since that time, several studies (2, 8, 9, 11, 12) have been made with particular emphasis upon washing.

Removal of Insect Residues

Some of the physical and chemical factors affecting the efficiency of washing tomatoes prior to processing were investigated by Gould, Geisman, and Sleesman (3). The factors which were found to be important in soil and *Drosophila* egg and larvae removal were: (1) physical: soak time, soak temperature, agitation, rotation of tomatoes under spray rinse, number and type of nozzles, and spray pressure and volume; and (2) chemical: detergent type and concentration and chlorine concentration.

Their conclusions were that tomatoes should be soaked for 3 minutes in water at 130° F. while being vigorously agitated. Spray rinsing should follow soaking, with the fruit making at least two revolutions under the spray nozzles. The nozzles were placed 7 inches above the roller conveyor, with one nozzle for each square foot of surface. The nozzles recommended were of the fullcone type with a square spray pattern. A pressure of 130 psi gave optimum particle size and rinsing. A chlorine residual of 6 to 8 ppm was recommended for the soak operation and detergents at 0.25 percent concentration were recommended when *Drosophila* activity was heavy. The detergent which gave the best results was a low foaming alkaline detergent.

Twigg and Gulette (11, 12) reported on the use of a 0.2 percent lye solution for washing tomatoes to remove *Drosophila* eggs. They reported that lye solutions or highly alkaline detergents were equally effective in egg removal.

The Entomology Research Division of the Agricultural Research Service (7) investigated the effects of soak water temperature, soak time, irritants, and light on corn earworm and European borer removal. These investigators also stated that pyrethrin was the best irritant and that the soak water temperature should be 100° F. to produce the most activity of the borers.

Geisman and Gould (2) studied the effects of soak water temperature, soak time, agitation, air blast, number and type of nozzle, types and concentration of irritants, and types and concentration of detergents on corn earworm and borer removal. Their results were in agreement with those of the Entomology Research Division as to irritant and soak water temperature for corn borer removal. Geisman and Gould (2) also indicated that earworms could be rinsed from the ears but the European corn borer was more difficult to remove because both irritants and detergents were necessary. The detergent was a low foaming alkaline type and was used in a concentration of 0.25 percent.

Removal of Other Residues

From the foregoing, it can readily be seen that the use of wetting agents and detergents for washing fruits and vegetables facilitates the removal of insect residue. The investigators (2, 3, 11, 12) also stated that detergent washing facilitates removal of soil and other extraneous material. Mercer (8) in 1960 stated:

> "Detergents are widely used in the washing of fruits, tomatoes and many vegetables when these foods are prepared for canning, freezing, or fresh consumption. Of special significance to the food industry is the belief that detergent washing removes from raw foods the chemical dusts and sprays used for field control of insects and diseases."

In 1962, a study was made by the National Canners Association (9) to determine whether detergent residues were carried over from the wash into the finished products. The wetting agents evaluated were a nonionic, benzyl ester of polyethoxylated octylphenol and an anionic, sodium dodecylbenzene sulfonate type. Three commodities were utilized: asparagus, olives, and spinach. Their results indicated that by using radioactive tracer techniques, a sensitivity in detection of detergent residues of approximately 100 times the sensitivity of colorimetric methods was obtained.

As part of the previous study (9), three detergents varying in foaming characteristics were evaluated as to their effectiveness in removing bacterial spores. The investigators reported that low foaming detergents gave the best results. "The ability to remove spores varied inversely with the amount of foam produced by the detergent on the surface of the wash tank. Thick foam decreased agitation and lessened the spray impact." (9) These results indicated the possibility of detergent residues in the finished product from high foaming detergents.

Pesticide Chemicals

Since the literature concerned with pesticide chemicals is voluminous, only material pertinent to this research is reported here.

The precise details of procedure for identifying pesticide chemicals was not within the scope of this report. However, procedures have been thoroughly reviewed by Zweig (17, 18, 19, 20). He aptly stated the problem as follows:

> "Until about 20 years ago, the life of an analytical chemist working in the pesticide field was a relatively serene one. He had to be familiar with analytical methods for arsenic, lead, fluoride, pyrethrins, rotenone, and a few others. However, this serenity was shattered by the almost explosive expansion in the development of synthetic organic pesticides and food additives."

Literally, this meant that there was no single method for detecting residues and, in essence, the analyst must apply a series of methods to the sample in question to determine which chemicals may be present.

Of more direct concern to this study was the fate of the pesticide chemicals applied to crops. In two symposia (1, 13), excellent reviews were given of the status of knowledge on this subject.

Marth (6), in discussing the deposition of chlorinated hydrocarbons in biological material, indicated that these chemicals dissipated with time after application. Residues were more persistent in leafy vegetables than in those which produced a fruiting body. Marth also reported that residues were reduced when the vegetables were canned.

Westlake and San Antonio (16) reviewed the mechanisms involved in the degradation of the chlorinated hydrocarbons in soil, plants, and animals. Each chemical may be involved in several specific reactions which lead to the complete disappearance.

There were no investigations reported on the role of unit operations in processing fruits and vegetables in reducing residues of chlorinated hydrocarbon insecticides.

MATERIALS AND METHODS

There were two phases of this work. One involved the use of tritiated detergents to determine whether any detergent residue was present in the finished product. The second utilized two insecticides, labeled with carbon 14, to determine if the residue could be washed from tomatoes using recommended techniques.

Commodity Evaluated

The commodity used was tomatoes. The tomatoes (Rutgers variety) were obtained from The Ohio State University horticultural farm in Columbus, Ohio.

The tomatoes were harvested by hand and were taken to the Fruit and Vegetable Processing and Technology Division's pilot plant. The fruits were weighed and divided into fruits with cracks and fruits with-

TABLE 1.—Wetting Agents, Foam Characteristics, Recommended Concentrations, and Weights of Detergents Added to Soak Water.

Wetting Agent	Foam Characteristic	Recommended Concentration	Weight
		(ppm)	(g)
Polyoxyethylated Tall Oil	Low	2500	785
Sodium Lauryl Sulfate	Medium	1000	313
Sodium Dodecylbenzenesulfonate	High	1000	313

out cracks to determine whether these conditions caused a difference in residue.

Detergent Phase

Selection of Detergents: Three types of detergents, differing in foaming characteristics, were selected. Since foaming was related to the wetting agent used, the detergents, the wetting agents, and foam characteristics are given in Table 1.

One gram of each detergent was sent to Tracerlab, Inc. for tritiation, which was accomplished by the Wilzbach technique. Samples of each detergent were assayed to determine the specific activity. Each tritiated sample was added to sufficient quantity of untreated compound to provide enough material for replications of the experiments.

Washing Procedure: The soak tank was filled with 83 gallons of water. The detergents were added to the water separately in amounts recommended by the manufacturer. These amounts are given in Table 1.

The detergents were added after the soak water reached a temperature of 120° F. The soak water was held at this temperature throughout the experiments by injecting live steam mixed with air into the water. The steam and air also served as a source of agitation in the soak tank. After the detergents were added, the solution was thoroughly mixed for 5 minutes. Triplicate 10 ml. aliquots of the solution were removed to determine the radioactivity in the soak water prior to addition of the fruit.

