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FLAVOR AND BENZENE HEXACHLORIDE CONTENT OF PEANUTS

GROWN IN ROTATION
WITH COTTON,
DUSTED WITH INSECTICIDES
CONTAINING
BENZENE HEXACHLORIDE

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Flavor and Benzene Hexachloride Content of Peanuts Grown in Rotation With Cotton Dusted With Insecticides Containing Benzene Hexachloride

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INTRODUCTION

Studies previously carried out in the United States Department of Agriculture have shown that the direct application of benzene hexachloride (BHC), either as the technical grade or as lindane, to soils in which peanuts are to be grown may result in definitely off-flavored products (7, 11).² On the basis of these findings and in view of the fact that BHC had already been implicated as causing off-flavors in several products, notably potatoes, the Bureau of Entomology and Plant Quarantine has recommended that neither technical BHC nor lindane be applied directly to the soil in which peanuts are to be planted in the season of application or in which they are already growing. However, left unanswered was the further question as to whether soils previously planted with cotton that was dusted or sprayed with BHC might contain sufficient residues of the insecticide to result in off-flavors in peanuts grown in rotation with the cotton. The importance of this question was emphasized in 1947 and 1948 when a number of commercial processors reported the occurrence of undesirable off-flavors in peanut butter and candies made with some lots of peanuts.

To obtain information on the possibility that off-flavors may develop in peanuts that follow BHC-treated cotton, cooperative studies were initiated by the Production and Marketing Administration, the Bureau of Entomology and Plant Quarantine, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Bureau of Human Nutrition and Home Economics of the United States Depart-

¹ The authors are indebted to the Agricultural Marketing Service for financial assistance in obtaining the 1950 peanut and soil samples and to the Entomology Research Branch for their collection; to Fred W. Poos and Lorin C. Fife, Entomology Research Branch, for supplying the 1951 and 1952 peanut and soil samples; and to Robert D. Chisholm and Louis Koblitsky, Entomology Research Branch, for preparing the soil samples for analysis. They are indebted also to Victor R. Boswell and staff, Horticultural Crops Research Branch, for preparing the peanut butter and to the following members of the Human Nutrition Research Branch: Elsie H. Dawson for advice on planning the palatability studies; Eleanor L. Geissenhainer and Ruth A. Redstrom for assistance in carrying out the palatability studies; and Albert B. Parks and Elsie F. Dochterman for statistical designs and analysis of the data.

² Italic figures in parentheses refer to Literature Cited, p. 25.

ment of Agriculture.³ In these studies, carried out over a period of 3 years, palatability evaluations and chemical analyses for BHC were made on peanuts that followed BHC-treated cotton, both on commercial fields and on experimental plots of known history with respect to prior exposure to insecticides. Soil samples, taken from plots and fields in which the peanuts grew, were also chemically assayed for BHC residues.

MATERIALS

1950 SAMPLES

PEANUTS.—Eighty-two samples of peanuts were collected in 1950 by the Bureau of Entomology and Plant Quarantine from fields previously planted to cotton and located in four of the principal cotton-producing areas. The samples included Spanish from Georgia, Runner from Georgia and Alabama, and Virginia Bunch from North Carolina and South Carolina. These are referred to in this publication as “commercial samples.” Samples of the peanuts grown on fields reported as previously used for cotton dusted with a BHC insecticide are designated as “treated,” and those grown on fields not so used as “untreated.” The standard 3-5-40 dust used contained 3 percent of the gamma isomer of BHC (present as approximately 23 percent of 13 percent gamma technical BHC), 5 percent of DDT, and 40 percent of sulfur and was applied directly to the cotton plants. The approximate percentage isomeric composition of the technical BHC was: Gamma, 13; alpha, 65; beta, 10; and delta, 9; with 3 percent of other chlorinated materials. Dustings varied widely as to amount and frequency of application.

In addition to the commercial samples, the Department supplied its own control samples: Spanish from Texas, Runner from Alabama, and Virginia Bunch from Virginia, grown cooperatively by State agricultural experiment stations under standard conditions in soils known to have had no prior application of BHC.

The 82 commercial samples varied in size, method and degree of curing, and amount of weather damage. The distribution by variety was: Spanish, 14; Runner, 38; and Virginia Bunch, 30. About one-fifth (16) were reported as “untreated.” Sixty-four were from fields reported as “treated” in the previous year, 1949; in a few cases the fields had also been treated in 1948 and 1947. One sample was reported as “treated” in 1948 only, and the remaining sample was from peanuts interplanted in 1950 with BHC-treated cotton.

SOILS.—Soil samples were taken from 39 of the fields from which peanut samples were obtained in 1950.

1951 SAMPLES

PEANUTS.—The nature of the samples collected in 1950 was such that flavor of the peanuts tested may have been affected by several

³ Since the research reported in this publication was performed, a reorganization of the Department of Agriculture has changed the affiliations and names of the various cooperators. The units of the former Bureau of Entomology and Plant Quarantine, Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Bureau of Human Nutrition and Home Economics concerned with these studies are now parts of the Entomology Research Branch, the Horticultural Crops Research Branch, and the Human Nutrition Research Branch, respectively, all of the Agricultural Research Service. The part of the former Production and Marketing Administration that cooperated in this work is now part of the Agricultural Marketing Service.

variables that could not be experimentally controlled. For this reason the investigations were continued with collection and examination of samples grown in 1951, which included some lots of peanuts produced with more rigid control of experimental variables. The latter consisted of 9 samples of Virginia Jumbo peanuts grown at the Tidewater Field Station, Holland, Va. Eight were from plots where cotton treated with standard 3-5-40 BHC dust, prepared from 13 percent gamma grade of insecticide, had been grown the previous year, and the ninth was from a plot with a history of no prior exposure to BHC. The peanuts were field cured in stacks in the usual manner. Because the preceding cotton experiments were planned with other objectives than that of providing plot pretreatments for the 1951 peanut studies, applications of insecticide to the cotton in 1950 (3.8 to 5.1 pounds per acre of gamma BHC) were 2 to 3 times the rate of application recommended for practical control of cotton insects.

Samples from 11 fields of commercial peanuts were also collected by the Bureau of Entomology and Plant Quarantine in 1951. Eight were from fields where growers reported that cotton treated with standard 3-5-40 BHC dust had been grown during one or both of the immediately preceding years, and 3 were from fields reported as previously not exposed to the insecticide. These samples, all grown in South Carolina, consisted of 2 lots of Spanish and 9 of Virginia Bunch peanuts.

SOILS.—Soil samples were taken from the 9 plots on the Tidewater Field Station at the time the peanuts were harvested in the fall.

1952 SAMPLES

PEANUTS.—Because the trend in BHC insecticides is toward the use of grades containing higher concentrations of gamma isomer, experiments were set up to obtain information on the flavor and BHC content of peanut butter made from peanuts following cotton on which dust made from a BHC containing 36 percent of the gamma isomer was used. These experiments were started in May 1951 on plots not previously treated with BHC located on two farms near Florence, S. C., and at the Pee Dee Experiment Station. Cotton growing on 13 plots at the experiment station and at the 2 farms nearby (Hill farm and Turner farm) was treated with dust made from 36 percent gamma BHC. Five additional plots were left as untreated controls.

