Table I. Recovery Following Addition of Known Amounts of Various Compounds to Liver

Compound	No. of Tests	Range, P.P.M. Added	Recovered	Range Recovery, %
Phenothiazine	5	8–20	8–18.6	97–101.5
Phenothiazone	5	7–18	6.5–17.6	87.2 –100
Thionol	5	2– 9	1.8– 7.5	83.5 – 93
Phenothiazine-5-sulfoxide	5	4–15	3.2–13.5	86.5 – 94

sented in Table I. Known amounts also were added as single tests to kidney, bile, intestinal contents, and two samples of commercial feed stuffs. In each case, the recovery of the individual compound was within the ranges reported for that compound in Table I, column 5.

The quantitative determination of phenothiazine and phenothiazone was based on their conversion to the amber-colored *N*-nitroso derivatives. This was carried out by treating the phenothiazine eluate directly with nitrous acid and in the case of phenothiazone, by first reducing the eluate and then treating it with nitrous acid. In both instances the colors were stable for at least 1 hour. In the case of thionol, advantage was taken of its intense blue color in alkaline solution which had a strong absorption band at 590 mμ, possibly the spectrum of the phenolate ion (*3*). The color was not stable at high concentrations and so was read as soon as possible after addition of the alkaline buffer.

Phenothiazine-5-oxide is converted to the sulfonium salt (*1, 2, 5*) when it is dissolved in strong acid. The resulting orange-pink solution had an absorption band at 445 mμ and was unstable; however, addition of one drop of ferric chloride solution produced a stable color with a maximum absorption at 520 mμ.

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PESTICIDES AND FOOD FLAVOR

Effect of Insecticides and Fungicides on the Flavor Quality of Fruits and Vegetables

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A northeast regional project (NE-15) was activated in July 1954 to determine the effects of pesticides on the quality of fruits and vegetables by means of organoleptic tests. Its primary concern was to uncover any association of poor flavor quality or off-flavor with pesticidal treatments.

The first task of the committee was to determine the extent of agreement on sample ratings among panels in different laboratories through exchange of samples. A second objective was the development of a scoring technique which would quickly, economically, and precisely evaluate the off-flavor hazard in the use of pesticides.

Preliminary Procedure

In 1954, a lack of uniform test material hampered the work of the committee because the project was activated too late to plant and treat crops specifically for the study. The use of crops designed for other purposes forcefully pointed to the necessity of an adequate supply of samples as uniform as is possible with biological material and controlled in every respect except for the variable under study.

Some of the first year's experiments were confounded by extraneous influences whereby significantly different results could erroneously be attributed to pesticides. Three examples illustrate this confounding.

Incomplete sealing of a few cans of snap beans resulted in flat-sour development, thereby nullifying an experiment.

The inclusion of some immature squash (to obtain sufficient control sample) resulted in overprocessing at the same time-temperatures that were optimum for mature squash. The resulting scorched flavor confounded the results of the study.

Apple juices from methoxychlor-treated trees were significantly lower-scored and in some cases rated as off-flavor by nearly all of the participating laboratories. It was known that the methoxychlor-treated trees were heavily

During 6 years, seven experiment stations and the Bureau of Human Nutrition, U. S. Department of Agriculture, tested by organoleptic methods the effects of pesticides on the flavor of 20 vegetables and three fruits. Common samples were exchanged and evaluated by the cooperating agencies, using a method developed by the group. Some pesticides were tested enough times (11 to 68 tests) to derive a picture of the distribution of flavor effects in terms of a control sample—i.e., better, equal, poorer, slight, and definite off-flavor. Five single insecticides and one fungicide were associated with a notable degree of poor flavor quality. Six combinations of pesticides had adverse effects on flavor. Some of these seemed to be related to specific components of the multiple treatments, while others were ascribed to interaction. No ill effect on flavor quality was noted in association with ten insecticides, three fungicides on potatoes, and three fungicides on apples.

FLAVOR EVALUATION

Rate Flavor Only. Ignore all Other Differences

Name ____________ Project NE 15

Date ____________ Product ____________

Instructions: Check the column where you think each sample belongs.

Sample	Better than Standard in Flavor	Equal to Standard in Flavor	Below the Standard in Flavor: No Detectable Off-Flavor	Below the Standard in Flavor: Slight Off-Flavor	Below the Standard in Flavor: Definite Off-Flavor Not Acceptable	Describe Off-Flavor[1] if Possible
1						
2						
3						
4						
5						
6						
	(+2)	(+1)	(0)	(-1)	(-2)	

[1] List of suggested words:

Bitter	Fragrant	Oily	Salty
Burnt	Medicinal	Putrid	Sour
Earthy	Metallic	Puckery	Spicy
Flat	Musty	Rancid	Sweet
			Woody

Figure 1. NE-15 score sheet for flavor evaluation

Values assigned to each category are given in parentheses below columns. The values are used for mean score calculations.

damaged by mites and the apples, therefore, less ripe. Thus a maturity difference was associated with the pesticide treatment. In consequence, the results from that treatment had to be omitted.