Ten pounds of tomatoes were placed in the soak tank and allowed to soak for 3 minutes while being vigorously agitated. The fruits were then conveyed on a roller conveyor under a high pressure spray manifold. The nozzles were placed at a height of 7 inches above the fruit and were the fullcone type, designed to produce a square spray pattern. Spray pressures were varied from 0 to 50 to 130 psi. The fruits made approximately 2½ revolutions while under the spray manifold.

Extraction of Juice: After the fruits had passed under the sprays, juice was extracted by immediately placing the fruits in a laboratory extractor. The extractor was scrubbed between each lot and assayed for radioactivity.

Assay to Determine Radioactivity: Samples of the juice (extraction yielded about 8 to 9 lb. juice) and soak water were thoroughly mixed. Three 10 ml. aliquots were removed from each sample (juice or water). These aliquots were placed in clean polyethylene vials with a mixture of dioxane, a primary scintillator, PPO (2, 5-Diphenyloxazole), and a secondary scintillator, POPOP (1, 4-bis-2-50-Phenyloxazole-Benzene).

A Packard Tri-carb liquid scintillation spectrometer was used to determine radioactivity. Standards of tritium were used to standardize the instrument. Samples of the chemicals used were counted to serve as a blank. Nonradioactive tomato juice plus the chemicals were assayed to determine the possible quenching due to the pigments in the juice.

Insecticide Phase

Selection of Insecticides: Insecticides of the chlorinated hydrocarbon class were selected for investigation because of their persistence and the possibility of a health hazard (1). While the literature revealed evidence of reduction of these residues by canning, there was little reported on the role of each unit operation involved in processing.

Two chemicals were selected: 1,2,3,4,10,-hexachloro-6, 7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, exo 5,8-dimethanonophthalene (dieldrin) and 1,1,1,-Trichloro-2,2-bis (p-chlorophenyl) ethane (DDT). These compounds had been in common use for tomatoes and differed in their persistence as a residue as indicated by the number of days prior to harvest. Dieldrin could be applied no later than 7 days prior to harvest, while DDT could be applied no later than 30 days before harvest.

Application of Labeled Insecticide: Both chemicals were uniformly labeled with carbon 14. A solution containing 0.5 millicuries (mc) of either compound was diluted to 100 ml with benzene. Two microliters of this solution were sprayed on each tomato fruit with a syringe atomizer. The plants were growing in gravel culture. The spray was applied at various stages of maturity but fruits smaller than ½ inch in diameter were not sprayed. The fruits were harvested when they reached maturity. For the purposes of this study, maturity was defined as being No. 1 according to the U. S. Standards for Grades of Canning Tomatoes (14).

Autoradiography of Tomato Fruits: After the spray was applied, the fruits were allowed to air dry for 30 minutes. Samples were then harvested and indicated as 0 days after application. For dieldrin treatments, additional fruits were harvested every other day beginning with 1 day after application and this procedure was continued until the 7th day. Fruits treated with DDT were harvested in the same manner until the 7th day and then were harvested on alternate 3 and 4-day periods until the 28th day. Alternate day harvests were then conducted until the 34th day after application. This procedure was replicated three times for each chemical.

After harvesting, the tomato fruits were prepared for autoradiography. The procedure was as follows:

1. Sliced fruits into approximately 1/8-inch thick slices.
2. Placed slices on saran wrap so that the saran covered both sides of the slice. An 8- x 10-inch frame can be used to keep slices within the limits of the film.
3. Arranged slices so that the calyx end slice was in the upper left hand corner. Slices were placed in consecutive order from left to right until all slices were arranged on the plastic.
4. Sealed the plastic on all edges.
5. In a darkroom, placed x-ray film (Eastman Kodak x-ray type AA) in cardboard casettes. (It may be necessary to use more than one casette per fruit. If so, casettes should be identified accordingly.)
6. Placed package of fruit slices on film.
7. Sealed casettes. (It may be necessary to use several layers of masking or friction tape on edges of casettes.)
8. Marked identification code on casettes and placed casettes directly in freezer at 0° F.
9. Exposed for 21 days.
10. Removed casettes from freezer.
11. In a darkroom, removed x-ray film and placed in x-ray developer for 10 minutes. (Developer solution must be 68-70° F.)
12. Placed film in stop bath for 5 minutes.
13. Placed film in acid fixing bath for 5 minutes.
14. Washed in running tap water for 1 hour.
15. Allowed film to dry.

The autoradiograms thus made were compared for intensity of exposure to radioactivity. Since all fruits were treated with the same amount of radioactivity initially and exposure and developing procedures were standardized, the density of the image was proportional to the amount of radioactivity remaining on the fruits. With this technique, the image indicated whether the chemical was absorbed or adsorbed on the fruit.

Washing Procedure: Tomatoes were harvested as indicated in 10-lb. lots. The washing procedure which was determined as most nearly ideal from the detergent phase of this study was utilized.

Extraction of Juice: Juice was extracted from the fruits as previously indicated. Aliquots were removed in triplicate for liquid scintillation.

Assay to Determine Radioactivity: The procedure for determining radioactivity as previously described was followed. The scintillation spectrometer was standardized, using carbon 14 as the standard.

Statistical Analysis: Statistical analysis of the radioactive count was determined according to the methods of Jarrett (5). Analysis of variance of the data was calculated using the methods of Snedecor (10).

RESULTS AND DISCUSSION

The two phases of this study are presented and discussed separately. The implications and applications of these phases also are considered.

Detergent Phase

As previously mentioned, the tritiated detergent samples were added to the soak water. Samples of the water were taken immediately after the detergents were thoroughly mixed in the water. These samples were assayed for radioactivity and the specific activity was calculated as counts per minute per gram (c/m/g), using the method reported in the Radiological Health Handbook (15). These results are presented in Figure 1.

The highest specific activity was obtained with the low foaming detergent, with the medium foaming detergent only slightly lower. The specific activity of the high foaming detergent was 6.0 and 7.5 times less than that of the medium and low foaming detergents, respectively. While the specific activities as shown in Figure 1 were averages of three replications, the specific activity of each material varied no more than 2 percent between replicates. All activities were significantly above background.

Sound Fruits: Lots of sound tomatoes were soaked in each of the tagged solutions and the fruits were given varying rinse treatments. The juice was extracted and assayed for radioactivity. The results are presented in Figures 2, 3, and 4 for high, medium, and low foaming detergents, respectively, for sound tomato fruits. The initial specific activity of the soak water is shown in each case for comparative purposes. The background reported was for untreated tomato juice.