Analyses made by the Pennsylvania Salt Manufacturing Company⁴ and in the laboratories of the Bureau of Entomology and Plant Quarantine, Beltsville, Md., indicated that the gamma BHC content of the dust was approximately 3.0 percent, provided by 8.3 percent of mixed isomers containing 36 percent of gamma BHC. The approximate isomeric composition of the technical BHC was gamma, 36; alpha, 29; delta, 31; and epsilon, 4 percent. The insecticide was applied to the cotton plants at rates providing total gamma BHC dosages ranging from 1.3 to 5.0 pounds per acre.

In the spring of 1952, the plots described above were planted to Virginia Runner peanuts. On April 18 before the peanuts were

⁴ Gamma BHC, 3.08 percent; other BHC isomers, 5.25 percent; diluent, 91.67 percent.

planted, one-half of the Turner farm plot that had been exposed to 16 applications of insecticide was treated with activated carbon at the rate of 200 pounds per acre. The peanuts, harvested in November 1952 were field cured in stacks in the usual manner.

SOILS.—In the spring of 1952 prior to planting of peanuts, soil samples were obtained from 12 of the experimental plots, and at the time of harvesting all plots with the exception of the carbon treated plot, were sampled.

METHODS

PREPARATION OF SAMPLES

SOILS.—The preparation of analytical soil samples involved screening, mixing, and subsampling of the crude soil samples. The samples were prepared by the Moorestown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine.

PEANUT BUTTER.—To insure uniform sampling of the peanuts for palatability testing and for chemical analyses, a portion of each sample was shelled, cleaned, roasted, and processed into peanut butter in a laboratory of the Bureau of Plant Industry, Soils, and Agricultural Engineering. Previous studies on peanut butter prepared in this laboratory had shown that it was not possible with the available equipment, to control the roasting process precisely. These uncontrolled variations in roast, affecting both color and flavor of the peanut butter, increased the difficulty of palatability evaluation. To reduce the effect of this variable, the peanuts used for control samples were roasted to light, medium, and dark shades to permit closer matching with the commercial samples during the palatability tests. All samples reserved for testing were stored at 38° F. until needed for scoring and were allowed to come to room temperature before being served to judges.

PALATABILITY STUDIES

Using different sensory testing procedures, two independent sets of ratings of the 1950 and 1951 samples were made by workers in the Bureau of Human Nutrition and Home Economics (BHNHE) and the Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE). These groups of workers are hereafter referred to as Panel A and Panel B, respectively. The 1952 samples from South Carolina were rated by Panel A only.

RATINGS BY PANEL A

Although all persons serving on Panel A had had some experience in judging foods exposed to BHC, they were given further training before they scored the 1950 samples. As many different brands of peanut butter as could be found on the local market were procured. The panel studied these samples plus additional samples prepared in the BPISAE laboratory, giving special attention to the relation between flavor and dark, medium, or light roasts. As a result of testing numerous samples and discussion of the relative flavor quality of each, panel members agreed on one sample as having the most natural peanut flavor; this was used as an overall reference sample with a score of 5.

In scoring the experimental samples the presence or absence of off-flavor was rated by a panel of 10 judges using 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.

A known reference sample was served at each testing session to provide a uniform basis for scoring. Experimental samples to be scored as "unknown" were matched with the reference as to variety and degree of roast (estimated by color and flavor), in order to limit the effect of these two variables on the comparisons. Three experimental samples selected at random, were scored at each testing session. Samples were scored at 3-minute intervals to reduce fatigue and allow for detection of aftertaste which might affect scoring of subsequent samples. Judges were asked not to smoke or eat for 1 hour after each session and to report any "delayed perception" of off-flavor if such occurred so that any samples with such off-flavor might be retested individually. No definite evidence of delayed effects was observed during these tests. In general, each commercial sample was scored once by the panel. Controls were scored as unknowns as often as feasible, and the panel also rescored a limited number of samples that were scored low the first time they were rated. Scores for samples that were tested at a session in which the control was included as an unknown were analyzed separately.

Prior to the palatability evaluation of the 1951 samples, additional testing and training was given the judges. Available for this purpose was peanut butter that had been prepared earlier from peanuts grown in soil treated with technical BHC at a dosage rate to give 1 pound of gamma isomer per acre. Analysis of this sample showed a technical BHC content of approximately 7 p. p. m.; in preliminary tests even untrained judges rated it as having very strong off-flavors characteristic of BHC. Aliquots of this peanut butter were mixed with a natural flavored peanut butter to provide test samples containing approximately 3.5, 1.8, 0.9, 0.4, and 0.2 p. p. m. of BHC. Portions of these samples were served, 3 at each panel session, to 14 prospective judges in a series of tests providing for decreasing amounts of off-flavor as the threshold test progressed. For this training a 10-point rating scale was used with 10 indicating no off-flavor; 8, barely perceptible off-flavor; 6, perceptible off-flavor; 4, slightly strong off-flavor; and 2, strong off-flavor.

The results of these training tests for prospective judges have been recorded in an earlier publication (12). It will be sufficient to note here that the tests provided for selection, from the 14 prospective judges, of 6 individuals plus 2 alternates to serve on the panel for judging the 1951 and 1952 samples. These selected judges all demonstrated ability to identify the samples of peanut butter containing 1.8 p. p. m. of BHC and generally showed some indication of detection at the 0.9-p. p. m. level. Definite off-flavors were not observed by any of the judges in the samples containing 0.4 and 0.2 p. p. m. of BHC.

Panel tests on the 1951 and 1952 samples were carried out as in 1950, the only difference being that ratings were made on the 10-point scale rather than on the 5-point scale used in 1950.

With the 1951 samples, separate palatability studies were made on the group of commercial samples and those from the Tidewater Experiment Station. For the latter, the design used was a twice-replicated balanced lattice with a randomized distribution of samples for testing by 6 judges on 4 days. The reference sample was pre-

sented each day as a known sample and was included as a coded control at least once in the samples given to each judge. Each judge rated the flavor of 3 samples at each judging session. A variance analysis of the scores was made, mean scores being adjusted for block differences since removal of such differences contributed to the precision of the results.

For the palatability study of the 11 commercial samples and their control collected in 1951, a randomized design based on 3 replications of a 3 x 4 triple rectangular lattice was used. Six judges rated 3 samples per day for 6 days, giving 9 scores per sample.

The experimental designs for the palatability studies on the 1952 samples were selected to provide for analysis of the data by the incomplete block method of Cochran and Cox (4) as well as by the ranked-pair method of Terry, Bradley, and Davis (15). Samples from each field block were evaluated separately because tests indicated heterogeneity among data for blocks from the same location. The design used with the samples from the experiment station provided 4 replications of scores per sample per judge; that used with samples from the Hill farm, 3 replications per sample per judge; and from the Turner farm, 4 replications of each sample in each of 3 scoring sessions.

