

## Flavor of Sebago Potatoes Grown in Soil Treated with Chlordan, Heptachlor, Dieldrin, Aldrin, or Endrin

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Studies were made of flavor of Sebago potatoes grown in 1952, 1953, and 1954 in soil treated with chlordan, heptachlor, dieldrin, aldrin, or endrin. Potatoes from untreated plots were tested. Insecticides were applied by different methods to experimental plots and commercial farms. In the first year's tests, no significant amount of off-flavor was found in potatoes grown in soil treated with chlordan, heptachlor, or dieldrin. The use of a 2-pound dosage of aldrin in three tests resulted in flavor scores lower than those for other treatments, but significantly low in only one test. In the second year, significant off-odor and off-flavor were present in the case of a 2-pound dosage of heptachlor on a commercial farm where chlordan, dieldrin, and endrin were applied. At another location the second year neither aldrin or heptachlor caused a significant amount of off-flavor. Growth of potatoes for the third consecutive year in soils treated with aldrin, heptachlor, or chlordan resulted in no injurious effect on their flavor when cooked. Significant differences were not apparent between sound and wireworm-injured potatoes from untreated plots in the third year. Off-flavored products may result from unknown contamination of the soil, from a particular insecticide treatment-soil type-location combination, or a variation in the composition of the insecticidal material, even though the same insecticide treatment causes no flavor defects under other environmental conditions.

**T**HE PREVALENCE OF OFF-FLAVOR in potatoes grown in soil treated with benzene hexachloride or lindane (99% gamma isomer) has been established (7, 5, 6, 9). Because of the association of off-flavor in potatoes with soil treatment with technical benzene hexachloride or lindane, the Entomology Research Branch, as well as most of the state extension services, now recommend that neither of these insecticides be used on soils in which potatoes are to be grown. Impetus has been given to investigations to determine what other organic insecticides can be used to control soil-infesting potato insects without impairing the flavor of the tuber.

This study presents findings on chlordan, heptachlor, dieldrin, aldrin, and endrin, insecticides which have proved effective for the control of certain species of wireworms affecting potatoes (13), and have not been definitely associated with off-flavor. Satisfactory control of wireworms was obtained with soil application of aldrin at 3 pounds per acre, chlordan at 5 pounds per acre, and dieldrin at 6 pounds per acre without marked alteration of flavor or quality (8). In peanuts grown using 4 pounds of aldrin or 2 pounds of dieldrin per acre as soil treatments, flavor was not affected and was comparable to the flavor of

peanuts grown without treatment (2). Flavor of sweet potatoes grown in soil treated with 5 pounds per acre of chlordan was practically as good as that of the untreated ones (3). When Stone, Foley, and Bixby (11) submitted potatoes grown in soil treated with 4 pounds per acre of aldrin or 20 pounds of chlordan to experienced tasters, however, significant amounts of off-flavor were found. Tasters were unable to detect any off-flavor in green lima beans or tomatoes grown under the same conditions. Some investigators have obtained inconclusive or conflicting results in the taste-testing of potatoes grown in chlordan-treated soil (4, 5, 7).

In connection with the wireworm-control experiments of the Entomology Research Branch in Charleston, S. C., palatability of Sebago potatoes was studied by the Human Nutrition Research Branch during three successive years, 1952, 1953, and 1954, to discover if their flavor was adversely affected when grown in insecticide-treated soil. The potatoes were grown at the South Carolina Agricultural Experiment Station and on three local commercial farms, under conditions of varying dosage rates of insecticide and methods of application for purposes of comparison. In the third year, samples of potatoes from

untreated plots were also provided for tests to evaluate potato flavor in relation to wireworm injury.

### Soil Treatment Procedures

In 1952 and 1953 the insecticides were applied "broadcast" or "in row" before planting operations; in 1954 applications were broadcast. Four insecticides were used in 1952: chlordan, aldrin, dieldrin, and heptachlor. Applications were made about 2 weeks before planting, by three different methods: mixed with fertilizer, broadcast on the soil surface, and disked; mixed with sawdust, broadcast on the soil surface, and disked; and mixed with fertilizer, applied in the row, and stirred. After being harvested June 19, the potatoes were held about 1 week in common storage in a dark basement before shipment to this laboratory. One sample of potatoes purchased on the Washington, D. C., market was used to complete the experimental design for the statistical analysis and was used as an additional control for the palatability tests.