The data in Figure 2 indicated that high foaming detergents adhered to the fruits when no rinse was given, as well as when either 50 or 130 psi rinse pressures were used. There was a slight reduction of detergent residue by 50 psi rinse. With the high foaming detergent, a thick and tenaceous foam blanket formed and in certain instances overflowed the sides of the soak tank. When the experiments using 50 psi spray rinse were performed, it was noted that the foam blanket was broken and slightly reduced. This may be the reason that this treatment

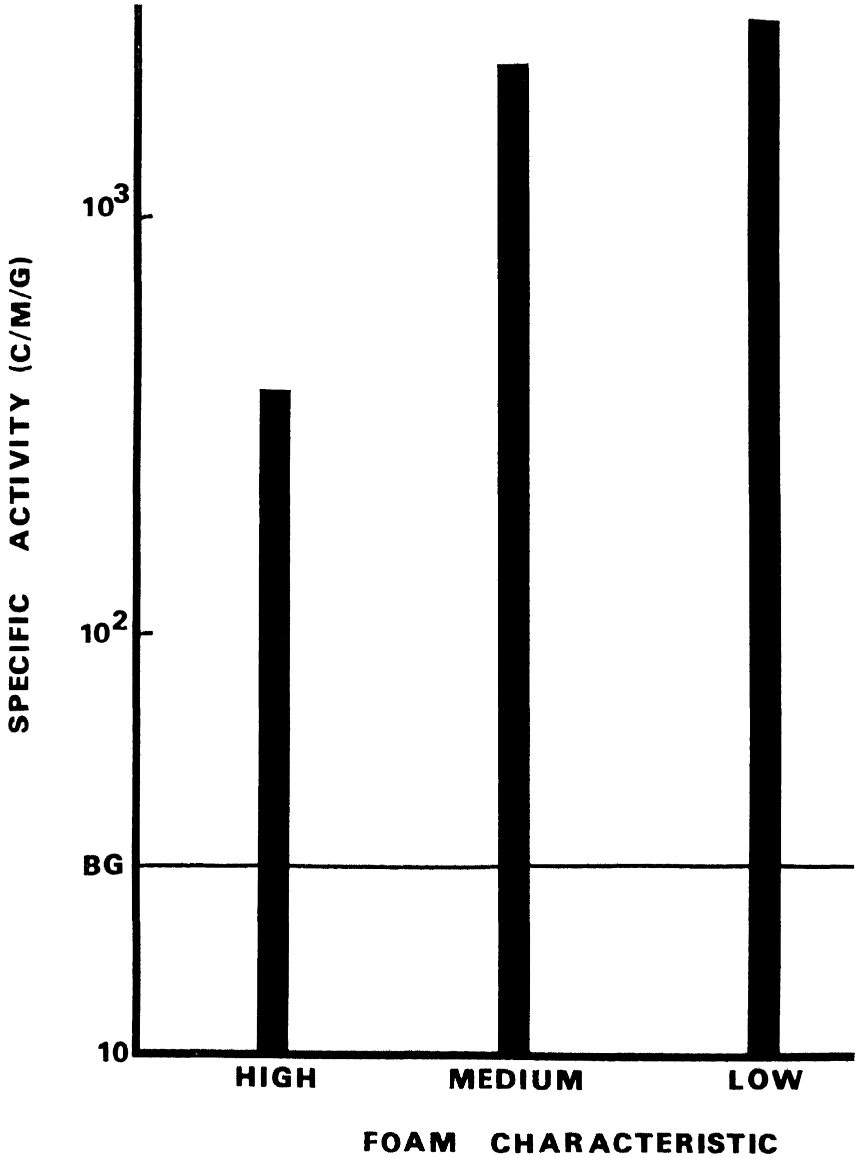


Fig. 1.—Specific activity of soak water containing detergents of different foaming characteristics.

resulted in lower residues. At the spray pressure of 130 psi, the foam blanket appeared to thicken due to the increased agitation of the surface by the spray water.

The medium foaming detergent (Figure 3) gave results similar to those for the high foaming detergent. There was less pick-up of this type of detergent than the high foaming detergent, as indicated by the difference in specific activity between the soak water and the 0 psi (no rinse) treatment for sound fruits. As with the high foaming detergent,

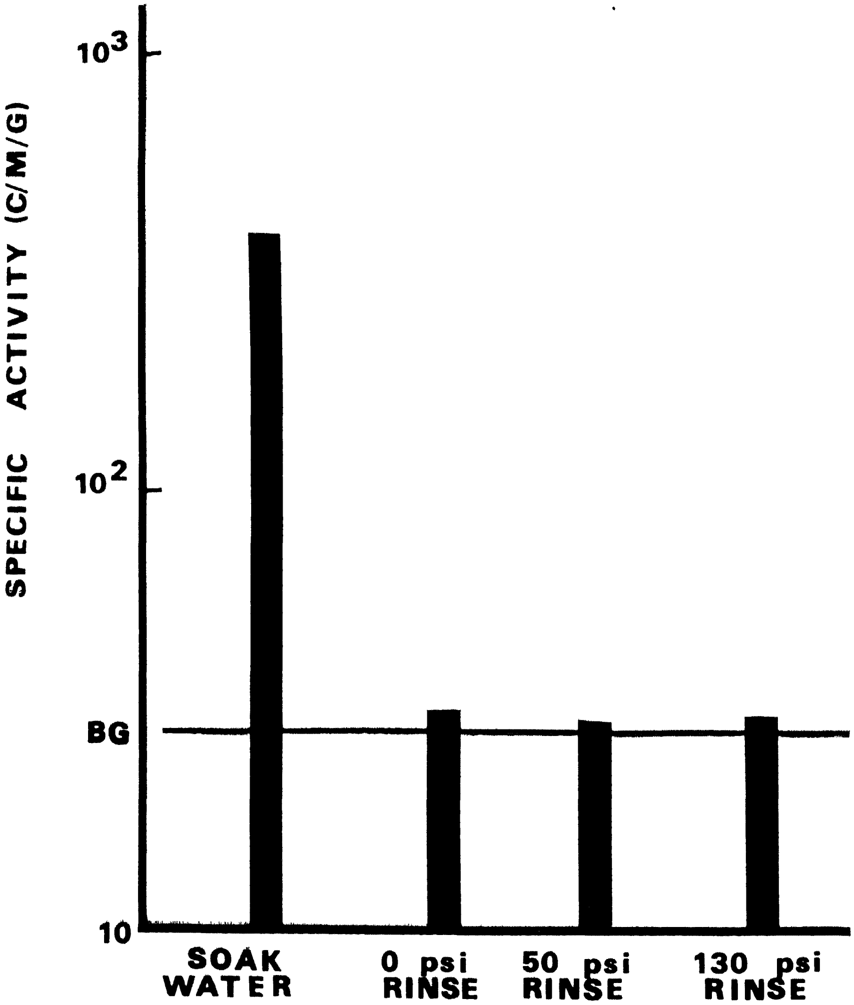


Fig. 2.—Specific activity of tomato juice from sound tomato fruits using high foaming detergents by rinsing treatment.

a thick blanket of foam formed but it was less tenaceous and did not overflow the soak tank to as great an extent. A 50 psi rinse reduced the specific activity below background and this indicated complete re-