RATINGS BY PANEL B

Two volunteer tasting panels of 20 persons each from the staff of BPISAE judged 72 samples of peanut butter from the 1950 peanut collections. The samples were rated in groups according to variety and geographic origin. For the rating of each variety, control samples of the same variety and roast were furnished. Each sample was tested by 20 persons, unless otherwise stated. Samples were presented to panel members in pairs, 1 pair in the morning, 1 in the afternoon. Of each pair, 1 sample was a commercial sample and the other was a control, but the identity of neither was known to the testers. Panel members tested the 2 samples at random, with an interval of 15 to 20 minutes between samples to allow for detection of aftertaste.

Panel members were instructed to rate the samples for flavor on a scale of 1 to 10; 10 was described as a perfect score, 5 very strong off-flavor, and 1 inedible.

Separate analyses of variance were performed on the scores for each variety and geographic region of origin according to a paired plot design in order to avoid, insofar as feasible, differences associated with type or region.

In the palatability tests on the 1951 samples each taster was given 3 samples of peanut butter at each test period. One of these samples (labeled "S") was identified to the tasters as having been made from nuts known to have been grown in soil free of any insecticide. Of the 2 samples given as unknowns, 1 was known to be identical to "S" and the other was from peanuts which may or may not have been grown on insecticide-treated soil. These 3 kinds of samples were recorded as the "identified standard," the "unidentified standard," and the "treated sample." Each taster was asked to indicate which of the 2 unknowns was the unidentified standard. He was also asked to rate all 3 samples on the 10-point scale used for rating the 1950 samples.

The scores given the samples were used in an analysis of variance.

DETERMINATION OF BENZENE HEXACHLORIDE CONTENT

The soils and peanut butter samples were analyzed by the Schechter-Hornstein (14) colorimetric method for BHC as modified by Hornstein (9). Briefly, peanut butter samples were extracted with methylene chloride, the methylene chloride was evaporated on a steam bath, and glacial acetic acid was added to the residual peanut oil. Soil samples were extracted directly with acetic acid. The BHC in acetic acid was dechlorinated by the use of zinc and the benzene formed was nitrated to *m*-dinitrobenzene. This latter compound in the presence of methyl ethyl ketone and strong alkali gives a violet red color that can be measured photometrically. This analytical procedure is reliable to as low as 0.1 p. p. m. of BHC when applied to soils, and to about 0.2 p. p. m. when applied to peanuts (9).

RESULTS

PALATABILITY STUDIES

Average flavor scores for the individual samples of peanut butter prepared from the 1950 collections of commercial peanuts and their comparable controls are presented in tables 1, 2, and 3. The results

TABLE 1.—SPANISH PEANUTS, 1950: *Flavor scores and benzene hexachloride content of peanut butter made from peanuts grown in fields with and without history of benzene hexachloride-treated cotton crops*

Total insecticide ¹ applied to cotton (pounds per acre)	BHC isomers per acre		State in which peanuts were grown	Peanut butter, medium roast		
	Total	Gamma		Mean flavor score		BHC content
				Panel A ²	Panel B ³	
	<i>Pounds</i>	<i>Pounds</i>				<i>P. p. m.</i>
210-----	48	6. 3	Georgia--	4. 0	7. 79	0. 09
110-----	25	3. 3	--do----	4. 4	7. 12*	. 13
96-----	22	2. 9	--do----	4. 9	7. 14*	. 11
85-----	20	2. 6	--do----	4. 4	8. 10	. 06
72-----	17	2. 2	--do----	4. 6	8. 35	. 00
60-----	14	1. 8	--do----	4. 6	7. 95	. 10
60-----	14	1. 8	--do----	4. 5	9. 00	. 08
60-----	14	1. 8	--do----	4. 0	⁴ 9. 15*	0
60-----	14	1. 8	--do----	4. 4	8. 55	0
48-----	11	1. 4	--do----	4. 0	9. 15	. 08
48-----	11	1. 4	--do----	4. 0	8. 30	. 06
45-----	10	1. 3	--do----	4. 8	7. 40	. 03
40-----	9	1. 2	--do----	4. 2	7. 75	. 10
0-----		0	--do----	4. 0	8. 20	-----
Control-----	-----	0	Texas----	4. 7	-----	-----

¹ 3-5-40 dust applied in 1949.

² Each sample rated by 10 persons on a 5-point scale: 5, no off-flavor; 1, very strong off-flavor.

³ Each sample rated by 20 persons on a 10-point scale: 10, no off-flavor; 5, very strong off-flavor; 1, inedible.

⁴ This treated sample superior to control.

*Score significantly (P=.05) different from control.

provide no definite evidence that observed off-flavors can be attributed to the production of peanuts in rotation with BHC-treated cotton. Among the 65 treated commercial samples that followed BHC-treated cotton, Panel A scored only 4 significantly lower on flavor than their comparable controls; while 3 were scored higher. Separate analyses were made of scores from sessions in which the control was included as an unknown; for this reason differences between sample and control scores for some sample means within such groups were found to be statistically significant whereas comparable or even greater differences were not significant in the overall analysis. In the overall analysis, no untreated sample was scored significantly lower than its control and no significant correlations between palatability scores and reported insecticide applications were observed.

One of the lowest scoring samples (table 2) was interplanted in 1950 with BHC-treated cotton and was therefore exposed to direct contact with the insecticide. The BHC content of this sample, 0.49 p. p. m., was almost four times as high as that of any of the other 1950 commercial samples.

Trends in the results of the scoring by Panel B (tables 1, 2, 3) provide a picture generally comparable to that of Panel A. Of the treated commercial samples, 5 were scored significantly lower and 2 higher than their controls. Two untreated samples were also scored significantly low but off-flavor in one of these was attributed to improper curing (table 3). Two of the 3 samples that followed cotton receiving the heaviest reported insecticide treatments (table 1) were scored significantly low and these were among the 15 samples showing a BHC content of 0.10 to 0.13 p. p. m.

Among the samples that were scored low on flavor, the 2 panels agreed on only 1 (table 3). This was also one of the samples having a relatively high BHC content (0.14 p. p. m.). Aside from the above noted samples, however, there was no apparent correlation between flavor scores and chemically determined BHC content of the 1950 samples.

A general picture of the results is provided by the scatter diagrams, figures 1 and 2. These figures show the differences between panel scores for the commercial samples and those for their comparable variety controls. The distribution of score differences by Panel A (fig. 1) shows no apparent correlation between reported BHC dosages and panel scores. The number of scores for the treated commercial samples that fall above and below scores for the comparable control samples is approximately equal. A similar distribution of score differences is shown for the untreated commercial samples. The same general pattern is presented by Panel B scores (fig. 2).

The only valid conclusion that may be derived from these data is that of the commercial samples the general average scores of both the "treated" and the "untreated" samples did not differ significantly from the average scores of the untreated controls from experiment station plots. The few observed instances of significant differences between single samples and their appropriate experiment station controls were not definitely correlated with dosage of BHC. In connection with the commercial samples it should be emphasized that: The information on insecticide treatments used for cotton crops was based on recollection of growers as to times, frequency, and quantities of application, rather than on written records; methods of

curing and handling were not standardized; and "treated," "untreated," and control samples were usually from different farms where soil and other conditions may have had variable effect on peanut quality. Because of these several uncontrolled variables, inconclusive results were considered possible when the tests were initiated. This risk was assumed because the importance of obtaining an early answer

FIGURE 1.—Panel A: Differences in scores for off-flavor for peanut butter prepared from commercial and from experiment station control peanuts.

