in the first 20 ml. of *n*-butyl ether percolate following the change in refractive index. The next 40 to 50 ml. of percolate will not show a positive yellow color test when extracting with 1*N* sodium hydroxide.

When the desired zone (the only remaining zone) descends to within 3 to 5 mm. from the bottom of the adsorbent, collect the next 35-ml. cut and extract with exactly 5.0 ml. of 1*N* sodium hydroxide. Filter the sodium hydroxide extract through a plug of cotton directly into a 1-cm. cuvette and record the transmittance at 430 m$\mu$ with reference to water. The color is stable; however, it is recommended that the transmittance be recorded within an hour.

**Standard Curve** Prepare a standard curve from a benzene solution of Ovex containing 10 $\gamma$ per ml. Dilute 2-, 5-, 10-, 15-, and 20-ml. aliquots to 300 ml. with benzene and follow the procedure as described for the pulp analysis including chromatography. The per cent transmittances obtained are plotted on semilogarithmic paper.

### Experimental Results

Data obtained by the authors are shown in Table I.

This nitrosation and chromatographic procedure was developed to eliminate the interfering materials and produce a reasonable control sample blank. Nine determinations of 100 grams each of the control pulp yielded an average blank of 0.11 p.p.m. with a mean deviation of $\pm$0.02.

As the amount of untreated dried pulp was limited, it was possible to run only three fortified recoveries and three control samples. However, the results are almost identical to the results obtained on the fresh pulp.

The three dried pulp controls produced identical blanks of 13.3 mg. or 0.13 p.p.m.

### Discussion

Any variations in the nitrosation procedure as described will alter the chromatographic separation. For example, normal nitrosation procedures are usually performed by bringing the nitrosation mixture to a boil. The extract of such a mixture when placed on the adsorbent will produce three distinct zones, the usual yellow interference zone and two others, one of which will become fixed to the top of the column and remain there throughout the entire elution procedure for the second zone. The recoveries based on this second zone will vary between 40 and 60%.

Low recoveries will also result from varying the acetic acid concentration of the nitrosation mixture. The nitrosation method as described produces an acetic acid concentration of 50 to 55% by volume.

The single 25-ml. water wash on the carbon tetrachloride extract of the nitrosation mixture is necessary to reduce the acid content prior to the chromatographic separation. Neglecting this wash will cause the evolution of carbon dioxide and the subsequent eruption of the adsorbent.

To obtain a uniform chromatographic procedure an adequate supply of the magnesium carbonate and Celite No. 545 mixture should be set aside for subsequent use. To eliminate variations in the chromatographic separation of samples expected to contain less than 20 $\gamma$ of Ovex, determinations should be carried out in groups of four.

1. Untreated control
2. Fortified untreated control (at least 20 $\gamma$ of Ovex)
3. Treated sample
4. Treated sample (duplicate of No. 3)

The percolate data obtained from the fortified standard 2 can be used to cut the desired portion of the untreated control and treated sample chromatograms. The actual cut volume necessary containing the entire sample is about 15 ml. To ensure complete recovery and eliminate slight variations in columns even with the suggested grouping, a total cut of 35 ml. is recommended.

This procedure should be applicable to other citrus fruits and simple phenols and phenoxy compounds where similar phenolic-like materials interfere.

### Literature Cited


(1) Averell, P. R., Norris, M. W., *Anal. Chem.* **20,** 753 (1948).
(2) Chapin, R. M., *J. Ind. Eng. Chem.* **12,** 771 (1920).
(3) Deichman, W., Schafer, L. J., *Anal. Chem.* **14,** 310 (1942).
(4) Gunther, F. A., Jeppson, L. R., *J. Econ. Entomol.* **47,** 1027–32 (1954).
(5) Kutchinski, A. H., Luce, E. N., *Anal. Chem.* **24,** 1188 (1952).
(6) Sannie, C., *Bull. soc. chim.* **4,** 580 (1937).
(7) Wetlaufer, L. A., Van Natta, F. J., Quattlebaum, H. B., *Anal. Chem.* **11,** 438 (1939).



