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FLAVOR CHANGES

Effects of Chlorinated Hydrocarbon Insecticides on Flavors of Vegetables

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Aldrin, dieldrin, endrin, chlordan, heptachlor, lindane, and toxaphene were tested for their possible effects on the flavor of 12 vegetable crops. The treated vegetables were evaluated in the form or forms in which they are most commonly consumed. The triangular taste tests indicated that lindane treatments caused considerable damage to the flavor of most of the crops studied. Other insecticides were less pronounced in their effects on flavor. The results of flavor evaluations after prolonged storage of insecticide-treated raw and canned vegetables were similar to results obtained with fresh samples. Changes in flavor were more pronounced in canned samples than in raw or cooked samples.

The effects of insecticides on the flavor of fruits and vegetables have been investigated, since 1947, by many research workers in the fields of entomology and food technology. Extensive studies have been conducted on the effects of benzene hexachloride on the flavor of food crops to which it has been applied. These studies have been concerned with the effects of this chemical on flavor when applied to soils in which the crops were subsequently grown, and when applied to the foliage of fruits and vegetables. A review of the effects of benzene hexachloride and lindane has been compiled by Hinreiner and Simone (*7*). Other synthetic organic insecticides have been investigated for their possible effects on the flavor of fruits and vegetables, but the available information is limited.

Aldrin and dieldrin have been investigated extensively and the results, most of which are listed in the "Agricultural Handbook for Aldrin and Dieldrin" (*13*), appear favorable for both chemicals. Gilpin and coworkers (*3*) have investigated the effects, on the flavor of peanuts, of aldrin and dieldrin dust applications to the soil and foliage of peanuts and found that the flavor was not affected. These chemicals did not affect the flavor of lima beans and carrots when applied to the soil (*9*). Soil and foliage applications of aldrin had no effect on the flavor of potatoes (*4, 7, 8, 10, 15*), tomatoes (*4, 6, 15*), carrots (*6, 7*), sweet potatoes (*7*), and beets (*6*). Hening, Davis, and Robinson (*6*) found off-flavors in pureed squash when aldrin had been applied to the soil at the rate of 4 pounds per acre. They did not detect a change in flavor, however, when the squash was grown in soils containing 8 pounds of aldrin per acre. Applications of dieldrin to soils have not had much effect on the flavor of crops subsequently grown in the treated areas. Potatoes (*7, 8, 10*), carrots (*6, 7, 9*), beets, tomatoes, and squash (*6*), and sweet potatoes (*7*) have been reported to be free from flavor changes due to soil treatments with dieldrin.

A relatively new compound, endrin, is being studied for its possible effects on the flavor of vegetable crops. Hinreiner and Simone (*7*) have reported no off-flavors due to applications of endrin to the soils in which potatoes, carrots, and sweet potatoes were grown.

The effects of chlordan treatments on the flavor of a number of vegetable crops have been reported. Stone, Foley, and Bixby (*15*) found that applications of 20 pounds of chlordan to the soil caused off-flavor in potatoes. Boswell reported off-flavors in potatoes when chlordan was applied to the soil at 8 and 15 pounds per acre, but not when applied at the rate of 75 pounds per acre (*2*). Potatoes, however, generally were not off-flavor when lighter rates of application of chlordan were employed (*4, 5, 7, 8, 10*). No significant differences in flavor due to chlordan treatments were noted with carrots (*6, 7, 9, 14*), snap beans (*9, 11, 14*), sweet potatoes (*7*), peas (*14*), tomatoes (*4, 6, 15*), cucumbers (*14*), or beets (*6*). Gould and associates (*4*) reported off-flavors in tomatoes, carrots, potatoes, and lima beans when chlordan sprays were employed under certain conditions. The effects of chlordan treatments are subject to variations due to climatic conditions and soil type (*2*).

Heptachlor treatments have not had any measurable effect on the flavor of the vegetables studied. Lindgren, Anderson, and Frost (*9*) reported no changes in flavor of lima beans and carrots grown in soils treated with 5 pounds per acre of heptachlor. Kirkpatrick and coworkers (*8*) found heptachlor treatments to have no effect on the flavor of potatoes in two out of three years. Hinreiner and Simone (*7*) tested sweet potatoes, carrots, and potatoes in soils treated with heptachlor and did not detect changes in flavor.