FIGURE 2.—Panel B: Differences in scores for off-flavor for peanut butter prepared from commercial and from experiment station control peanuts.

TABLE 2.—*RUNNER PEANUTS, 1950: Flavor scores and benzene hexachloride content of peanut butter made from peanuts grown in fields with and without history of benzene hexachloride-treated cotton crops*

BHC isomers per acre			State in which peanuts were grown	Type of roast	Mean flavor score		BHC content
Total	Gamma	Panel A ²			Panel B ³		
<i>Pounds</i>	<i>Pounds</i>						
75 ⁴	17	2.2	Georgia	Medium	3.7*	-----	<i>P. p. m.</i> 0.49
80	18	2.4	Alabama	do	4.9	8.10	.09
75	17	2.2	Georgia	do	4.9	9.10	0
72	17	2.2	do	do	⁵ 4.8*	8.50	.08
72	17	2.2	do	do	4.6	9.20	.04
72	17	2.2	do	do	4.5	8.65	.05
72	17	2.2	do	do	4.6	9.05	.06
72	17	2.2	do	do	⁶ 3.8*	8.05	.12
72	17	2.2	do	do	4.9	8.50	0
65	15	2.0	Alabama	do	4.4	7.65*	.11
60	14	1.8	do	do	4.8	⁵ 9.05*	.09
60	14	1.8	Georgia	do	4.6	9.00	.09
60	14	1.8	do	do	4.6	8.80	.09
60	14	1.8	do	do	4.1	8.40	.10
60	14	1.8	do	do	4.4	8.20	.13
50	13	1.5	do	do	4.8	7.75	.07
50	13	1.5	Alabama	do	4.8	8.70	.05
50	13	1.5	do	do	⁵ 4.8*	8.50	.07
48	11	1.4	Georgia	do	4.2	8.25	0
38	9	1.1	do	do	3.9	8.60	.10
38	9	1.1	do	do	4.4	8.05	.12
36	8	1.1	do	do	4.0	7.25	.06
36	8	1.1	do	do	4.8	8.20	.09
22	5	.7	Alabama	do	4.6	8.75	.09
10	2	.3	Georgia	do	4.2	8.55	0

0	0	0	do	do	4.7	8.50	
0	0	0	do	do	4.6	7.85	
0	0	0	do	do	4.4		
0	0	0	do	do	4.1		
Control	0	0	Alabama	do	4.4		
71	16	2.1	Georgia	Dark	4.6	8.30	.09
60	14	1.8	do	do	4.6	8.15	0
60	14	1.8	do	do	4.6		.13
(8)			do	do	4.0	8.55	.03
0	0	0	do	do	4.7	8.00	
0	0	0	do	do	4.7	8.05	
0	0	0	do	do	4.5	8.70	
0	0	0	do	do	4.4	8.80	
0	0	0	do	do	4.3		
Control	0	0	Alabama	do	4.6		

¹ 3-5-40 dust applied in 1949.

² Each sample rated by 10 judges on a 5-point scale: 5, no off-flavor; 1, very strong off-flavor.

³ Each sample rated by 20 persons on a 10-point scale: 10, no off-flavor; 5, very strong off-flavor; 1, inedible.

⁴ Peanuts interplanted in cotton that was dusted.

⁵ This sample superior to the control.

⁶ Average of 20 judgments.

⁷ Average of 100 judgments.

⁸ Application not recorded.

*Score significantly ($P = .05$) different from control.

TABLE 3.—VIRGINIA BUNCH PEANUTS, 1950: Flavor scores and benzene hexachloride content of peanut butter made from peanuts grown in fields with and without history of benzene hexachloride-treated cotton crops, and benzene hexachloride content of soil samples

Total insecticide ¹ ap- plied to cotton (pounds per acre)	BHC isomers per acre		State in which peanuts were grown	Peanut butter			BHC content of soil in which peanuts were grown
	Total	Gamma		Type of roast	Mean flavor score		
					Panel A ²	Panel B ³	
70	Pounds 16	Pounds 2.1	South Carolina	Light	4 3.2*	6.20*	P. p. m. 0
70	16	2.1	do	do	4 4.0		.09
40	8	1.2	do	do	3.9	8.20	0
30	7	0.9	do	do	4.2	7.30	.06
Control	0	0	Virginia	do	4 4.4		.10
80	18	2.4	South Carolina	Medium	3.8	7.20*	.07
60	14	1.8	do	do	4.6	8.30	.04
50 ⁵	13	1.5	do	do	6 4.7*	8.30	.08
50	13	1.5	do	do	3.8		0
40 ⁵	9	1.2	do	do	4 4.3		.06
40	9	1.2	do	do	3.9		.07
30 ⁵	7	.9	North Carolina	do	4.6	7.95	.11
30	7	.9	South Carolina	do	4.2	7.85	.08
12	3	.4	do	do	4.2	8.15	0
0	0	0	do	do	4 4.2		.05
Control	0	0	Virginia	do	3.7		
70 ⁵	16	2.1	North Carolina	Dark	4.2	7.00*	.08
70	16	2.1	do	do	4.4	8.05	.01
60	14	1.8	South Carolina	do	4.6		.06
50	13	1.5	do	do	4.8	8.45	.09
50 ⁷	13	1.5	do	do	8 4.0*	7.90	.04
40	9	1.2	do	do	4.2	8.00	0
40	9	1.2	do	do	4.3	7.65	.10
40	9	1.2	do	do	4.2	8.15	0

30 ⁵	-----	7	.9	-----do-----	-----do-----	8 3.7*	8.05	.04	.08
30	-----	7	.9	-----do-----	-----do-----	4.1	8.50	.11	.04
12 ⁵	-----	3	.4	North Carolina	-----do-----	4.4	7.95	.08	.06
0	-----	0	0	South Carolina	-----do-----	4.6	8.20	-----	-----
0	-----	0	0	-----do-----	-----do-----	4.4	7.65	-----	-----
0	-----	0	0	-----do-----	-----do-----	4.4	7.60	-----	-----
0	-----	0	0	-----do-----	-----do-----	4.0	⁹ 6.75*	-----	-----
0	-----	0	0	North Carolina	-----do-----	4.0	7.55*	-----	-----
Control	-----	0	0	Virginia	-----do-----	8 4.8	-----	-----	-----

1 3-5-40 dust applied in 1949.
2 Each sample rated by 10 judges on a 5-point scale; 5, no off-flavor; 1, very strong off-flavor.
3 Each sample rated by 20 persons on a 10-point scale; 10, no off-flavor; 5, very strong off-flavor; 1, inedible.
4 Average of 20 judgments.
5 Approximately equal applications of dust to cotton in 1947.
6 This sample superior to the control.
7 Applied in 1948.
8 Average of 30 judgments.
9 Sample spoiled by improper curing.
*Score significantly (P=.05) different from control.

to this problem seemed to make acceptance of that chance preferable to postponement for the minimum period of 2 years required to set up controlled cotton-peanut rotation experiments.