*Received for review October 12, 1955. Accepted May 17, 1956.*


**PESTICIDE RESIDUES**

# Flavor of Selected Vegetables Grown in Pesticide-Contaminated Soils


**GLADYS L. GILPIN, ALBERT B. PARKS, and HOWARD REYNOLDS**

**Human Nutrition Research Branch, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.**



**Undesirable off-flavors were detected in carrots, turnips, and green beans which were grown without insecticide treatment in soils contaminated with residues of technical benzene hexachloride (BHC) or lindane applied to preceding crops. Soil residues of the alpha, beta, and delta isomers of BHC also resulted in off-flavors in carrots. Heavy residues of aldrin (both technical and purified), dieldrin, heptachlor, Dilan, toxaphene, chlordan, endrin, isodrin, TDE, technical DDT, and methoxychlor did not cause significant flavor changes.**


The possibility of off-flavors in food crops from use of insecticides, especially with respect to carry-over of benzene hexachloride (BHC) in the soil, and conflicting reports concerning the effect on flavor of food crops of other insecticides carried over in the soil, point up the need for further study of the effect of growing various foods in soil exposed to contamination by residues of insecticides used in previous years.

Off-flavors were reported in potatoes grown in soil 2 (*11*) or 3 years (*8*) after the last application of benzene hexachloride (BHC). Off-flavors were also found in peanuts and peanut butter prepared from peanuts grown in soil treated with heavy applications of BHC

(*2, 12, 13*) which had been used previously for cotton. Heavy dosages of lindane caused off-flavors in peanuts grown the year after insecticide treatment, but chlordan up to 75 pounds per acre and toxaphene at 120 pounds per acre appeared to have no deleterious effect on flavor of peanuts (*2*). Maclinn, Reed, and Campbell suggest that flavor was affected when potatoes were grown in soil used the previous year for crops treated with 1 pound of lindane per acre but was not affected by $^1/_4$-pound or $^1/_2$-pound treatments (*11*). Kirkpatrick, Mountjoy, and Albright reported that potatoes from soil treated the previous year with 1 pound of lindane were scored significantly lower in flavor than those from untreated soil (*10*). In further studies Kirkpatrick and coworkers reported off-flavors in some varieties of potatoes but not in others, grown in soil exposed the previous year to $1^1/_4$ pounds of lindane per acre (*9*).

Analyses made by the U. S. Department of Agriculture (*1*) showed wide variations in the persistence of different insecticides in soils. Of the insecticides studied, DDT and TDE were among the most persistent, dieldrin and toxaphene somewhat less persistent, and chlordan, aldrin, BHC, and lindane the least persistent. Indications were that endrin probably ranks with DDT and that isodrin is slightly less persistent. Soil type has been reported to affect the persistence of some insecticides. Persistence of BHC and DDT was greatest in sandy soils, least in muck, and about the same in loam; decreased persistence appeared to correlate with increasing soil organic matter (*3, 7*).

The present paper reports results of palatability studies made by the Human Nutrition Research Branch on carrots grown in 1953, carrots, turnips, and green beans grown in 1954, and carrots and turnips grown in 1955. All the vegetables were grown as part of a study of the effects of insecticides in soils upon plants, made by the Horticultural Crops Research Branch, Plant Industry Station, Beltsville, Md. The vegetables were not treated directly with insecticides but were exposed to soil residues of several insecticides that had been applied at excessively heavy rates to preceding crops. Chemical determinations of organic chlorine as a measure of insecticide residues in the crops were made by the Entomology Research Branch.

### Insecticide Treatments

Two groups of plots were used for growing the crops included in these studies. With both groups, plot tests were duplicated for each treatment.

**Group A Plots** were 6 × 6 foot plots that had been used during 1951 and 1952 for five successive crops—oats and spinach (half of each plot to each species), beans, beans, radishes, and rye—treated with aldrin (technical), aldrin (purified), dieldrin, heptachlor, Dilan, BHC (technical), toxaphene, chlordan, endrin, and isodrin. Control plots not previously exposed to insecticides were also included.