A study was made of the effects of seven of these chlorinated hydrocarbon insecticides on the flavor of 12 vegetables. All chemicals were supplied by their basic manufacturers and included aldrin, dieldrin, endrin, chlordan, heptachlor, lindane, and toxaphene. These compounds were tested on snap beans, beets,

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Table I. Rates of Application of Chlorinated Hydrocarbon Insecticides in All Years

(Pounds of actual insecticide per acre)

	On Vegetable Foliage		In Soil	
	Normal	Heavy	Normal	Heavy
Aldrin	0.25	1	2	8
Dieldrin	0.25	1	2	8
Endrin	0.25	1	2	8
Chlordan	1.0	4	4	16
Heptachlor	0.25	1	2	8
Lindane	0.25	1	2	8
Toxaphene	1.5	6	6	24

Table II. Processing Treatments and Evaluation Intervals Employed for Measuring Flavor Effects of Insecticide Treatments

Vegetable	Processing Treatment	Evaluation Intervals, Months' Storage	Years Examined
Beets	Canned	0–9	1952–53
Carrots	Raw	0	1953–54
	Cooked	0	1952
	Canned	0–9	1953–54
Cabbage	Cooked	0	1952–54
Cucumbers	Raw	0	1954–55
Onions	Cooked	0	1952
	Canned	0–9	1952–54
Potatoes	Cooked	0–6	1952–53
	Canned	0–9	1953
Pumpkin	Canned	0–9	1953–54
Radishes	Raw	0	1953–54
Rutabagas	Cooked	0–6	1952–53
Sauerkraut	Canned	0–9	1953–54
Squash	Canned	0–9	1953–54
Tomato juice	Canned	0–9	1954–55
Snap beans	Canned	0–9	1953–54

cabbage, carrots, cucumbers, onions, potatoes, pumpkin, radishes, rutabagas, squash, and tomatoes. The tests were begun in 1952 and continued through four growing seasons. Both soil and foliage treatments of each insecticide were applied and the flavor of the treated vegetables was compared to that of untreated vegetables by means of triangular tests. Each treated vegetable was evaluated for flavor in a form, or forms, in which it is normally consumed (raw, cooked, and/or canned) in each of two years. In addition, storage tests were conducted on all the canned vegetables and on some of the raw vegetables. The results of this three-year study are too lengthy to present in their entirety, but a condensation of the data is presented in Tables III and IV.

Experimental

Field Procedures. The vegetable crops were grown near the truck crops area of Kenosha County, Wis., on land not previously treated with insecticides. All chemicals were applied to permanently marked, thrice-replicated plots 25 by 40 feet in size. In each year, soil treatments were applied shortly before planting, and were disked into the soil to a depth of about 3 inches. The vegetables were planted so that a 40-foot row of each was grown in both the treated and untreated plots. Applications of insecticides were made to the foliage of all vegetables approximately one month after emergence and repeated at specified intervals until about one month before harvest.

The rates of application of each insecticide are presented in Table I.

Cultivation was kept to a minimum to reduce the hazard of dragging small quantities of insecticides from one plot to the next. At maturity, representative samples were harvested from each plot for flavor and residue analysis. Harvest was made so as to ensure uniformity of size, weight, and maturity of the crop. Although insect injury was a constant hazard to untreated plots and even to certain treated plots, heterogeneity of samples was negligible.

Five to 10 pounds of treated and untreated vegetables were packaged in kraft or polyethylene bags, and sent immediately to various chemical company laboratories for residue analysis. Flavor evaluations were conducted on all vegetables which had received the heavy applications of the various insecticides.

Processing Procedures. The procedures followed in canning the vegetables were in accordance with usual commercial practice. Specific reference

Table III. Significance of Difference between Flavor of Treated and Untreated Canned Vegetables

(Determined by triangular taste tests. No significant difference noted for snap beans or tomato juice with insectide treatments)