In 1953, endrin was included in the tests. All insecticides were applied during January and, with the exception of endrin, were used in a granular form (30 to 60 mesh) that contained 5 to 10%

**Table I. Mean Odor and Flavor Scores<sup>a</sup> for Cooked Potatoes Grown in Untreated Plots and Plots Treated with Clordan, Aldrin, Dieldrin, or Heptachlor, 1952**

Location of Test and Insecticide Treatment	Dosage, lb./Acre	Palatability Factor	
		Odor <sup>b</sup>	Flavor <sup>c</sup>
Experiment Station, test I			
Applied in fertilizer			
Chlordan, broadcast	4	5.0	4.7
Chlordan, in row	4	4.8	4.1
Aldrin, broadcast	2	4.6	4.2
Aldrin, in row	2	4.4	3.2
Untreated	0	4.5	4.0
Experiment Station, test II			
Applied in sawdust, broadcast			
Chlordan	4	4.7	4.4
Aldrin	2	4.5	3.9
Dieldrin	2	4.9	4.6
Heptachlor	2	4.7	4.0
Untreated	0	4.5	4.5
Commercial farm, test III			
Applied in sawdust, broadcast			
Chlordan	4	4.8	3.9
Aldrin	2	4.2	3.6
Dieldrin	2	4.6	4.3
Heptachlor	2	4.5	4.1
Untreated	0	4.5	4.4
Market control	0	4.0	3.8

<sup>a</sup> Means of 5 judges' scores, 2 replications.

<sup>b</sup> Score of 5 represents natural, desirable odor; 1, undesirable, very strong off-odor.

<sup>c</sup> Score of 5 represents natural, desirable flavor; 1, undesirable, very strong off-flavor.

of the technical grade of the insecticide. A powdered form of endrin was mixed with sawdust. All insecticides were well distributed either by hand or with a rotary hand duster. Those applied broadcast were thoroughly mixed into the soil with a disk harrow or a rotary tooth harrow. Those applied in row were concentrated in a small furrow and lightly stirred during the fertilizing and planting operations. When harvested, a composite sample of potatoes was taken from the various replications of each treatment in each experiment. The potatoes were kept in storage at about 45° F. from a week or two after harvest the last of May, until they were shipped to the laboratory at Beltsville, Md., July 16, 1953.

Aldrin, heptachlor, and chlordan were the insecticides tested in 1954. A granular form of each of the three insecticides was broadcast over the field plots with a hand-operated fan duster on January 20, 1954, and disked into the soil within a few days. The potatoes were planted within 2 weeks, harvested between June 8 and 15, and held in cold storage at about 45° to 50° F. between June 18 and July 8 before being shipped to Beltsville July 9.

Each lot was a composite of potatoes from four field plot replications of each experimental treatment, except that lots from commercial farm B came from only two such replications. When received at the Beltsville laboratories tubers were in good condition, with the exception of the lots selected as containing wireworm injury. According to the ter-

minology used in the U. S. Market Standards for potatoes, the injured tubers did not necessarily show enough wireworm feeding to be regarded as "damaged."

#### Procedures for Palatability Tests

Four to six firm tubers of uniform size and shape and free of greening were selected for each cooking sample. Wireworm injury was present in 1953 only on untreated tubers from commercial farm B, in which case this injury appeared on almost every tuber. In 1954 an average of two to three injuries from wireworm feeding appeared on each tuber in the untreated lots selected as injured. In the first 2 years cooking samples were stored at 55° F. during the testing period and those for each day's cooking test were withdrawn the afternoon before cooking tests were made. They were held on trays in the laboratory at approximately 80° F. to allow tubers to warm to room temperature. During the 4-day testing period in 1954 samples were stored in paper bags in the laboratory at room temperature or approximately 90° F.