A total of 45 pounds per acre of aldrin (technical), aldrin (purified), dieldrin, endrin, and isodrin was applied in 1951 and 1952. The applications consisted of four separate sprayings of 2.5 pounds each on spinach, beans, beans, and radishes and two sprayings on rye. Heptachlor, Dilan, BHC (technical), toxaphene, and chlordan were sprayed on each of the first four crops at the rate of 20 pounds per acre in four separate applications of 5 pounds each and on the fifth crop at 10 pounds per acre in two 5-pound applications, making a total of 90 pounds per acre.

Imperator and Danvers carrots planted in these plots on April 27, 1953, were grown without insecticide treatment and harvested on July 16. In the autumn of 1953 a rye cover crop growing on these plots was sprayed twice at 10 pounds per acre of aldrin (technical), aldrin (purified), dieldrin, endrin, and isodrin, making a cumulative total of 65 pounds per acre of each insecticide, or the rye was sprayed twice with 20 pounds per acre of heptachlor, Dilan, BHC (technical), toxaphene, and chlordan, making a total of 130 pounds per acre of each insecticide.

Crop residues were returned to the soils—the entire plants from the spinach and rye crops, vines only from the bean crops, and tops from the radishes.

All of these plots were planted to Red Core Chantenay carrots April 21, 1954; no insecticides were used on this crop, which was harvested July 26. Purple White-Top Globe turnips, also grown without insecticides, were raised on these plots in 1955.

**Group B Plots** were 3 × 6 foot outdoor cold-frame plots used during the years from autumn 1949 to autumn 1953 for a succession of 13 crops—peas, beans, beans, rye, peas, corn, beans, peas, beans, radishes, rye, oats, beans—all but two of which were treated with aldrin (technical), dieldrin, toxaphene, chlordan, BHC (technical), alpha isomer of BHC, beta isomer of BHC, delta isomer of BHC, lindane, gamma isomer of BHC (specially purified), technical DDT, methoxychlor, and TDE. In most cases each treated crop was sprayed four times to give total applications of 10 and 20 pounds per acre, respectively, of each insecticide on each crop. The cumulative totals were 95 and 190 pounds per acre at the two treatment levels. Crop residues, consisting of the entire plants of the corn and rye crops and vines from the peas and beans, were turned into the soil. No crop residues from the radishes were left on the plots. Purple White-Top Globe turnips were planted in these plots on March 23, 1954, grown without insecticide applications, and harvested June 9. Plots not exposed to prior insecticide treatments were provided for growing control samples. Stringless Black Valentine beans were planted July 29, 1954, and harvested September 16; carrots were grown on these plots in 1955; no insecticides were used.

### Samples and Experimental Designs for Palatability Studies

**Carrots, 1953 Crop.** Forty-four samples of Imperator and Danvers carrots grown on group A plots were included in the palatability study. They consisted of four replications of the composited check sample and four replications of each of 10 composited samples of carrots which followed the series of crops treated with the aldrin (purified), aldrin (technical), endrin, dieldrin, isodrin, chlordan, toxaphene, heptachlor, Dilan, and BHC (technical). The design for this study was a 5 × 5 simple lattice giving one rating by each judge on each of the four replicates of each treated sample, two ratings per judge on each of the four replicates of the check sample, and one rating per judge on each of two composite samples made up from the duplicate check samples from each of the two field blocks. There were ten palatability sessions with five samples rated per session, and five persons serving as judges.

**Carrots, 1954 Crop.** Sixteen samples of Red Core Chantenay carrots grown on group A plots previously exposed to Dilan, isodrin, and technical BHC, and carrots from control plots were judged for flavor by a trained palatability panel. A randomized block plan giving one rating by each of six judges on each of the four replicates of each sample treatment from the two field blocks was used. There were four sessions, with four samples rated per session. Samples from the same field block representing the three insecticide treatments and the untreated control were rated at the same session, but samples within blocks were randomized. The untreated sample tested at each session was presented both as a known reference sample and as a coded control.