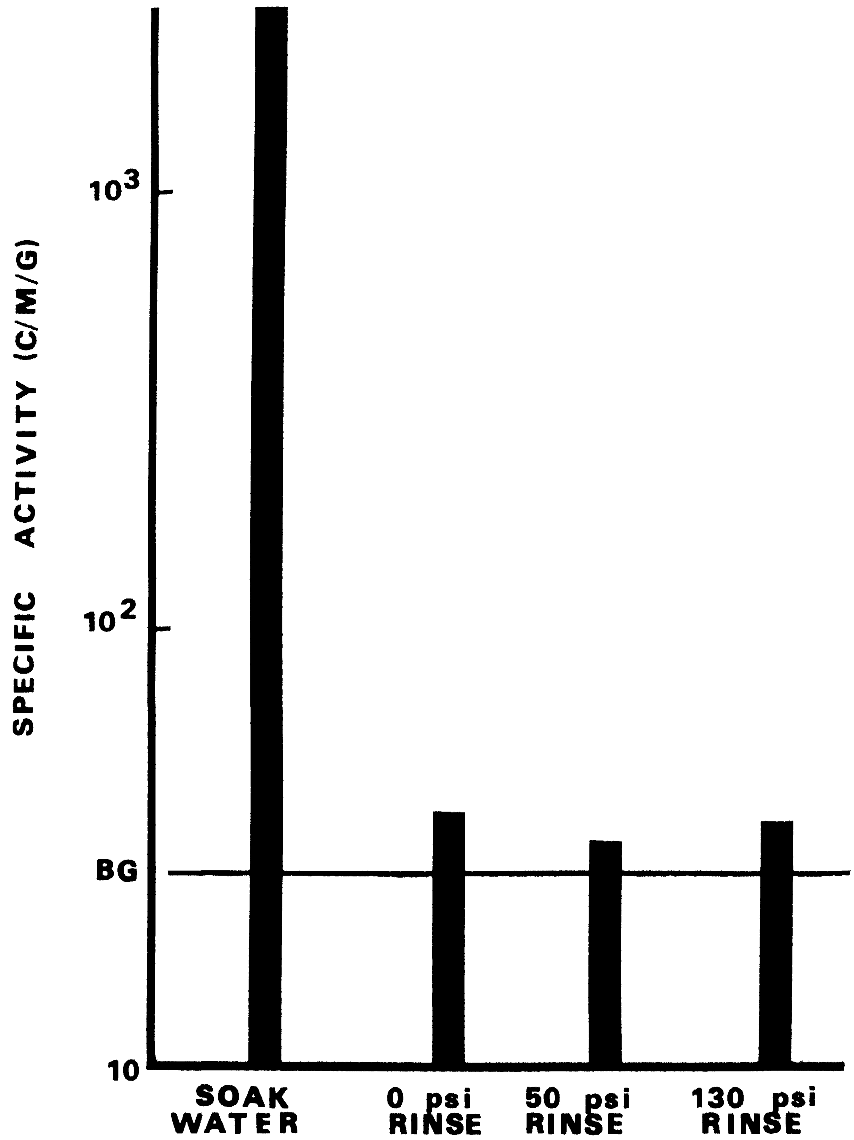


Fig. 3.—Specific activity of tomato juice from sound tomato fruits using medium foaming detergents by rinsing treatment.

moval of the residue. The 130 psi rinse only slightly reduced the specific activity. The reason for this result was the same as for the high foamer.

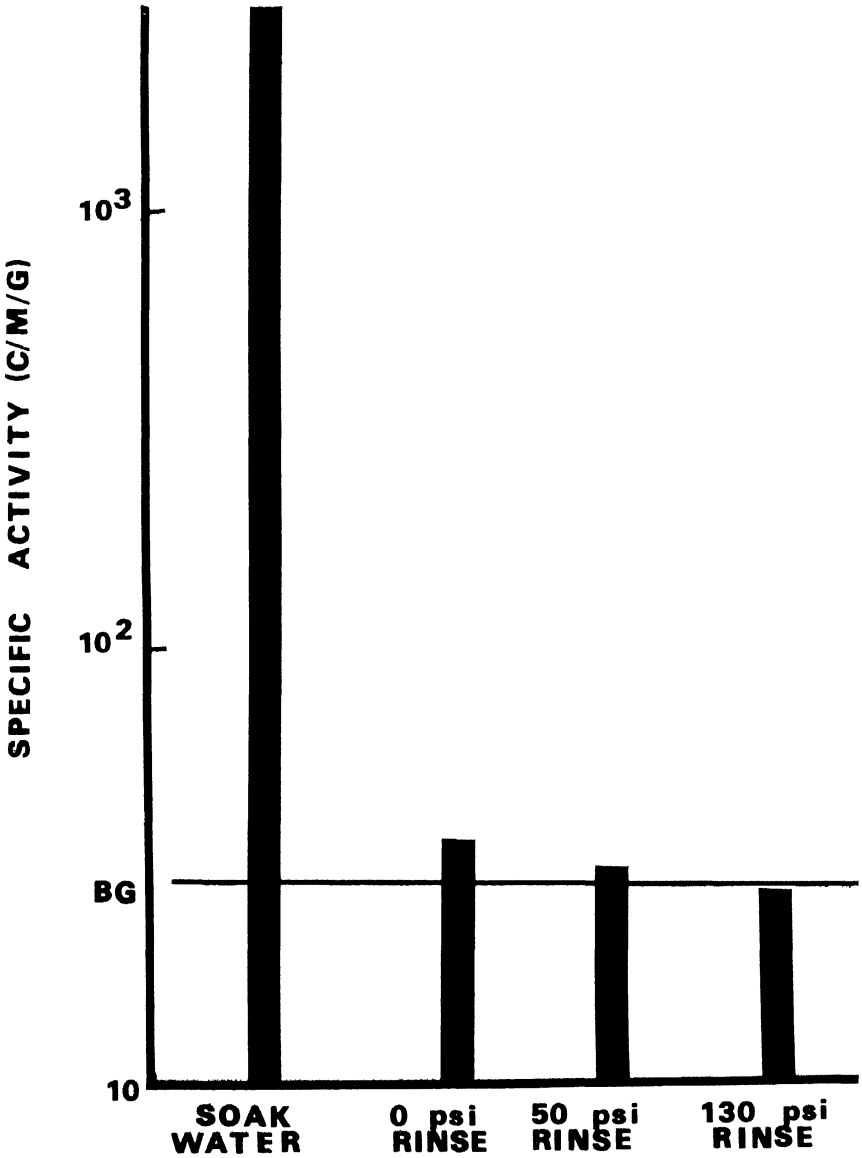


Fig. 4.—Specific activity of tomato juice from sound tomato fruits using low foaming detergents by rinsing treatment.

The low foaming detergent produced entirely different results. The data in Figure 4 indicate that the fruits which were not rinsed picked up more of this type of detergent than either of the other two types. As spray pressure increased, however, the amount of detergent carried into the finished product decreased to 0 at 130 psi rinse. The foam cap was easily dispersed and degraded constantly. The data indicate that a 50 psi rinse was not adequate for removal of detergent residues.