Flavor scores for the 1951 commercial samples from South Carolina are presented in table 4. Panel A scored all and Panel B scored 4 of the treated samples significantly lower than the control. Both panels scored 2 of the 3 untreated samples significantly low. In view of these low scores for 2 of the 3 untreated samples the results provide little basis for attributing the low scores given the treated commercial samples to growth of the peanuts in rotation with BHC-treated cotton. It may be noted also that the control sample was an exceptionally well-flavored peanut butter and was scored high by both panels.

TABLE 4.—SOUTH CAROLINA, 1951: *Flavor scores and benzene hexachloride content of peanut butter from commercial samples of peanuts that followed benzene hexachloride-treated cotton*

VIRGINIA BUNCH

Total insecticide ¹ applied to cotton (pounds per acre)	BHC isomers per acre		Peanut butter		
			Mean flavor score		BHC content
	Total	Gamma	Panel A	Panel B	
	<i>Pounds</i>	<i>Pounds</i>			<i>P. p. m.</i>
110-----	25	3. 3	6. 8	² 6. 3	0. 12
80-----	18	2. 4	2. 8*	² 6. 2	. 27
80-----	18	2. 4	5. 6	² 6. 1	. 03
72 ³ -----	17	2. 2	8. 0	7. 7	. 20
60 ³ -----	14	1. 8	7. 5	6. 6	. 14
60-----	14	1. 8	5. 8	6. 9	. 23
60-----	14	1. 8	7. 1	6. 9	. 20
0-----	0	0	7. 1	² 6. 4	0
0-----	0	0	⁴ 8. 2	6. 8	0

SPANISH

70 ⁵ -----	16	2. 1	7. 3	² 6. 3	0. 20
0-----	0	0	5. 5	⁶ 5. 7	0

VIRGINIA JUMBO

Control-----	-----	-----	10. 0	7. 6	0
--------------	-------	-------	-------	------	---

¹ 3-5-40 dust applied in 1950.

² Score significantly lower ($P=.05$) than control.

³ Cotton on these plots also treated with 40 pounds per acre of dust in 1949.

⁴ Only sample not scored significantly lower ($P=.05$) than control by Panel A.

⁵ Cotton on this plot also treated with 70 pounds per acre of dust in 1949.

⁶ Score significantly lower ($P=.01$) than control.

*Score significantly lower ($P=.05$) than other commercial samples.

With one exception, there were no significant differences among scores given by Panel A to the different commercial samples. The score of 2.8 for one sample of peanut butter from Virginia Bunch peanuts that followed cotton treated in 1950 with 80 pounds per acre of BHC dust was significantly lower than scores for all other commercial samples. There were more instances where judges reported off-flavors described as characteristic of contamination by BHC in this sample than in any of the other samples. However, various comments, such as "sour," or "very objectionable off-flavors," suggest that factors in growing or curing other than BHC contamination may have been responsible for the extremely unpalatable flavor of the sample.

Palatability scores on the 1951 experiment station samples from Holland, Va., are presented in table 5. Panel A rated 2 of the samples from peanuts that followed cotton receiving 3.8 pounds of gamma BHC per acre, and all of those from peanuts that followed cotton treated with 5.1 pounds per acre, as significantly off-flavored in comparison with the control. While there is some overlapping of scores between treatments, the general mean scores of 8.1 and 7.1 for the samples following the low- and high-BHC cotton treatments, respectively, are both significantly lower than the score of 9.8 given the control sample, and also differ significantly from each other. The results indicate that in this instance definite off-flavors in peanut butter resulted from the growing of peanuts in soil on which BHC-treated cotton was grown the preceding year.

It will be seen also that among the 1951 experiment station samples from Holland, Va., correlation of BHC content with cotton treatment is generally comparable with that shown by panel scores (table 5). Panel scores did not correlate perfectly, however, with the chemically determined BHC levels. The fact that the control sample was generally scored 10, with a panel average of 9.8 out of a possible maximum of 10, adds confidence to an assumption of real detection of off-flavors in the samples from peanuts that followed BHC-treated cotton. This assumption finds further support in judges' descriptions of observed off-flavors. Among the 32 judgments on the samples from peanuts that followed cotton given the 3.8-pounds-per-acre treatment, there were 11 notations (35 percent of judgments) of off-flavors typical of BHC. Among the samples from peanuts that followed the more heavily treated cotton (5.1 pounds per acre), 18, or 56 percent, of the scores were accompanied by such descriptions. No typical BHC flavors were ascribed to the control samples.

Panel B scores (table 5) show the same general tendency as those by Panel A, though agreement on low-scoring samples was not perfect.

Mean flavor scores for the 1952 samples from South Carolina, which followed cotton treated with BHC containing 36 percent of gamma, are given in table 6 and those that are significantly low are designated. The ranked-pair analyses (p. 6) are not presented, but significant findings were the same for both this method and the analysis of variance. Results of the ranked-pair analyses also indicated that the judges were scoring consistently with each other.

Only 1 of the 4 treated lots from the Pee Dee Experiment Station was significantly inferior to its control. The sample in plot B from a field receiving 2 pounds of the gamma isomer of BHC per acre was scored significantly lower than the samples from the untreated field

TABLE 5.—TIDEWATER FIELD STATION, HOLLAND, VA., 1951: Flavor scores and benzene hexachloride content of peanut butter from peanuts that followed benzene hexachloride-treated cotton

Total insecticide ¹ applied to cotton (pounds per acre)	BHC isomers per acre		Number of appli- cations	Flavor score of peanut butter				BHC content	
	Total	Gamma		Panel A		Panel B		Peanut butter	Soils
				Sample mean	Treat- ment mean	Sample mean	Treat- ment mean		
127-----	Pounds 29	Pounds 3.8	7	<div> <div>6.6*</div> <div>9.2</div> <div>9.4</div> <div>7.2*</div> </div>	<div>8.1*</div>	<div>6.7</div> <div>6.3*</div> <div>7.1</div> <div>6.9</div>	<div>6.75</div>	<div>P. p. m.</div> <div>0.20</div> <div>.40</div> <div>.61</div> <div>.56</div> <div>.72</div> <div>.64</div> <div>1.39</div> <div>.82</div>	0
171-----	39	5.1	10	<div>7.1*</div> <div>6.1*</div> <div>7.4*</div> <div>7.7*</div>	<div>7.1*</div>	<div>7.1</div> <div>5.7**</div> <div>6.0**</div> <div>6.3*</div>	<div>6.28*</div>	<div>P. p. m.</div> <div>0.20</div> <div>.40</div> <div>.61</div> <div>.56</div> <div>.72</div> <div>.64</div> <div>1.39</div> <div>.82</div>	0
0-----	0	0	0	-----	9.8	-----	7.6	0	0

¹ 3-5-40 dust applied in 1950.*Score significantly lower ($P=.05$) than control.**Score significantly lower ($P=.01$) than control.