**Carrots, 1955 Crop.** Thirteen carrot samples evaluated in 1955 were grown on group B plots used previously for untreated crops and crops sprayed with aldrin (technical), BHC (technical), alpha, beta, and delta isomers of BHC, chlordan, DDT (technical), dieldrin, lindane, methoxychlor, TDE, and toxaphene. These samples came from the plots which had received a cumulative insecticide total of 190 pounds per acre of each insecticide.

A randomized block design giving two scores per judge for each treatment (one each for replicate samples from two field blocks) was used. The untreated sample was presented only as a coded control. There were three sessions for each of two blocks, with four or five samples tested per session. Five experienced judges served on the panel.

**Turnips, 1954 Crop.** Eight samples of Purple White-Top Globe turnips grown on group B plots previously exposed to technical BHC, gamma-BHC (specially purified), or lindane (commercial sample).

The samples from plots exposed to the higher dosages of the insecticides were served in random order to a panel of eight persons at one judging session and those from soil exposed to the lower dosages at another session. The first sample tasted at each session was one of the untreated samples served as a known reference. A duplicate untreated sample was also served as an unknown coded control randomized among the treated samples.

**Turnips, 1955 Crop.** Eleven samples of turnips grown on the group A plots followed a series of crops which had been treated with aldrin (technical), aldrin (purified), dieldrin, endrin, isodrin, heptachlor, Dilan, BHC (technical), toxaphene, and chlordan or on untreated plots were taste-tested.

The plan used was based on a 3 × 4 simple rectangular lattice which gave two scores per treatment per judge (one each for samples from two field blocks) and four scores per judge for the control sample, which was presented only as a duplicated coded sample. There were six judging sessions, three for samples from two different field blocks. Five experienced persons made the palatability evaluations.

**Green Beans, 1954 Crop.** Ten samples of stringless Black Valentine beans grown on the group B plots following a series of crops treated with one of the following insecticides were evaluated for flavor: chlordan, dieldrin, toxaphene, TDE, DDT (technical), methoxychlor, toxaphene, lindane, and aldrin. Beans from two plots on which preceding crops had been grown without insecticide treatments were provided for controls. All samples from the plots exposed to the higher dosage of insecticide were tested, but only selected samples from plots exposed to the lower dosage were rated. Treatments selected for the latter were those associated with the two lowest and the two highest scoring samples from the tests on beans from soil exposed to the higher dosages of insecticide—namely, BHC, lindane, chlordan, and the comparably untreated check. A panel of seven experienced persons rated these samples.

Because of limitations on time and materials for taste testing, 9 of the 10 samples of beans from the plots exposed to the larger dosage of insecticide were scored in a 3 × 3 simple lattice. The sample from soil exposed to DDT was scored as an extra sample in two of the scoring sessions. Seven persons scored all samples twice, except the one from soil exposed to TDE, which was suffi-

**Table I. Mean Palatability Scores for Carrots and Turnips from Untreated Plots or Plots Previously Exposed to Insecticides**