To prepare the potatoes for cooking, raw tubers were washed, dried, weighed, pared, and weighed again. An iron-constantan thermocouple was threaded into one tuber from each cooking sample, so that its junction recorded the internal temperature at the center of the tuber. Thermocouples were also used to record water temperature in the cooking pan. Cooking was done on identical electric

units, with voltage and wattage controlled. In the 1952 and 1953 tests each cooking sample, averaging 790 grams, was cooked in 900 ml. of distilled water in covered enamelware pans of 3-quart capacity. In 1954, each sample was cooked in water equal by volume to the weight of the potatoes. In all tests the potatoes were cooked to an internal temperature of 205° F. (96° C.) as recorded by a potentiometer, drained in colanders, weighed, and mashed through ricers. To obtain well blended samples, the riced potatoes were stirred 30 strokes with a fork. No seasonings were added. Individual portions of each sample were measured into coded white porcelain dishes and served to the judging panel while hot.

Palatability was judged at individual tables in a room separate from that in which the samples were prepared. Potatoes were judged for odor and flavor, using a 5 to 1 scale—5 representing natural and desirable odor and flavor and 1, very strong and undesirable off-flavor or odor. The judges were asked to identify detectable off-flavors and odors. The palatability panel was composed of five food specialists of the Human Nutrition Research Branch experienced in judging potato quality. With the exception of a replacement for one member of the panel in the second year, all members had been trained in taste-testing potatoes grown by treatment with insecticides. Other than the one replacement, the membership of the panel remained constant throughout the 3 years.

Similar statistical designs of the incomplete block type were used in the three palatability experiments: a 4 × 4 simple lattice in 1952, a 3 × 4 simple rectangular lattice in 1953, and a 3 × 3 simple lattice in 1954. Each plan provided two scores per sample per judge. Scores for flavor were subjected to analysis of variance (10) and means were compared by Tukey's method (12).

#### Results

Mean odor and flavor scores from tests I, II, and III (Table I) in the 1952 study showed that slight to moderate off-flavor was detected by the panel mostly in the aldrin-treated samples, which with one exception were scored between 3.0 and 4.0. These scores suggested the occurrence of more off-flavor in the aldrin-treated samples than in samples from other insecticide treatments. On the basis of the over-all analysis of variance, however, difference among flavor scores for the 16 samples were not significant.

The possible effects of location and method of application were then considered. Further analyses of the three tests showed that aldrin applied with fertilizer in row was scored significantly lower at the 5% level than the other

three samples in test I; in tests II and III aldrin was not significantly different from other treatments. When the combined means for the aldrin-treated and the chlordan-treated potatoes in test I were compared, the resulting mean for aldrin-treated potatoes was significantly lower than that for chlordan-treated samples. Also, the mean flavor score for application with fertilizer in row with chlordan or aldrin was significantly lower than for the broadcast application in fertilizer.

No significant differences were indicated from a combined analysis of the mean flavor scores of cooked potatoes from plots in test II at the Experiment Station and test III at the commercial farm (Table I) where chlordan, aldrin, dieldrin, and heptachlor were applied in sawdust broadcast.

In another comparison, however, made between the mean flavor scores for all aldrin-treated, chlordan-treated, and untreated samples from each of the three tests in 1952 (Table I) the mean score for aldrin-treated samples was significantly lower at the 5% level than the mean score for either the chlordan-treated or the control samples. A further comparison of the mean scores from the broadcast application of aldrin and chlordan in sawdust (tests II and III) with those from the broadcast application of these two insecticides in fertilizer (test I) revealed no significant differences.

Mean odor scores reported in Table I were generally higher than those for flavor but followed a similar trend.

The off-flavors observed by the judges were described as: bitter, sweet, musty, medicinal, astringent, benzene hexachloride, nutty, stale, and earthy.