TABLE 6.—SOUTH CAROLINA, 1952: Flavor of peanut butter made from peanuts grown in soils previously used for cotton dusted with benzene hexachloride

Total insecticide ¹ applied to cotton (pounds per acre)	BHC isomers per acre		Number of appli- cations	Mean flavor score ²				Turner farm	General mean
	Total	Gamma		Pee Dee Experiment Station		Hill farm			
				Plot A	Plot B	Plot A	Plot B		
0	Pounds 0	Pounds 0	0	9.2	9.6	9.9	9.1	8.5	9.3
42	3.5	1.3	4					8.8	8.8
49	4.1	1.5	4			7.7*	9.4		
68	5.6	2.0	6	8.6	6.2*				
84	7.0	2.5	8					8.9	7.4
88	7.3	2.6	8			9.4	7.3*		8.9
132	11.0	4.0	12	9.4	9.6				8.4
143	11.9	4.3	12			9.5	7.2*		9.5
168	14.0	5.0	16					8.9	8.3
168 ³	14.0	5.0	16					8.5	8.9
									8.5

¹ 3 percent gamma benzene hexachloride dust applied in 1951.

² A score of 10 indicates no off-flavor; 8, barely perceptible off-flavor; 6, perceptible off-flavor; 4, slightly strong off-flavor; and 2, strong off-flavor.

³ Activated carbon applied at rate of 200 pounds per acre before planting peanuts.

*Significantly lower, at 5-percent level, than other means in same column.

and from a field receiving 4 pounds of the gamma isomer. Since the comparable sample from plot A receiving 2 pounds per acre of gamma isomer was not significantly different from the other samples with which it was compared, it seems probable that the off-flavor found in the sample from plot B was due to factors other than the BHC treatment. The roast of this sample was probably one factor, since the most frequent comment of the judges in describing its flavor was that it was green or raw. This sample was a lighter roast than either of the other samples with which it was compared, a fact that makes flavor analysis of peanut butter very difficult and probably accounts, at least in part, for the low score of 6.2.

Among the Hill farm samples the flavor scores, even when significantly low, indicate only slight off-flavor and show no correlation with the dosage of insecticide to which soil was exposed or consistency among samples from replicate plots. In connection with such apparent inconsistencies, the possibility needs to be considered that soil residues of BHC, following a specific treatment of cotton with this insecticide, and the effect of such residues on the flavor of a following crop of peanuts may vary with such factors as soil type, rainfall, or other environmental conditions. In the samples from the Turner farm only barely perceptible off-flavors were noted; there were no significant differences among these flavor scores. The sample from the plot treated with activated carbon did not differ significantly from the others. The general means of all flavor scores for each treatment also show no correlation with the quantities of insecticide to which soils were exposed.

BENZENE HEXACHLORIDE CONTENT

PEANUTS.—The analytically determined BHC content of some of the peanut butter samples has been noted in connection with the preceding discussion of palatability evaluations. With the exception of the sample that was interplanted with cotton and showed 0.49 p. p. m. of BHC, the highest BHC content observed in the 1950 samples was 0.14 p. p. m. and only 15 samples showed 0.10 p. p. m. or more of the insecticide (tables 1, 2, 3). With the noted exception, all of the determined concentrations were below the 0.2-p. p. m. limit of reliability of the analytical method when applied to peanuts. Within the limits of the method, therefore, no significant amounts of BHC were found in the 1950 peanut samples that followed BHC-treated cotton and the data evidence no relationship between insecticide residues in the peanuts and amounts of BHC applied on cotton that preceded them.

The BHC content of the 1951 commercial samples (table 4) averaged somewhat higher than in the 1950 samples. Of 8 samples that followed BHC-treated cotton, only 1 contained less than 0.10 p. p. m. of BHC while 5 showed from 0.20 to 0.27 p. p. m. In the 1951 experiment station samples from Holland, Va., however, BHC was found in all 8 of the samples of peanuts that followed cotton treated with BHC containing 13 percent of gamma (table 5). The quantities found correlated generally with the cotton treatments and approached 1 p. p. m. in 3 of the 4 samples that followed cotton treated with insecticide dosages providing 5.1 pounds of the gamma isomer per acre.

Among the 1952 peanut samples, which followed cotton treated with BHC containing 36 percent of gamma at application rates providing 1.3 to 5.0 pounds of gamma per acre, all determined BHC contents were under 0.2 p. p. m. (table 7). Within the limits of the analytical method, therefore, none of these samples contained significant amounts of BHC.

SOILS.—The highest observed BHC content of the soil samples examined in 1950 was 0.13 p. p. m. (table 3). In other samples analyzed, observed BHC contents of 0.10 p. p. m. or less were within the estimated limits of reliability of the analytical method when applied to soils. As with the peanuts, the BHC content of the soils showed no regular correlation with reported applications of insecticide to cotton crops grown in the soils tested.

Among all soil samples tested, highest concentrations of BHC were found in the 1951 samples from the Tidewater Field Station, Holland, Va. (table 5). Concentrations of BHC, ranging from 0.48 to 0.65 p. p. m. in the soils treated with 3.8 pounds of gamma per acre and from 0.64 to 1.39 p. p. m. following the 5.1 pound applications were all well above the 0.1 p. p. m. limit of reliability of the analytical method when applied to soils and were generally correlated with the amounts of insecticide applied. These, as well as the 1950 samples, were all from soils used for cotton treated with BHC containing 13 percent of gamma. It was observed that the BHC content of the soils tended to be higher than that of the peanuts grown in the soils.

All but one of the concentrations of BHC in the 1952 soil samples, where cotton treated with BHC containing 36 percent gamma had been grown, were at or below the 0.2 p. p. m. level of reliability of the analytical method (table 7). In this one case (Turner farm, eight applications, fall sampling) the amount found, 0.12 p. p. m., was of borderline significance, particularly since a sample collected from this plot in the spring showed only 0.05 p. p. m. of BHC.

Averages of the BHC content of the peanut and soil samples from treated fields are shown below:

Material sampled:

	<i>P. p. m.</i>
1950:	
Peanuts, commercial.....	0.07
Soils, commercial fields.....	.04
1951:	
Peanuts, commercial.....	.16
Peanuts, Holland samples.....	{ 1.33
	{ 2.71
Soils, Holland samples.....	{ 1.58
	{ 2.91
1952:	
Peanuts, South Carolina samples.....	.06
Soils, South Carolina, spring.....	.04
Soils, South Carolina, fall.....	.05

¹ Cotton treated with 127 pounds of 3-5-40 dust; 3.8 pounds of gamma BHC per acre.

² Cotton treated with 171 pounds of 3-5-40 dust; 5.1 pounds of gamma BHC per acre.

TABLE 7.—SOUTH CAROLINA, 1952: Benzene hexachloride content of soils used for growing cotton that was dusted with this insecticide and of peanuts grown subsequently in the same soils

PEE DEE EXPERIMENT STATION

Total insecticide ¹ applied to cotton (pounds per acre)	BHC isomers per acre		Number of appli- cations	Benzene hexachloride found in—							
	Total			Soil		Peanut butter					
				Spring		Fall		Plot A		Plot B	
				Plot A	Plot B	Plot A	Plot B	Plot A	Plot B		
68-----	Pounds	Pounds	6	P. p. m.	P. p. m.	P. p. m.	P. p. m.	P. p. m.	P. p. m.		
132-----	5.6	2.0	12	-----	-----	0.04	0.02	0.01	0.08		
	11.0	4.0		-----	-----	.02	.03	.09	.07		

HILL FARM

49-----	4.1	1.5	4	0	0.03	0	0.05	.07	0
88-----	7.3	2.6	8	.10	0	0	.02	.00	0
143-----	11.9	4.3	12	.08	.01	.09	.10	.15	.15

TURNER FARM

42-----	3.5	1.3	4	0	-----	0	-----	0	-----
84-----	7.0	2.5	8	.05	-----	.12	-----	.10	-----
168-----	14.0	5.0	16	.10	-----	.10	-----	.00	-----
168-----	14.0	5.0	² 16	-----	-----	-----	-----	-----	-----

¹ BHC dust containing 3 percent of gamma applied in 1951.