| Insecticide Used | Total Application of Insecticide to Preceding Crops, Lb./Acre | Mean Palatability Scores: Flavor[a] | Mean Palatability Scores: General acceptability[b] |
|---|---|---|---|
| | CARROTS[c] | | |
| 1953 crop | | | |
| Check (untreated) | None | 3.1 | 2.5 |
| Aldrin (purified) | 45 | 3.2 | 2.4 |
| Chlordan | 90 | 3.0 | 2.4 |
| Endrin | 45 | 2.8 | 2.4 |
| Dieldrin | 45 | 2.8 | 2.3 |
| Toxaphene | 90 | 2.8 | 2.1 |
| Aldrin (technical) | 45 | 2.6 | 2.0 |
| Heptachlor | 90 | 2.6 | 2.0 |
| Dilan | 90 | 2.5 | 2.2 |
| Isodrin | 45 | 2.4 | 1.9 |
| BHC (technical) | 90 | 1.0 | 1.0 |
| 1954 crop | | | |
| Check (untreated) | None | 4.9 | 3.7 |
| Dilan | 130 | 4.9 | 3.6 |
| Isodrin | 65 | 4.9 | 3.5 |
| BHC (technical) | 130 | 1.1 | 1.1 |
| 1955 crop | | | |
| Check (untreated) | 0 | 4.9 | 3.9 |
| Chlordan | 190 | 5.0 | 4.0 |
| Dieldrin | 190 | 5.0 | 4.0 |
| DDT (technical) | 190 | 5.0 | 3.9 |
| Methoxychlor | 190 | 4.9 | 3.8 |
| TDE | 190 | 4.9 | 3.6 |
| Aldrin | 190 | 4.9 | 3.6 |
| Toxaphene | 190 | 4.9 | 3.5 |
| Lindane | 190 | 3.4 | 2.6 |
| BHC (beta isomer) | 190 | 3.4 | 2.5 |
| BHC (technical) | 190 | 3.1 | 2.4 |
| BHC (alpha isomer) | 190 | 2.4 | 1.7 |
| BHC (delta isomer) | 190 | 1.9 | 1.3 |
| Test difference[d] | | | |
| For 1953–1954 crops | | 0.9 | 0.8 |
| For 1955 crops | | 0.9 | 0.6 |
| | TURNIPS[e] | | |
| 1954 crop | | | |
| Check (untreated) | None | 4.5 | 3.8 |
| BHC (gamma) | 190 | 3.5 | 2.9 |
| Lindane | 190 | 2.4 | 1.6 |
| BHC (technical) | 190 | 1.9 | 1.6 |
| Check (untreated) | None | 4.8 | 4.2 |
| BHC (gamma) | 95 | 2.2 | 1.9 |
| Lindane | 95 | 2.5 | 2.0 |
| BHC (technical) | 95 | 1.5 | 1.1 |
| 1955 crop | | | |
| Check (untreated) | 0 | 4.4 | 4.3 |
| Chlordan | 130 | 4.9 | 4.8 |
| Dilan | 130 | 4.6 | 4.5 |
| Dieldrin | 65 | 4.5 | 4.5 |
| Aldrin (technical) | 65 | 4.4 | 4.3 |
| Isodrin | 65 | 4.3 | 4.1 |
| Endrin | 65 | 4.2 | 4.1 |
| Toxaphene | 130 | 4.1 | 4.0 |
| Aldrin (purified) | 65 | 3.8 | 3.7 |
| Heptachlor | 130 | 3.8 | 3.5 |
| BHC (technical) | 130 | 1.1 | 1.1 |
| Test difference[d] | | | |
| 1954 crop | | 1.1 | 1.0 |
| 1955 crop | | 1.5 | 1.5 |

[a] Scoring done on a 5-point scale with 5 indicating no off-flavor; 4, perceptible off-flavor; 3, slightly strong off-flavor; 2, moderately strong off-flavor; and 1, very strong off-flavor.

[b] Scoring done on a 5-point scale with 5 denoting very good; 4, good; 3, fair; 2, poor; and 1, very poor general acceptability.

[c] 1953 crop, means for check sample based on 50 scores, for all other samples, 20 scores; 1954 crop, means based on 24 scores; 1955 crop, means based on 10 scores.

[d] Any difference between means for the same crop year equal to or greater than the test difference is significant at the 5% level.

[e] 1954 crop, means for each sample based on 8 scores; 1955 crop, means for check sample based on 20 scores; for all other samples, 10 scores.

cient in amount for only one tasting session. There were six tasting sessions; three samples were rated at each of the first five sessions and four samples at the sixth.

The four samples selected for evaluation from the plots exposed to the lower dosage of insecticide were taste-tested in randomized blocks. All were rated twice except the untreated control, which was insufficient for two sessions. The sample from chlordan-treated soil was considered a supplementary control sample, because, in the first test, beans grown in soil exposed to this insecticide from the preceding applications of 20 pounds per acre per crop were given a score comparable to that of the untreated control.

### Statistical Analyses

Separate analyses of variance (4, 14) were computed for the various groups of data arising from the experiments mentioned above. Comparisons of individual means within those groups were made by applying Duncan's new multiple range test (6) at the 5% level.