According to the data obtained in 1953 (Table II) mean scores of 3.7 and 2.7 for odor and flavor, respectively, for the heptachlor-treated sample from farm A, however, were significantly lower than mean scores for any of the other treated samples or for the untreated control sample from the Experiment Station. In comparison with scores of 4.1 for odor and 3.3 for flavor for the untreated sample from farm B, which served as the control for farm A, the odor score of 3.7 for heptachlor was significantly lower, although the corresponding flavor score of 2.7 was not. Odor and flavor scores for the untreated sample from farm B, almost every tuber of which showed wireworm injury, were lower than for any of the other samples except heptachlor as reported above, but only the flavor score, 3.3, was significantly lower. Differences among all the other mean scores in Table II were not significant.

The low flavor score for the farm B untreated sample indicated the influence of uncontrolled experimental variables in adversely affecting the scores. The low scores for the heptachlor sample

from farm A indicated either a treatment effect or some uncontrolled variable such as the particular insecticide treatment-soil-location combination. On the other hand, comparable samples (untreated and heptachlor-treated) at the Experiment Station were rated 4.0 or above for both odor and flavor.

Samples from plots receiving aldrin treatment which were significantly off-flavored in one of the 1952 test locations received scores of 4.1 or above in 1953, showing no significant amount of off-odor or off-flavor.

The laboratory staff detected off-odors in the steam emitted from several samples as they were being drained and mashed. Off-odors in single samples from plots treated with 4 pounds per acre of chlordan broadcast, 2 pounds per acre of heptachlor broadcast, 2 pounds per acre of dieldrin broadcast, and 2 pounds per acre of aldrin in row were described as off, pungent and off, musty and off, and pungent, respectively. Off-flavors noted by the palatability panel were described as: musty, bitter, stale, earthy, astringent, sunburned, nutty, and green.

No significant differences were found in the third year (1954) among odor and flavor scores of treated and untreated samples from commercial farm A (Table III, all lots). Mean scores from plots treated with 2 pounds per acre of heptachlor, although the lowest of the three insecticide treatments, were not significantly different from the aldrin or chlordan treatments or from the untreated samples at this location. A single sample from the heptachlor-treated plot was the only one to which descriptive comments such as musty, insecticide, and off were assigned.

The fact that in 1953 the samples from heptachlor-treated plots at this location scored significantly lower than those from other treatments may explain the lower scores obtained for this insecticide in the third year. Local environmental factors and/or the effect of the insecticide itself have apparently influenced results obtained. Scores on samples from the 1954 aldrin-treated plots, like those in 1953, reflected no treatment effects. Since the aldrin applied in 1952 was from a different lot than that used in the other 2 years, it is possible that a lot to lot variance in the formulation of the insecticide itself may have been responsible for flavor alteration in 1952.

Significant differences were not apparent between sound and wireworm-injured potatoes, the mean odor and flavor scores for both groups representing all locations being 4.4. When the means of the sound and wireworm-injured potatoes were compared within each location, the findings were similar.

### Summary

Three years' results were presented on the odor and flavor evaluation of cooked Sebago potatoes grown at the South Carolina Agricultural Experiment Station, Charleston, S. C., and on three commercial farms in soils treated with 4 pounds per acre of chlordan broadcast or in row and 6 pounds per acre broadcast, respectively, 2 pounds per acre of aldrin broadcast or in row, 2 pounds per acre of dieldrin broadcast, and 2 pounds per acre of heptachlor broadcast or in untreated soil. Endrin, 1 pound per acre, was used only in 1953.

**Table II. Mean Odor and Flavor Scores<sup>a</sup> for Cooked Potatoes Grown in Untreated Plots and Plots Treated with Chlordan, Heptachlor, Dieldrin, Aldrin, or Endrin, 1953**

Location of Test and Insecticide Treatment	Dosage, Lb./Acre	Palatability Factor	
		Odor <sup>b</sup>	Flavor <sup>c</sup>
Experiment Station			
Chlordan, broadcast	4	4.5	4.2
Chlordan, in row	4	4.6	4.5
Heptachlor, broadcast	2	4.4	4.4
Dieldrin, broadcast	2	4.5	4.4
Aldrin, broadcast	2	4.3	4.3
Aldrin, in row	2	4.6	4.1
Untreated	0	4.4	4.0
Commercial farm A			
Chlordan, broadcast	6	4.5	4.2
Heptachlor, broadcast	2	3.7 <sup>d</sup>	2.7 <sup>d</sup>
Dieldrin, broadcast	2	4.3	3.8
Endrin, broadcast	1	4.6	4.1
Commercial farm B			
Untreated	0	4.1	3.3 <sup>d</sup>

<sup>a</sup> Means of 5 judges' scores, 2 replications.