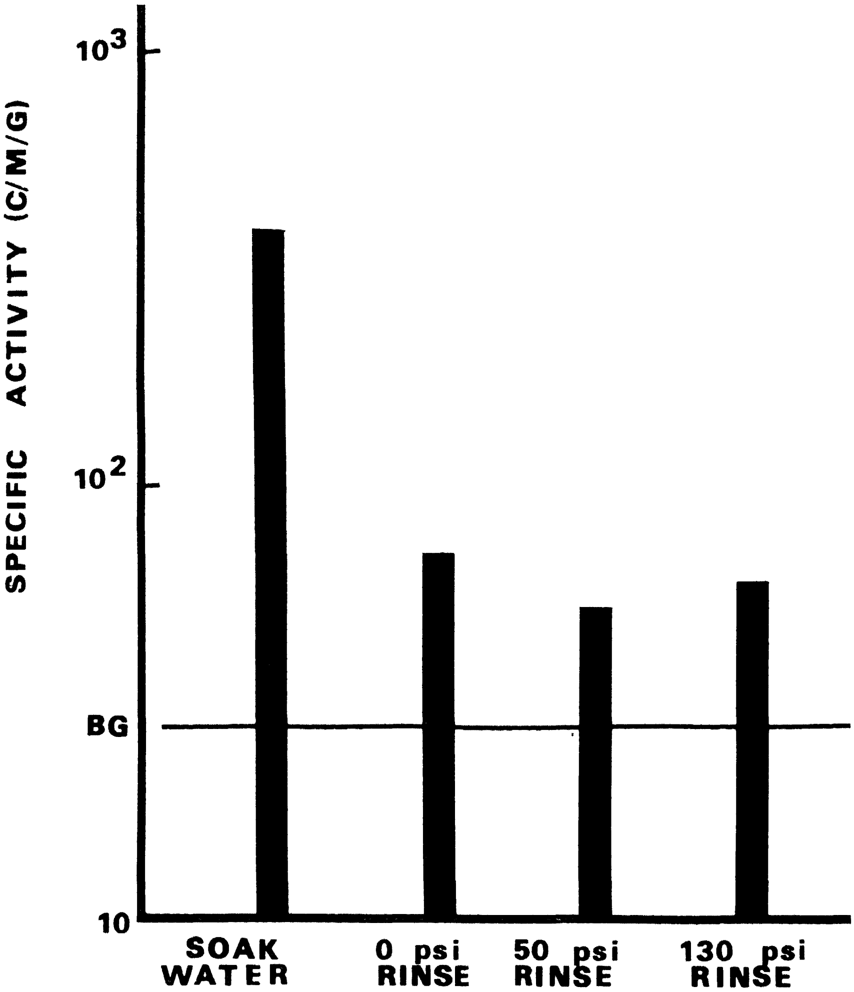


Fig. 5.—Specific activity of tomato juice from cracked tomato fruits using high foaming detergents by rinsing treatment.

Cracked Fruits: The foregoing experiments were duplicated with cracked fruits to determine whether cracks enhanced the possibility of detergent residue in the finished product. The results are shown in Figures 5, 6, and 7.

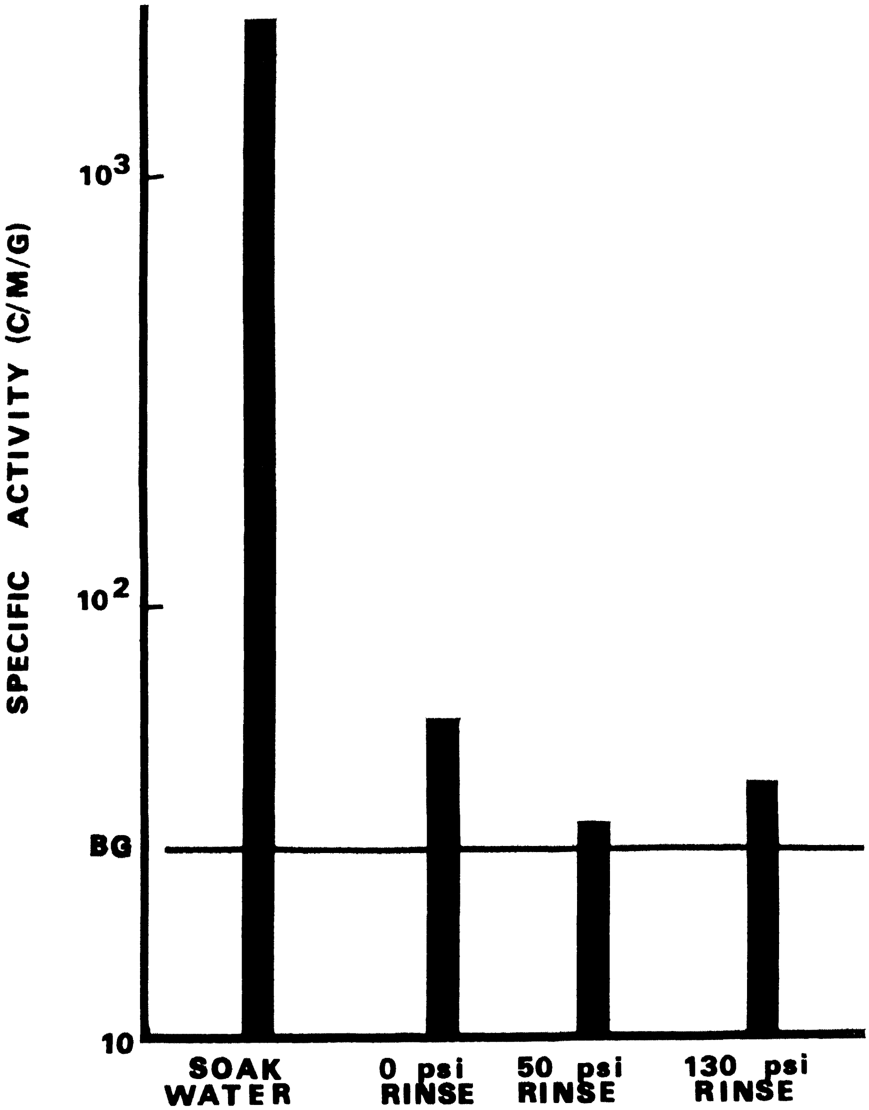


Fig. 6.—Specific activity of tomato juice from cracked tomato fruits using medium foaming detergents by rinsing treatment.

The adherence of high foaming detergent (Figure 5) to the cracked fruits was more than twice that which occurred with sound fruits. It seems logical that the degree of cracking or size of cracks would affect detergent pick-up. Since the number and size of cracks were not re-