### Procedures for Palatability Tests

After harvesting, all of the vegetables used in these experiments were washed in running water, drained, packaged in paper bags, and held under refrigeration for a few days while the palatability evaluations were carried out. Samples from plots previously exposed to insecticide treatments were stored separately from the control samples. Vegetables too small to be marketable were excluded from the samples for taste testing unless the size for an entire plot was small.

Before cooking, all vegetables were washed again, rinsed, and drained on absorbent paper. Carrots were thinly pared, then cut into 1/4-inch crosswise slices. One-pound samples of sliced carrots were cooked in 1 cup of boiling distilled water until tender (about 20 minutes). Turnips were pared and diced; 1-pound samples were cooked until tender (18 minutes) in 3/4 cup of boiling distilled water. Tip and stem ends of green beans were removed, and beans were cut into 1/2-inch pieces. One pound of each sample was cooked for 25 minutes in 3/4 cup of boiling distilled water. Identical covered borosilicate glass saucepans were used for cooking the various samples under study. Each sample was prepared, cooked, and served in a separate set of equipment to prevent any possibility of transfer of flavor from one sample to another. The cooking of the various samples to be rated at each judging session was arranged so that individual samples were ready for serving at 3-minute intervals. A heaping tablespoon of each sample of drained vegetable was served hot to each panel member on a coded, heated, white china plate.

The samples were scored for flavor on a five-point scale, with 5 indicating no off-flavor and 1, very strong off-flavor. Any detected off-flavor was named. They were also rated for general acceptability, which was an over-all rating based on color and texture as well as flavor, on a five-point scale with 5 denoting very good, and 1, very poor products.

The palatability panels that rated these foods were comprised of home economists, most of whom had some previous experience in rating palatability of foods in relation to insecticide treatments. The number of panel members varied from five to eight for the taste tests on the different vegetables, depending on the design of the experiment and the number of people available at the time of the study. Previous to the judging sessions on each type of vegetable, the check sample was served several times to the persons on the rating panel to acquaint them with the flavor of that vegetable when grown in plots not previously exposed to insecticides. In addition, for the tests on carrots in 1954, a composite of the four samples exposed to BHC residues was presented to illustrate the off-flavor due to contamination by this insecticide. In no other case were samples available to train the panel by use of a known off-flavored vegetable.

### Results and Discussion

The results of the palatability tests are presented in Tables I and II. In any column the difference between two means is significant if it equals or exceeds the test difference in the last line of the column.

Flavor and general acceptability scores for vegetables grown without insecticide treatment on plots which had been used previously for crops treated with BHC in the several forms and at the excessively heavy dosage levels tested were generally significantly lower than scores for the controls and for the other test samples (Tables I and II). There were no significant differences between scores for vegetables grown on plots that had received excessively heavy dosages of any of the other insecticides under study, though there were a few instances, discussed later, where lower scores with increased dosages suggest trends which might be proved significant by more comprehensive data.

**Carrots.** The judges rated the 1953 and 1954 samples of carrots from technical BHC-treated plots 1.0 or 1.1 out of possible maximum scores of 5.0 on both flavor and general acceptability (Table I), and the off-flavors were so strong and objectionable that these samples were considered inedible by the panel members.

Organic chlorine content of unpared carrots of the 1953 crop from BHC-treated plots indicated insecticide residues of the order of 8 to 21 p.p.m. Limited tests showed that paring these samples, as would be done before cooking or serving them raw, would greatly reduce the amount of insecticide residue; however, taste panel members have been able to detect off-flavors from very small

**Table II. Mean Palatability Scores for Green Beans Grown in 1954 on Untreated Plots or Plots Exposed to Insecticides**

(Cumulative dosages of 190 or 95 pounds per acre previous to use for green beans)