² Activated carbon applied at rate of 200 pounds per acre prior to peanut planting.

DISCUSSION

It is recognized that such factors as soil type, climatic conditions during the growing and curing of peanuts, and methods and duration of curing may affect the flavor of peanuts. However, it was either impossible or not feasible to control these variables in relation to the peanut samples collected from commercial growers' fields in 1950 and 1951. It is possible, therefore, that the effects of such variables on peanut quality may have obscured effects of soil residues of BHC on the flavor of these peanuts. In this connection, however, it may be noted that the BHC content of peanuts determined chemically generally paralleled the results of the palatability tests. Among those samples of peanuts collected in 1950 and 1951 from commercial fields and analyzed chemically, the BHC content was low and with few exceptions, for the most part in the 1951 samples, was less than the 0.2-p. p. m. level of reliability of the analytical method when applied to peanuts. Low or nonsignificant concentrations of BHC in peanuts were generally paralleled by similarly low or nonsignificant concentrations of the insecticide in soils. In these studies, therefore, ordinary application to cotton of BHC as 3-5-40 dust did not result in significant accumulations of BHC in soils on which the cotton was grown or in peanuts which followed the cotton, nor was flavor of the peanuts correlated with prior exposure to BHC of the soils in which they were grown.

In contrast to the above findings, peanuts grown in 1951 at Holland, Va., in soils used the previous year for cotton that was treated with heavy dosages of BHC, did develop flavors characteristic of the insecticide and also accumulated determinable quantities of BHC. BHC was also recovered from soil samples from the treated plots in quantities ranging from 0.48 to 1.39 p. p. m. These results were obtained when peanuts followed cotton on experimental plots that received 3.8 to 5.1 pounds of gamma per acre derived from technical BHC containing 13 percent of gamma. Such treatments are 2 to 3 times the recommended rate of application. In practice, however, application rates may vary considerably and in instances of excessive use or of unusual difficulty in obtaining pest control, farmers may apply quantities of technical BHC dust to cotton in a single season that provide 4 to 5 pounds of gamma per acre, or even more. Thus, while the experimental dosages that were applied in 1950 on the Holland, Va., cotton plots were much higher than recommended, such dosages may occur in practice. Also, as Boswell (2) has noted, this insecticide does show some tendency to persist and to accumulate in soils following exposure to repeated or heavy dosages. It is possible, therefore, that under some conditions normal applications of BHC insecticides to cotton for 2 or more years could provide for sufficient accumulation of the insecticide in soils to adversely affect the flavor of peanuts or other food plants produced later in these soils.

While the 1950 and 1951 studies point to the dosage of insecticide used on cotton as the major factor in determining accumulation and carryover in soil of sufficient quantities of BHC to result in off-flavors and chemically determinable quantities of the insecticide in peanuts that followed the cotton, they also suggest that other factors may have been involved. One of the samples (table 1) collected from a commercial field in 1950 followed cotton reportedly treated with

210 pounds per acre of 3-5-40 dust (6.3 pounds of gamma BHC). Neither of the panels rated this sample as significantly off-flavored and its chemically determined BHC content of 0.09 p. p. m. is well below the estimated limit of reliability of the assay method. Two additional commercial samples (tables 1, 4) followed cotton treated with 110 pounds per acre of dust to provide applications of BHC (3.3 pounds of gamma per acre) approaching the 3.8 pounds of gamma used on one-half of the Holland plots in 1951. The chemically determined BHC contents of these samples were at or below the level of reliability of the analytical method and results of the palatability tests were irregular and hence of questionable significance. In this connection, Fleming and Maines (6) studying DDT in soils noted that its persistence is modified by many factors other than method of application such as organic content and texture of soil, cultural practices, and environmental conditions. They found DDT to be most persistent in sand, least in muck, comparable in different types of loam; in general decreased persistence correlated with increasing soil organic matter. Earlier studies by Chulski (3) indicated a similar relationship between soil type and persistence of BHC.

It is possible that some of the variant findings of the studies reported here may be attributable to such differences in character of soil in which the peanuts were produced. Insofar as data are available, however, all peanuts tested in this study were grown in soils that would be classified as sandy loams with the exception of the 1951 samples from Holland, Va. The latter were grown in soils classified as Woodstown fine loamy sand. If, as reported for DDT by Fleming and Maines (6), BHC is also most persistent in sands, then the finding of significant quantities of BHC and associated off-flavors in the Holland samples may be due in part to this factor. It also seems possible, though the authors are not aware of confirming evidence, that BHC in soils might be reduced more rapidly than under normal conditions during seasons of heavy rainfall. Climatological records, however, do not indicate any wide deviations from normal rainfall over the areas involved during the years 1949 through 1951.

A significant observation in the studies on the 1952 samples from South Carolina was that peanuts which followed cotton treated with BHC dust at rates providing up to 5 pounds of gamma per acre were not characterized by significant off-flavors nor did they contain significant quantities of the insecticide. Because of the high gamma content (36 percent) of the BHC used in these tests the heaviest dosage of 5 pounds of gamma isomer per acre deposited only 14 pounds per acre of total isomers in the South Carolina tests. This compared with a total deposit of 39 pounds per acre to provide the same dosage of gamma from BHC containing 13 percent of gamma in the Holland tests, in which significant quantities of BHC were found in samples of both soils and peanuts and the latter were characterized by off-flavors typical of BHC. It is pertinent to note here that studies with other products have shown that the alpha, beta, and delta isomers of technical BHC may also contribute to off-flavor development, and have indicated that effects of the different isomers on flavor may vary with the product treated (5).

Comparison of the results of the Holland and South Carolina tests indicates the flavor-tainting potentialities for peanuts of those isomers, other than the insecticidal gamma isomer, of technical grades of

BHC and emphasize the value of using high gamma content preparations on soils that may be subsequently used for this crop. In view of the numerous root crops which have been found to develop off-flavors when grown in soils contaminated with BHC, this consideration assumes added significance when such crops may be rotated with those that can be safely treated with BHC. As observed by Jameson and Peacock (10), for example, potatoes grown in soils treated with 1 to 4 pounds of BHC per acre developed characteristic off-flavors up to 3 years later. The time required for soil residues to be reduced below the level causing off-flavor correlated with the quantity of BHC applied. BHC of high gamma content is now available at reasonable prices. Its use on soils that are likely to be used subsequently for crops that are subject to off-flavor development through contact with soils containing residues of this insecticide would appear to be economically feasible as well as advisable from the point of view of product quality. At current prices, for example, the difference in cost between sufficient quantities of the 13- and 36-percent gamma grades of BHC to provide 3 pounds per acre of gamma would be only 30 cents per acre.