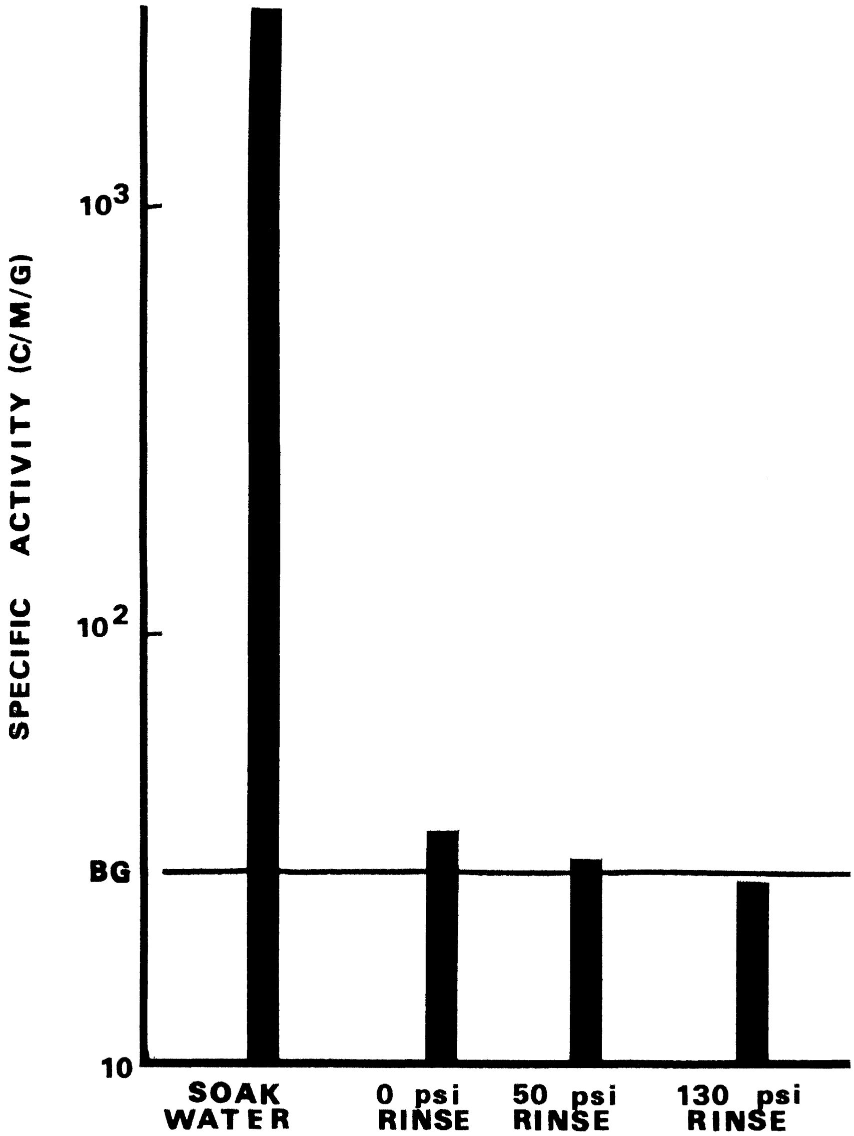


Fig. 7.—Specific activity of tomato juice from cracked tomato fruits using low foaming detergents by rinsing treatment.

corded, the specific activity would be relative. However, it is significant to note that the results of the spray rinse treatments were similar to those obtained for the same treatment with sound fruits. With this type of detergent, neither of the rinsing treatments could preclude the possibility of a detergent residue in the finished product.

Medium foaming detergent gave similar results to the high foaming detergent, as shown in Figure 6. The pick-up of detergent was not as great as for the high foaming detergent. The removal of residues from the cracked fruits followed the same trend as that of the sound fruits. Rinsing aided in the removal of the detergent but this operation did not completely remove the residue. It should be pointed out that the amount of detergent detectable by using radioactive tracers is 10^4 to 10^5 times smaller than that detected by chemical means. In other words, the residue detected in the juice from the 50 psi treatments would probably be at the threshold of detectability by chemical means.

The data in Figure 7 indicate that the pick-up of low foaming detergent did not significantly change when cracked fruits were used. The increase of spray pressure during rinsing reduced the residue. At 130 psi, there was no possibility of a detergent residue in the finished product.

Comparison of Detergent Types: Samples of the soak water were removed after completion of each experiment for assay for radioactivity. The specific activity was calculated. The percent reduction between initial specific activity (SA_i) and final specific activity (SA_f) was determined as:

$$\frac{SA_i - SA_f}{SA_i} \times 100 = \text{Percent Reduction} \quad (1)$$

These results are presented in Figure 8.

The greatest reduction in specific activity was obtained with the high foaming detergent. The reduction in specific activity indicated a reduction in the amount of detergent in the soak water as considerable amounts foamed over the side of the soak tank. This loss of detergent not only means a lowering of cleaning efficiency but also means a possible carryover and resultant residue in the finished product. Practically speaking, it also means an increased cost to the processor for, in order to maintain cleaning efficiency, a considerable quantity of detergent would have to be continuously added to the soak water.

Similar results were obtained with the medium foaming detergent, while low foaming was slightly but not significantly affected.

The results of this portion of the research indicated that both high and medium foaming detergents should be precluded from use in washing tomatoes. There were four reasons for this conclusion. These were:

1. The foam cap could interfere with cleansing.
2. The foam cap interfered with rinsing.
3. The loss of detergent due to foam overflow would be excessively expensive.
4. There would be a great possibility of a detergent residue in the finished product.

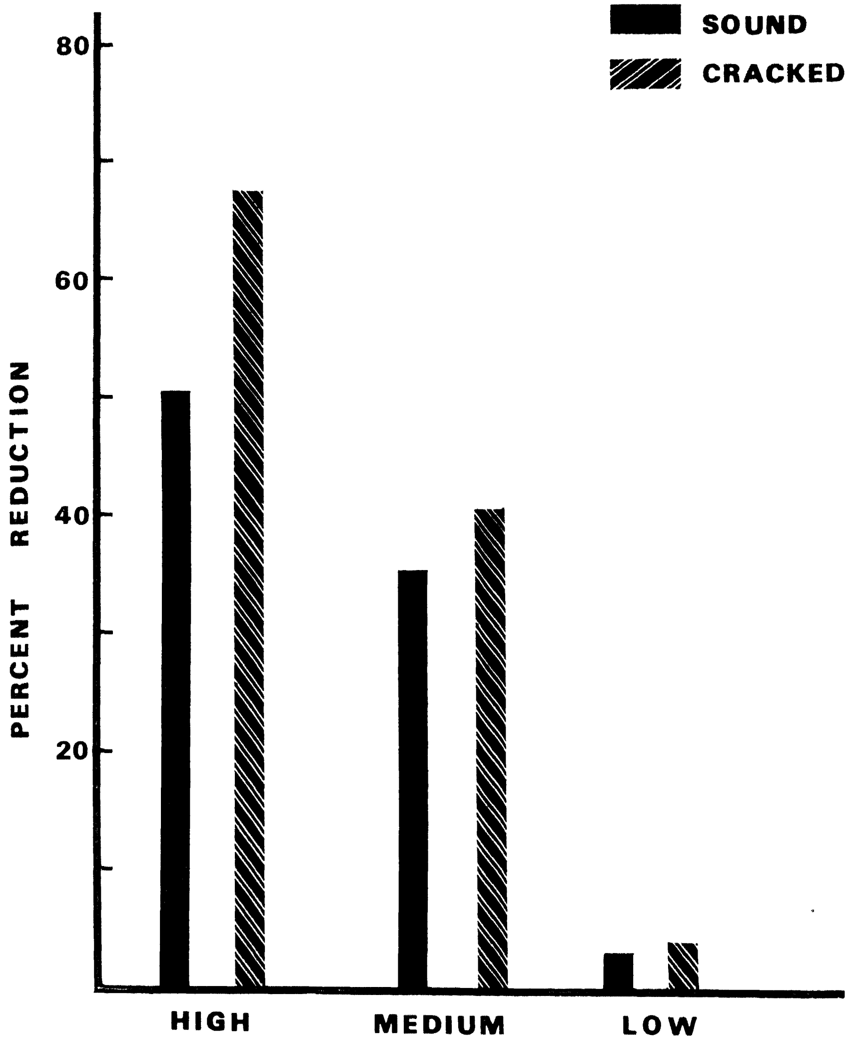
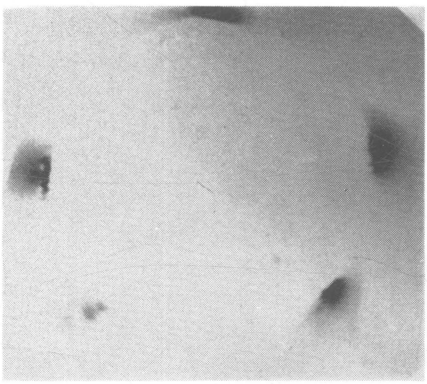


Fig. 8.—Percent reduction in specific activity of soak water for sound and cracked tomato fruits by detergent foam characteristics.