<sup>b</sup> Score of 5 represents natural desirable odor; 1, undesirable, very strong off-odor.

<sup>c</sup> Score of 5 represents natural, desirable flavor; 1, very strong off-flavor.

<sup>d</sup> Significantly lower at 5% level.

**Table III. Mean Odor and Flavor Scores<sup>a</sup> for Cooked Potatoes Grown in Untreated Fields and Fields Treated with Aldrin, Heptachlor, or Chlordan, 1954**

Location of Test and Insecticide Treatment	Dosage, Lb./Acre	Palatability Factor	
		Odor <sup>b</sup>	Flavor <sup>c</sup>
Commercial farm A			
Aldrin, broadcast	2	4.4	4.3
Heptachlor, broadcast	2	4.2	4.0
Chlordan, broadcast	6	4.4	4.4
Untreated, sound	0	4.1	4.2
Untreated, wireworm injured	0	4.3	3.8
	Mean	4.2	4.0 <sup>d</sup>
Commercial farm B			
Untreated, sound	0	4.5	4.5
Untreated, wireworm injured	0	4.5	4.5
	Mean	4.5	4.5
Experiment Station			
Untreated, sound	0	4.6	4.6
Untreated, wireworm injured	0	4.5	4.8
	Mean	4.6	4.7
All locations			
Untreated sound	Mean 0	4.4	4.4
Untreated, wireworm injured	Mean 0	4.4	4.4

<sup>a</sup> Means of 5 judges' scores, 2 replications.

<sup>b</sup> Score of 5 represents natural desirable odor; 1, undesirable, very strong off-odor.

<sup>c</sup> Score of 5 represents natural, desirable flavor; 1, very strong off-flavor.

<sup>d</sup> Significantly lower at 5% level than flavor mean scores for other 2 locations.

Wireworm-injured samples were tested only in 1954.

In the 1952 tests, aldrin-treated samples tended to be scored lower than samples from the other three insecticide treatments, but differences were not statistically significant when based on all samples evaluated. When based on differences among mean scores for samples that were directly comparable with respect to location and insecticide treatment, however, the mean score for samples from aldrin-treated soils was significantly lower at the 5% level than the mean score for samples from chlordan-treated or untreated plots. The mean flavor score for samples from application with fertilizer in row with chlordan or aldrin was significantly lower than that from the broadcast application in fertilizer.

Slight or no off-odor and off-flavor were found in 1953 in cooked potatoes which had been grown at the Experiment Station farm in soil treated with chlordan, heptachlor, dieldrin or aldrin or in untreated soil. At commercial farm A, where chlordan, heptachlor, dieldrin, and endrin were used, significant off-odor and off-flavor were noted in the case of a 2-pound dosage of heptachlor, while at commercial farm B, a significant amount of off-flavor was found for the sample grown in untreated soil. The latter sample showed considerable wireworm injury.

In 1954, no apparent detriment to flavor was exhibited from growth of potatoes in soils treated with 2 pounds per acre of aldrin, 2 pounds per acre of heptachlor, or 6 pounds per acre of

chlordan, at commercial farm A. Wireworm injury, though not extensive in the raw samples, did not seem to lessen the flavor quality of the cooked potatoes. Over-all means for flavor and odor in both the untreated injured samples and the untreated sound ones were identical. Location appeared to exert an influence on results obtained on the untreated potatoes; when scores for the sound and injured samples were combined, the flavor mean of potatoes from commercial farm A was significantly lower than those given to the Experiment Station and farm B samples.

In evaluating these results it is necessary to consider the possibility that off-flavored products may result from unknown contamination of the soil, a variation in the composition of the insecticidal material, or from a particular insecticide treatment-soil type-location combination, even though the same insecticide treatment causes no flavor defects under other environmental conditions.

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