Also favoring use of the high gamma grade of BHC is its lower content of the beta isomer (pp. 2, 3).

With respect to chronic toxicity, striking differences in fat storage and in elimination of the several isomers of BHC have been reported. While the gamma and delta isomers are deposited in body fat at the same concentration and the alpha isomer at twice the dietary concentration, the beta isomer is deposited at 10 times the dietary concentration. The alpha, gamma, and delta isomers are rapidly mobilized and eliminated in 2 to 4 weeks whereas the beta compound requires an estimated 3 to 6 months for complete removal from the body following cessation of exposure to the insecticide (1).

In evaluating the results of the Holland, Va., and the South Carolina studies it is necessary to note that the experiments were not directly comparable even if the assumption is made that such factors as soil type and climatic conditions were without significant effect. In the South Carolina tests the insecticide formulation contained neither sulfur nor DDT, both of which were constituents of the 3-5-40 dust used in the Holland, Va., tests. Currently, however, there is no evidence to indicate that either sulfur or DDT, in the quantities used, affects the flavor of peanuts, but it may be necessary to consider the possibility that one or both of these materials may potentiate the development of off-flavors by concurrently present soil residues of BHC. In this connection it may also be pertinent to note that other insecticides tested up to this time on peanuts have not significantly affected their flavor (7, 8).

Some of the findings of this study emphasize one of the questions that have occurred frequently in this work: Is the off-flavor, observed in peanuts grown in BHC-contaminated soils due to BHC per se, to decomposition products of BHC, or possibly even to changes in the food product itself caused by physiological response of the plant to the chemical? Musty odors associated with BHC have been attributed to overchlorinated materials such as heptachlorocyclohexanes and octochlorocyclohexanes (16) and to polychlorocyclohexenes derived by the removal of chlorine from the polychlorocyclohexanes (13). As noted earlier in describing the results of the peanut butter dilution

tests (p. 5), the off-flavor in the peanut butter made from peanuts grown in BHC-treated soil and shown by chemical analysis to contain approximately 7 p. p. m. of BHC was regularly described as characteristic of BHC. If the dilution test did provide a true measure of taste threshold to BHC flavor in peanut butter of approximately 0.9 p. p. m. for Panel A, then the lower quantities determinable chemically (table 5) would lead to the conclusion that the chemical determination of BHC is much more sensitive, at least for this product, and could therefore replace palatability tests. Here we see, however, that three of the samples from peanuts that followed BHC-treated cotton and were scored significantly lower than the control showed chemically determined BHC levels of 0.20, 0.45, and 0.50 p. p. m., considerably lower than the estimated 0.9 p. p. m. associated with the indicated panel threshold level. These panel scores may, therefore, be evidence that the off-flavor is not entirely due to BHC per se.

Some limited experiments carried out in these laboratories with BHC added to peanut butter show that flavor of the insecticide can be influenced by the carrier in which it is incorporated. A solution containing 300 p. p. m. of BHC in refined peanut oil was incorporated in a sample of peanut butter to provide for a BHC concentration of 10 p. p. m. An equal quantity of BHC-free peanut oil was incorporated in a second sample of the same peanut butter. When portions of these samples were submitted to the judging panel, no difference in flavor was observed but both were scored lower than a control sample of the same peanut butter with no added oil. To avoid the use of additional oil, which apparently lowered flavor scores, a portion of oil was removed by suction from another sample of the peanut butter. Enough technical BHC was dissolved in this oil to provide for approximately 15 p. p. m. of technical BHC in the peanut butter when the oil solution and peanut butter were remixed. When checked by the modified Schechter-Hornstein method, the concentration of BHC was determined as 13 p. p. m. Again, when served to the panel, there was no definite differentiation between this sample and appropriate controls containing no BHC. Similar results were obtained on panel evaluation of a peanut butter sample containing approximately 15 p. p. m. of 1,2,4-trichlorobenzene, a major degradation product that might be expected from BHC. As shown earlier, even inexperienced judges readily detected off-flavors in peanut butter made from peanuts grown in BHC-treated soils and containing as little as 1.8 p. p. m. of BHC. These results indicate, therefore, that BHC absorbed from the soil by peanuts may not be present as a solution in the oil component of the peanuts.

SUMMARY

Studies were made by use of sensory methods and chemical analyses to determine whether the production of peanuts in soils previously exposed to benzene hexachloride (BHC) applied as dust to cotton crops resulted in accumulation of the insecticide in the peanuts or adversely affected their flavor. Soil samples were also taken to investigate, by chemical analysis, possible relationships between residues of BHC in peanuts and in the soils in which they were grown.

The peanut and soil samples tested made up two major groups with respect to production histories. One group consisted of peanuts

grown during 1950 and 1951 in four of the principal cotton producing areas and collected from commercial growers' fields that had been previously planted to cotton which was treated with standard 3-5-40 BHC dust, and of soil samples from some of the same fields. Reported applications of BHC dust to cotton that preceded the peanuts provided an average of approximately 14 pounds of total BHC isomers (1.8 pounds of gamma isomer) per acre but ranged from 2 to 48 pounds per acre (0.3 to 6.3 pounds of gamma isomer). The second group of samples consisted of peanuts produced in 1951 and 1952 under more rigidly controlled conditions on experimental plots that had been used the immediately preceding years for growing cotton treated with BHC dusts. Of the latter, the 1951 samples followed cotton that was treated with heavy applications of 3-5-40 cotton dust, prepared with technical BHC containing 13 percent of the gamma isomer at dosage rates providing 29 and 39 pounds of total BHC isomers (3.8 and 5.1 pounds of gamma isomer) per acre. The 1952 samples from experimental plots in another location followed cotton treated with equally heavy dosages of gamma BHC (1.3 to 5.0 pounds per acre) but prepared with a 36 percent gamma grade of BHC. The heaviest dosage among the latter treatments deposited only 14 pounds of total BHC isomers per acre.

Among the samples of peanuts collected from commercial fields there were few observations of significant flavor defects and, when observed, off-flavors were not correlated with reported rates of application of BHC to preceding cotton crops. The chemically determined BHC contents of both peanuts and soils analyzed were generally too low to be considered of significance and, as with observed flavor defects, were not correlated with the quantities of insecticide applied to cotton that preceded the peanuts.

Peanuts that followed cotton that had been treated on experimental plots with unusually heavy dosages (3.8 or 5.1 pounds of gamma per acre) from technical BHC of 13 percent gamma content were characterized by definite off-flavors, and chemical analyses showed significant quantities of BHC both in the peanuts and in the soils in which they grew. The intensity of off-flavor and the BHC content of peanuts and soils were correlated with the dosage of insecticide applied to preceding cotton crops.

No significant association of off-flavors with insecticide treatment was observed in peanuts that followed cotton treated on experimental plots with 1.3 to 5.0 pounds of gamma per acre derived from a 36-percent gamma grade of BHC. Chemical analyses disclosed no significant quantities of BHC either in these peanuts or in the soils in which they were grown.

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