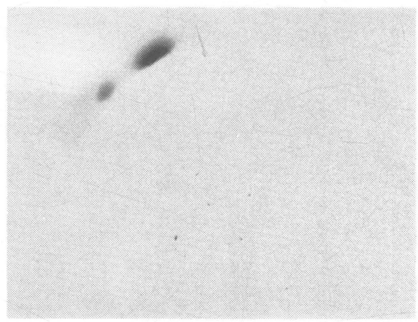
These results were similar to those reported by Mercer (8, 9) on washing asparagus. He recommended the use of low foaming detergent. As the results indicated, low foaming detergents in combination with a high pressure (130 psi) spray rinse could not produce a detergent residue in the finished product. Therefore, the procedure for washing tomatoes recommended by Gould, Geisman, and Sleesman (3) was not only successful in removing insect residues but also precluded detergent residues as well.

Insecticide Phase

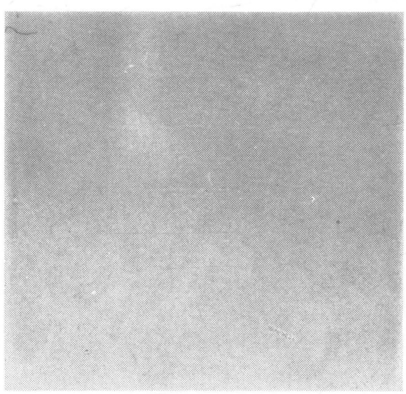
Based on the results of the previous phase, a procedure was established for washing tomatoes which might feasibly reduce or remove in-



a. ONE DAY



b. THREE DAYS



c. SIX DAYS

Fig. 9.—Autoradiograms of tomato fruits treated with dieldrin—C^{14} by days after application.

secticide residues. Prior to determining this aspect, tomato fruits were sprayed with labeled insecticides for autoradiography to determine the location of the insecticides.

Autoradiography: Autoradiograms were made according to the technique previously described. Using radiocarbon labeled dieldrin, autoradiograms indicated that the residue was reduced with time and at 5 days after application, no residue could be detected by this method. Inspection of the autoradiograms indicated that the insecticide residue remained on the fruit surface because of the clearly delineated boundary of the exposure (Figure 9).

These results indicated that washing to remove this residue was feasible. However, when labeled DDT was the insecticide used, the residue could be detected by autoradiography until the 14th day. After that time, this technique was not sensitive enough to detect the minute residue remaining.

The initial autoradiograms using DDT—C^{11} indicated that the residue remained on the surface for at least 14 days. This result greatly enhanced the possibility of removing the residue by washing.

Dieldrin Removal: Based on the results of the autoradiograms, a group of tomatoes was sprayed with dieldrin—C^{11} in the manner previously described for the evaluation of the washing procedure. As indicated by autoradiography, the residue decreased with time. This result was further substantiated by the results of liquid scintillation as shown in Figure 10.

The data in Figure 10 indicated that at 6 days after application, the dieldrin residue had completely dissipated. These results would be expected since dieldrin has a 7-day prior-to-harvest limit on its use.

When the tomatoes were washed by the procedure developed from the results obtained in the prior phase of this study, no dieldrin residue remained. A 50 psi rinse was then added to the washing treatment to determine how easily the residue could be removed. These results are shown in Figures 11 and 12.

The data indicated that at both 1 and 3 days after application, the dieldrin residue was almost completely removed by detergent washing followed by a 50 psi spray rinse. To accomplish complete removal, a 130 psi rinse was necessary. The most important result was the fact that complete removal could be accomplished at 1 and 3 days after application of dieldrin. This means that the processor, by proper washing, could eliminate the possibility of a dieldrin residue in tomato products even though the crop was harvested within 1 day after insecticide application.

DDT Removal: DDT created a more persistent residue than dieldrin. Traces of DDT were found even at 34 days after application. This is in agreement with chromatographic analysis of DDT in apples reported by Westlake and San Antonio (16). The results are reported in Table 2.

From the data in Table 2, it appears that the dissipation of the residue during the first 2 weeks after application was exponential with time. However, after that time, the residue dissipated very slowly and was still significantly present after 34 days.

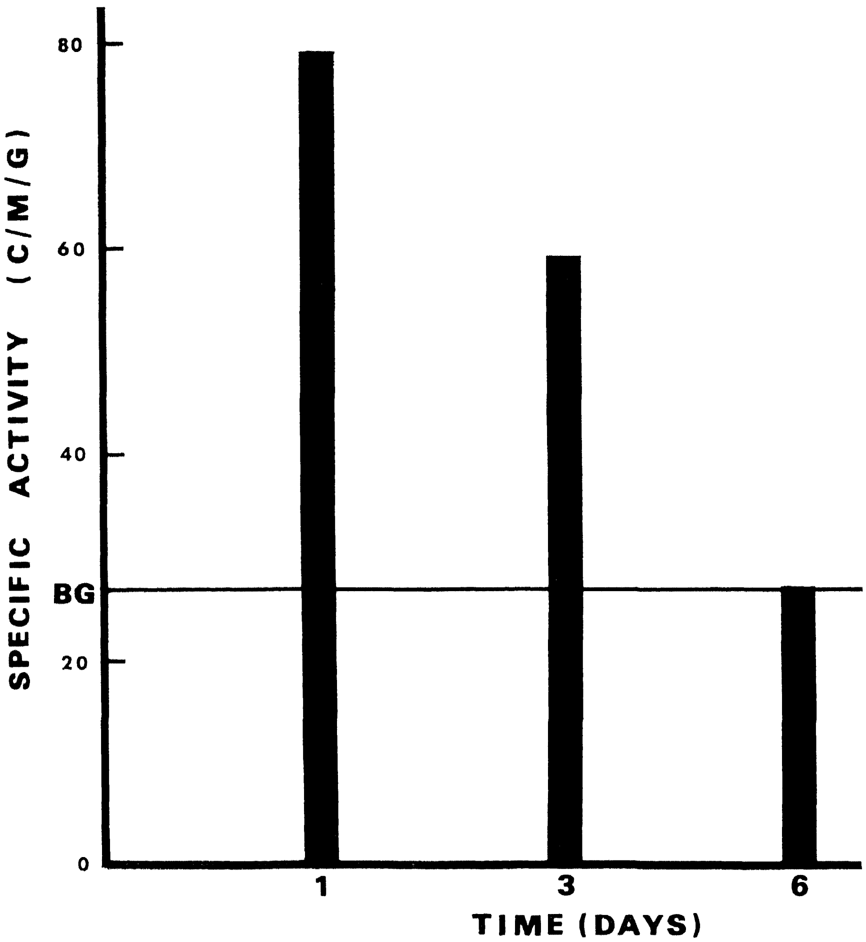


Fig. 10.—Specific activity of tomato juice from tomatoes treated with dieldrin—C^{14} by days after application.