Insecticide Treatment	Beets	Sauerkraut	Corrots	Onions	Potatoes	Squash	Pumpkin
Aldrin							
Foliage	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	S. 1%[a]
Soil	N.S.	S. 5%[a]	N.S.	N.S.	N.S.	N.S.	N.S.
Dieldrin							
Foliage	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	S. 5%[a]
Soil	N.S.	N.S.	N.S.	N.S.	N.S.	S. 5%[a]	N.S.
Endrin							
Foliage	S. 5%[a]	N.S.	N.S.	N.S.	N.S.	S. 5%[a]	N.S.
Soil	S. 0.1%[a]	S. 5%[a]	N.S.	N.S.	N.S.	S. 5%[a]	S. 5%[a]
Chlordan							
Foliage	N.S.	N.S.	N.S.	S. 5%[a]	N.S.	N.S.	S. 1%[a]
Soil	N.S.	N.S.	N.S.	N.S.	S. 0.1%[a]	N.S.	S. 5%[a]
Heptachlor							
Foliage	S. 5%[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Soil	N.S.	S. 5%[a]	N.S.	N.S.	N.S.	N.S.	S. 0.1%[a]
Lindane							
Foliage	S. 5%[a]	S. 0.1%[a]	N.S.	N.S.	S. 0.1%[a]	S. 5%[a]	N.S.
Soil	S. 0.1%	S. 0.1%[a]	S. 0.1%[a]	S. 0.1%[a]	S. 0.1%[a]	N.S.	N.S.
Toxaphene							
Foliage	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Soil	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[a] Undesirable effect. [b] Desirable effect.

was made to procedures as stipulated by the American Can Co. (1). Tap water was used in place of salt and/or sugar brines where recommended in the canning methods.

Vegetables prepared in the cooked form were heated in a steam chest for 30 minutes at 215° F., then mashed or ground to a uniform consistency. Vegetables prepared in a processed form were given exactly the same treatment in the processing procedures so as to preclude any effects on flavor other than those due to insecticide treatment. The vegetables which were evaluated for flavor in the raw form were washed, trimmed, peeled, and ground to a uniform consistency.

The processing treatments and evaluation intervals used for each vegetable are presented in Table II.

Flavor Evaluation Procedures. All vegetable samples were served to the taste panels at room temperature. Booth construction, lighting, temperature, and other external factors—such as noise and conversation—were carefully controlled (11). Approximately 125 men and women from widely varying backgrounds were screened for work on the taste panels. The screening consisted, primarily, of elimination of those demonstrating apparent "taste blindness" to the presence of the seven insecticides in very dilute solutions ranging from 0.1 to 100 p.p.m. Sixty persons were selected on the basis of their acuity to the seven insecticides in the very dilute solutions. After panel work was initiated, the judges were rated for relative performance ability by means of the following formula in which the term "entire panel" refers to all panels from six to 30 in which the individual participated, during any 2-month interval, encompassing a variety of products and treatments:

$$\text{Performance rating} = \frac{\text{individual \% correctly identified triangulations}}{\text{entire panel \% correctly identified triangulations}}$$

By means of the formula, calculated every 2 months, panels were adjusted, by selecting groups of individuals having low, medium, and high performance ratings, to achieve a balance of abilities and presumably a closer approximation of consumer reaction than would be obtained with more highly trained panels.

The results of the triangular tests were compiled in three categories: significance of the difference between treated and untreated samples (12), preference ratings of treated and untreated samples, and descriptions of the flavor of the treated samples. An untreated control sample was available for reference at all times during the tests. From 30 to 60 individual triangular tests per comparison were conducted, using 8 to 15 panel members.

Results and Discussion

By careful evaluation of the results obtained in this study and by comparison with results obtained elsewhere, some helpful recommendations can be made to aid growers in selecting the correct insecticides for their vegetable crops.

The results of the four-year study are presented in summarized form in Tables III and IV. The degrees of significance are averages obtained in condensing the specific results in each year and at each storage interval for the vegetables tested.

Desirable as well as undesirable changes in flavor occurred; however, only seven of the 45 significant changes in flavor due to insecticide treatment were rated desirable. In two instances, a significant change in flavor was indicated but the preference for the treated and untreated samples was equal. More undesirable changes in flavor occurred in vegetables when canned than when evaluated cooked or raw. This was especially evident with lindane treatments and is well illustrated in the results for carrots, which were evaluated in all three forms.

Applications of insecticides to the soil seemed to cause a few more instances of changes in flavor than did applications to the foliage. Of the 45 cases where changes in flavor of the vegetables were significant, 19 were due to foliage applications and 26 due to soil applications. Of the insecticides employed, lindane had the most pronounced effect on the flavor of the vegetables, especially when canned. Aldrin, dieldrin, endrin, chlordan, heptachlor, and toxaphene were generally less prone to cause changes in flavor.