| Insecticide Used | Total Application of Insecticide to Preceding Crops, Lb./Acre | Mean Palatability Scores[a] | |
|---|---|---|---|
| | | Flavor[b] | General acceptability[c] |
| Check (untreated) | None | 4.6 | 4.3 |
| Chlordan | 190 | 4.9 | 4.4 |
| Dieldrin | 190 | 4.6 | 4.1 |
| Methoxychlor | 190 | 4.6 | 4.1 |
| Toxaphene | 190 | 4.6 | 3.9 |
| Aldrin | 190 | 4.4 | 3.9 |
| TDE | 190 | 4.3[a] | 3.7[a] |
| DDT (technical) | 190 | 4.2 | 3.8 |
| Lindane | 190 | 3.6 | 3.0 |
| BHC (technical) | 190 | 2.3 | 2.1 |
| Check (untreated) | None | 4.7[a] | 4.1[a] |
| Chlordan | 95 | 4.7 | 4.2 |
| Lindane | 95 | 4.1 | 3.8 |
| BHC (technical) | 95 | 3.1 | 2.8 |
| Test difference[d] | | 1.0 | 0.9 |

[a] Based on 14 scores except TDE and untreated check for lower dosage samples (7 scores each).
[b] Scoring done on 5-point scale with 5 indicating no off-flavor; 4, perceptible off-flavor; 3, slightly strong off-flavor; 2, moderately strong off-flavor; and 1, very strong off-flavor.
[c] Scoring done on 5-point scale with 5 denoting very good; 4, good; 3, fair; 2, poor; and 1, very poor general acceptability.
[d] Any difference between means for same dosage level group equal to or greater than test difference is significant at 5% level.

concentrations of BHC (0.05 to 1.8 p.p.m.) in other test materials (*5*, *12*).

Residues of the other insecticides in unpared carrots tested in 1953 ranged from about 0.3 to 16 p.p.m., but flavor scores for specific samples were not related to the amounts of insecticide reported in carrots from the same lot.

Chemical analysis indicated that the 1954-crop carrot samples from BHC-treated plots contained appreciable amounts of organic chlorine, whereas those exposed to Dilan and isodrin contained only minute quantities.

In 1955 when the alpha, beta, and delta isomers of BHC and lindane were studied in addition to technical BHC, it was found that carrots grown in soil exposed to any of these forms of BHC were scored significantly lower than the control and those from the other treatments studied. The eating quality of the carrots was seriously damaged by any of the forms of benzene hexachloride, with the lowest scores resulting from exposure to the delta and alpha isomers.

These results parallel, to some extent, findings of previous investigations, in which more off-flavor was observed in lima beans grown in soils treated with delta BHC than with the other isomers, and potatoes from soil treated with the alpha isomer were scored significantly lower than when beta-BHC was applied (*5*).

In some cases carrots from plots exposed to the same insecticide were tested in two different years. It was found that where flavor of carrots was not significantly different from the controls the first year, the same result was obtained the second year, although insecticide dosages were considerably larger in the latter study.

**Turnips.** Flavor scores for the turnips grown in 1954 in soil contaminated with specially purified gamma-BHC, commercial lindane, or technical BHC, with one exception, were significantly lower than those for the controls (Table I). The sample grown in soil treated with the higher dosage of gamma-BHC, though not significantly lower in score than the control rated at the same time, appeared on the basis of judges' comments to have sufficient off-flavor to impair its eating quality. As the sample from soil treated with the lower dosage of the same insecticide was rated significantly lower than its control, it seems likely that further tests on the high dosage sample would have shown it also to be significantly lower than the control. Judges' comments indicated that in all of the samples from previously treated soil they detected unpleasant off-flavors which definitely impaired the flavor of the turnips. Very few and only minor comments were made on the flavor of the control samples. General acceptability scores paralleled flavor scores. The 1955 turnip samples grown on technical BHC-treated plots were also scored significantly lower on flavor and general acceptability than the other samples studied. Mean scores for the two years were 1.1 to 1.5 out of possible scores of 5, indicating serious impairment of eating quality.

Mean scores for flavor and general acceptability of turnips grown on plots previously treated with the other insecticides under study in 1955 were not significantly lower than those for the control. The scores of 3.8 for samples from soils containing residues of purified aldrin and heptachlor suggest minor flavor defects which would require more extensive testing to demonstrate or disprove. In this connection, previous investigations have provided similarly inconclusive data, suggesting that these two insecticides may, under some conditions, cause minor flavor defects in potatoes. Unpublished results of other tests carried out in 1955 on turnips grown in soils treated with heptachlor at 3 and 6 pounds per acre also showed a nonsignificant decrease in flavor scores with increasing dosages of heptachlor.