DDT was also more difficult to remove by washing. It could not be completely removed even at the 34th day after application. The results of the washing studies were calculated as percent reduction using equation (1) as previously defined. These data are presented in Table 3.

The data in Table 3 indicate that generally the reduction of DDT residue increased with time. It should be pointed out that the residue after 14 days was extremely small as indicated by the low specific activity. DDT has a very persistent residue which is difficult to remove by washing. These results indicate that this residue could be reduced.

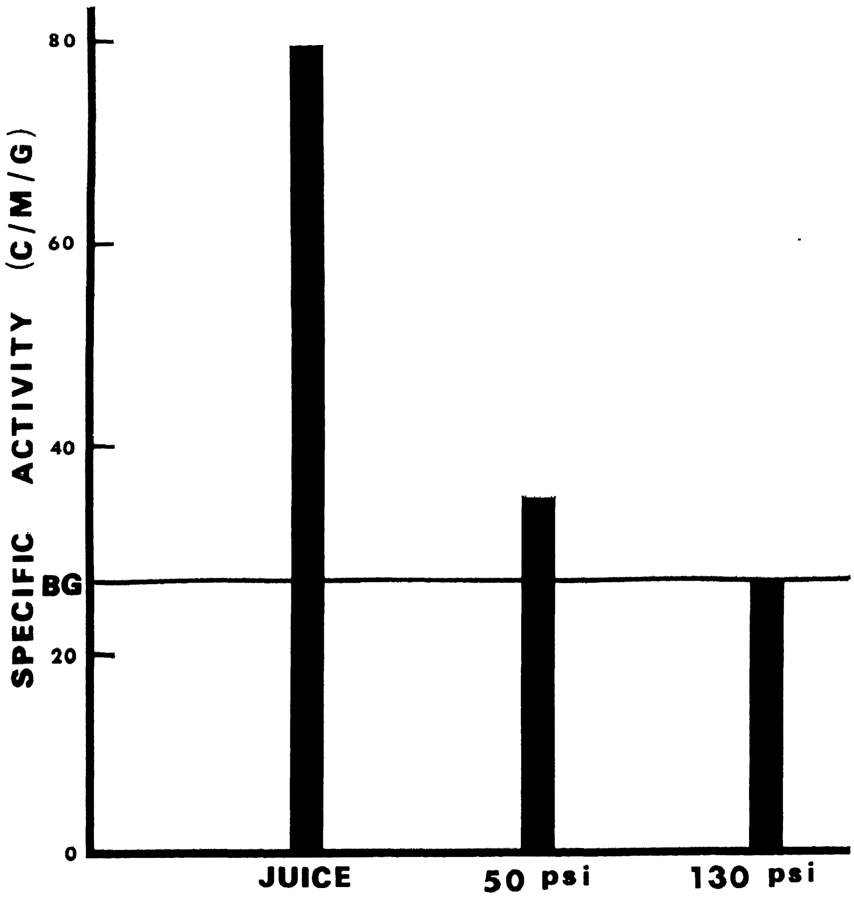


Fig. 11.—Specific activity of tomato juice from tomatoes treated with dieldrin—C^{14} 1 day after application by rinsing treatment.

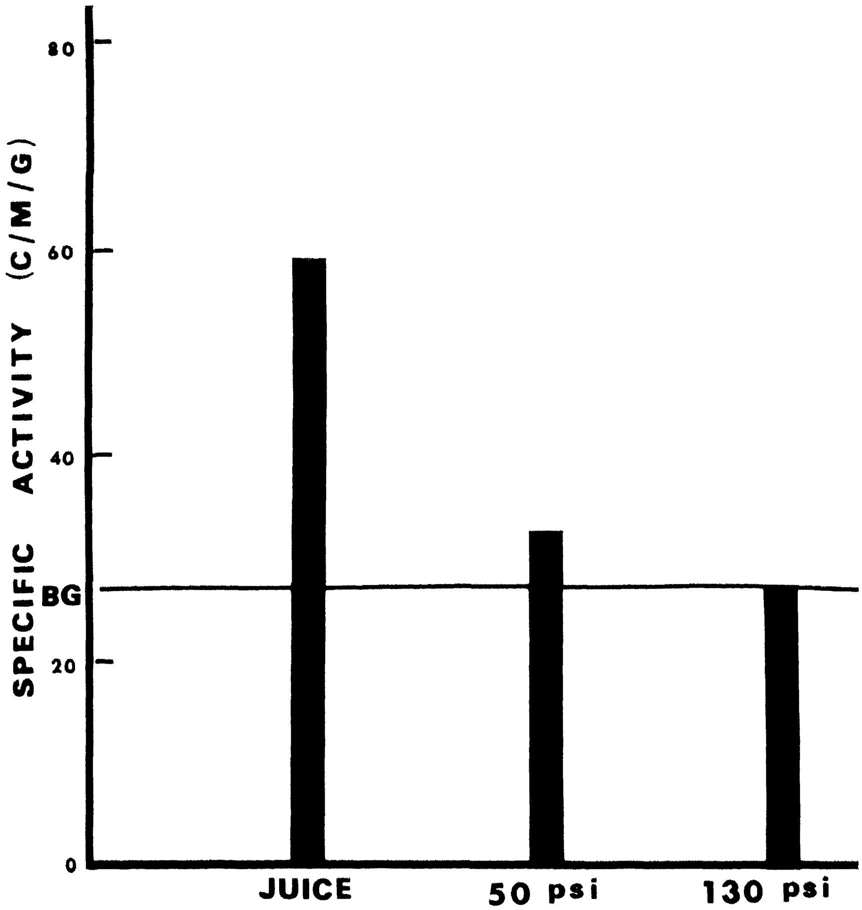


Fig. 12.—Specific activity of tomato juice from tomatoes treated with dieldrin—C^{14} 3 days after application by rinsing treatment.

TABLE 2.—Specific Activity of Tomato Juice at Various Days After Application of DDT—C^{11}.

Days After Application	Specific Activity* (c/m/g)
1	3500
3	1700
7	390
14	180
21	140
28	132
34	128

*The background for these samples was 120 c/m/g.

TABLE 3.—Average Percent Reduction on Specific Activity of Tomato Juice at Various Days After Application of DDT—C^{11}.

Days After Application	Average Percent Reduction
1	62.0
3	79.5
7	78.0
14	77.5
21	85.0
28	92.5
34	94.0

SUMMARY

The studies on the washing of tomatoes to remove residues were divided into two phases: the detergent phase and the insecticide phase.

The detergent phase consisted of comparing three different detergents, varying in their foaming characteristics, using both sound and cracked tomato fruits. In both cases, the medium and high foaming detergents could possibly become a contaminant in the finished product. When a low foaming detergent was used, no carryover was obtained for either sound or cracked fruits when soaking for 3 minutes was followed by 130 psi spray rinse.

Based on the above results, the insecticide phase was undertaken. Two chlorinated hydrocarbon insecticides were used—dieldrin and DDT. Dieldrin could be readily removed by proper washing even within 1 day of application. On the other hand, DDT had a persistent residue which could not be completely removed but which could be significantly reduced by proper washing. Thus, the tomato processor has a means available which will not only aid in removing soil but also reduce the possibility of pesticide residues in the finished product.

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