Some of the vegetables seemed susceptible to changes in flavor due to insecticide treatment (beets, sauerkraut, pumpkin, rutabagas), while others appeared to be more resistant (snap beans, carrots, tomatoes, cabbage, cucumbers). Correlation between chemical residue content of the fresh vegetables and observed flavor changes could not be made. There did not seem to be any increase in the number of flavor changes when the crops were grown in successive years in the same plots. Any build-up of insecticides in the soil of the treated plots was not reflected in the flavor of the vegetables.

Generally, prolonged storage of the

Table IV. Significance of Difference between Flavor of Treated and Untreated Raw and Cooked Vegetables

(Determined by triangular taste tests)

Insecticide	Cooked					Raw		
Treatment	Rutabagas	Cabbage	Onions	Carrots	Potatoes	Radishes	Cucumbers	Carrots
Aldrin								
Foliage	S. 5%[a]	S. 0.1%[a]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Soil	S. 0.1%[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Dieldrin								
Foliage	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Soil	S. 1%[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Endrin								
Foliage	S. 0.1%[c]	N.S.	. . .	. . .	N.S.	N.S.	N.S.	N.S.
Soil	5%[a]	N.S.	. . .	. . .	N.S.	N.S.	N.S.	N.S.
Chlordan								
Foliage	N.S.	N.S.	S. 5%[b]	N.S.	N.S.	N.S.	N.S.	S. 1%[b]
Soil	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Heptachlor								
Foliage	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Soil	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Lindane								
Foliage	S. 0.1%[c]	N.S.	N.S.	N.S.	N.S.	S. 5%[a]	N.S.	N.S.
Soil	S. 0.1%[b]	N.S.	S. 1%[a]	N.S.	S. 5%[a]	S. 0.1%[a]	S. 5%[a]	N.S.
Toxaphene								
Foliage	N.S.	N.S.	S. 1%[a]	N.S.	N.S.	N.S.	N.S.	N.S.
Soil	S. 5%[a]	N.S.	S. 0.1%[a]	S. 0.1%[b]	N.S.	N.S.	N.S.	N.S.

[a] Undesirable effect. [b] Desirable effect. [c] No preference.

treated vegetables in the raw or canned forms did not produce any changes in flavor. If a product had exhibited a significant change in flavor due to insecticide treatment when evaluated immediately, it usually had the same rating when evaluated after storage. Possible exceptions to this generalization were insecticide-treated canned onions which developed a flat flavor after 9 months' storage.

Some changes in color were noted to occur along with the changes in flavor. Canned beets were markedly affected by applications of endrin, the color turning from bright red to deep red-black. Some slight increases in the redness of yellow squash, pumpkin, carrots, and rutabagas as determined by the Hunter color difference meter were also noted.

The rates of application of insecticides used in these tests were approximately four times normal. In most cases when a flavor change occurred at four times the normal rate of application, a similar change occurred at normal rates of application (*16*). Lesser rates of application of the insecticides should, therefore, be made with caution. The selection of insecticides is greatly narrowed by consideration of flavor effects as well as tolerance specifications but this enforced decrease in utility will ultimately result in higher quality and purity of vegetable crops.

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SORGO ANALYSES

Methods for Extraction of Sucrose from Sorgo

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Accurate selection of commercial varieties of sorgo for sugar production required a dependable method for determining sucrose content. A study was made of three methods, using the chips, shreds, and extracted juice of the Rex variety, for sucrose and marc determinations. Either the hot- or the cold-water digestion method is suitable for the determination of sucrose in shredded sorgo. The sucrose yield from sorgo chips by the hot-water digestion method was 86% and by the cold-water method was only 40% of the amount extracted from the shreds. Purity and nitrogen determinations are also presented.

Sorgo research was started in the Imperial Valley of California during 1942 to evaluate available commercial varieties for sugar production. None of the commercial varieties was satisfactory; therefore a breeding program was started to develop high-yielding varieties possessing high sucrose content and adapted to growing conditions in the Imperial Valley. Since then a suitable variety has been developed which is promising for commercial culture and for sugar processing in sugar beet factories at a time when these factories otherwise are idle.

The accurate evaluation of commercial varieties and promising selections for sugar production required a dependable laboratory method for determining the sucrose content. A comparison of three laboratory methods for sucrose and marc determinations, as well as reducing sugars, purity, and nitrogen determinations are presented.

Materials Used and Preparation of Samples

Although better varieties are now available, Rex was used for this work because of its relatively high sucrose content.

The sorgo material used in these tests was selected and prepared in the following manner: Twenty-one sorgo stalks were taken at random, when the seed was in the hard-dough stage, from a sorgo experimental plot in the Imperial