Chemical analyses of the 1954 samples showed the organic chlorine content of all turnip samples, from both treated and control plots, to be within the limits of experimental error of the analytical method. No chemical analyses were carried out on the samples from the 1955 crop.

**Beans.** The scores given in Table II indicate that either technical BHC or lindane may also cause off-flavors in green beans. Beans from the soil exposed to treatments with BHC at both dosage levels were scored significantly lower on flavor and on general acceptability than all other samples. The sample exposed to contamination with lindane at the higher dosage was scored significantly lower for flavor and general acceptability than the untreated check and several of the other samples, but at the lower dosage was not scored significantly different from the control samples.

Beans from plots exposed to the heavier dosages (190 pounds per acre) of either BHC or lindane were scored lower on both flavor and general acceptability than those which followed the lighter dosages (95 pounds per acre). Although these changes were not significant, they suggest a relationship between score and level of BHC or lindane treatment. In contrast, the corresponding changes for the chlordan and check samples were negligible.

Scores for beans from plots exposed to chlordan, dieldrin, methoxychlor, toxaphene, aldrin, TDE, or technical DDT at a cumulative dosage of 190 pounds per acre were not significantly different from those for the control sample from untreated soil.

Judges' comments on off-flavor paralleled the flavor scores and showed that judges observed more undesirable off-flavors in beans from plots exposed to previous treatment with technical BHC or lindane than with the other insecticides under study. These observations of off-flavors, characteristic of exposure to BHC insecticides in beans from plants grown in soils treated with this insecticide, provide direct evidence that BHC or decomposition products responsible for off-flavors may be absorbed from the soil and translocated to the edible portions of the plant.


## Acknowledgment

Thanks are due to the Horticultural Crops Research Branch for providing the samples for these studies, to R. H. Carter of the Entomology Research Branch for chemical analyses, and to the following personnel of the Human Nutrition Research Branch: Ruth Redstrom, Marilyn Brown, Grace Linton, Carroll Kitzmiller, and Velma Chapman for valuable assistance in the laboratory.


## Literature Cited


(1) Am. Soc. Agronomy, *What's New in Crops and Soils* **6,** 30 (1954).
(2) Boswell, V. R., *J. Econ. Entomol.* **48,** 495–9 (1955).
(3) Chulski, K., Mich. Agr. Expt. Sta., *Quart. Bull.* **31,** 170–7 (1948).
(4) Cochran, W. G., Cox, G. M., "Experimental Designs," Wiley, New York, 1950.
(5) Dawson, E. H., Gilpin, G. L., Kirkpatrick, M. E., Weigel, C. A., J. AGR. FOOD CHEM. **1,** 399–403 (1953).
(6) Duncan, D. B., *Biometrics* **11,** 1–42 (1955).
(7) Fleming, W. F., Maines, W. W., *J. Econ. Entomol.* **46,** 445–9 (1953).
(8) Jameson, H. R., Peacock, F. C., *J. Sci. Food Agr.* **4,** 102–4 (1953).
(9) Kirkpatrick, M. E., Linton, G. S., Mountjoy, B. M., Albright, L. C., *Am. Potato J.* **32,** 259–64 (1955).
(10) Kirkpatrick, M. E., Mountjoy, B. M., Albright, L. C., *Ibid.*, **28,** 792–8 (1951).
(11) Maclinn, W. A., Reed, J. P., Campbell, J. C., *Ibid.*, **27,** 207–13 (1950).
(12) Reynolds, H., Gilpin, G. L., Hornstein, I., J. AGR. FOOD CHEM. **1,** 772–6 (1953).
(13) Reynolds, H., Gilpin, G. L., Hornstein, I., U. S. Dept. Agr., Circ. **952** (1954).
(14) Snedecor, G. W., "Statistical Methods," 4th ed., Iowa State College Press, Ames, 1946.



*Received for review May 11, 1956. Accepted July 17, 1956.*