These experiences emphasize the need for the quality investigator to have a completely detailed history of the samples from planting through all stages of growth, harvest, storage, and processing in order to evaluate cause with effect intelligently.

A four-point scale was used in 1954. This was built around a conception of average flavor: 4, better than average; 3, average; 2 and 1, slight and definite degrees of off-flavor. The method was considered by the judges to be wanting in two respects: a need for a labeled standard sample (untreated or previously shown to be of good quality) to give them a common reference point and a fifth scale point to indicate poorer than standard but not necessarily off-flavor.

Accepted Procedure

In 1955, a five-point scale with a labeled standard was adopted (Figure 1). The samples were judged in relation to a coded or "blind" reference sample, which was always included as an unknown. Scores of +2 to −2 were assigned for variance analysis, so that a final minus score indicated off-flavor, with its magnitude showing the degree of off-flavor (*2*, *3*). With this method, excellent agreement was obtained among several laboratories with panels differing in size and composition (*3*).

A list of suggested words was appended to the score sheet for the judges to use in identifying the off-flavor (if any), but the result was meaningless because of disagreement on the connotation of descriptive terms. Good correlations were obtained only in a general breakdown between words conveying "pleasant" *vs.* "unpleasant" taste sensations. Semantic agreement would undoubtedly be possible with intensive panel training on the the identification of individual flavors. This would presuppose the knowledge by the investigator of the specific off-flavor developed in the final product form (which could be a metabolite of entirely different flavor than the original additive) and be extremely time-consuming with panels having as many as 40 judges.

In a few instances, other organoleptic techniques were used: Ranking and paired comparisons were used for a number of tests. These methods do not lend themselves to an interpretation of off-flavor and must result only in "significantly better or poorer" than the standard. A five-point scoring technique was used in some tests by the Human Nutrition Research Division, in which 5 indicated no off-flavor and 4 to 1 were degrees of off-flavor.

The panels varied in number from five trained people to 40 or more. All laboratories selected judges who had demonstrated taste acuity in previous studies. In general, each unit in the tables represents a mean value from a minimum of 40 judgments (judge × replication). In relatively few instances the value was derived from 20 judgments (5 judges × 4 replications).

Most of the results from 1955 through 1960 are based on the 1955 NE-15 method (Figure 1) wherein two criteria had to be satisfied in order to label a sample "off-flavor": (A) It must be significantly ($P = 0.05$) lower-scored than the coded standard and (B) it must be associated with a minus score.

Results

In 1960, the project was terminated and a list of all of the tested pesticides was prepared.

The resulting data are shown in the tables. Table I demonstrates the effects of insecticides on the flavor of fruits and vegetables when a single insecticide was the only variable. Table II lists the observed influences of single fungicides on flavor. Table III shows the effects of multiple pesticides on flavor—

Table I. Flavor Evaluations of Crops Treated with Single Insecticides

Insecticide	Product	Location[a,b]	Total Lb. Actual[c]/Acre	No. of Crop Years	Tested by[b]	Flavor Compared to Standard[d]: Better	Equal	Poorer	Off-flavor
						Number of Tests			
Aldrin	Carrot, canned, stored, frozen, cooked	DE	2 1/2 and 3.0	3	EHK	2	3	1	
	Potato, new, stored, baked	E	2 1/2 and 3.0	3	E		4		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)[e]		
	Turnip, cooked	B	3 yr. = 65; test yr. = 0	1	C		(1)	(1)	
						2	7	1	
Amer. Cyan. 24055	Broccoli, frozen	F	2.0	1	FK		2		
Bacillus thuringiensis	Cabbage, raw, cooked	E	9.0	1	E		2		
BHC	Bean, snap, canned	F	1/4 and 3/4	1	DF		4		
	Peach, frozen, canned	F	0.25/100[f] (1 and 2 app.)	1	EFHK		2	5	3
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C				(4)
	Corn, frozen	K	0.125 to 1/2; test yr. = 0	1	K	(7)	(2)		
	Turnip, cooked	B	3 yr. = 130; test yr. = 0	1	C				(1)
							6	5	3
Chlordan	Cabbage, raw, cooked	E	9.0 to 40.4	2	E		4		
	Carrot, raw, cooked, canned, frozen	BDE	5.0 to 20.0	5	CDE	3	9	1	
	Parsnip, cooked	B	5.0 and 10.0	1	C		2		
	Potato, new, stored, baked	E	8.0 and 10.0	3	E		4		
	Turnip, cooked	B	5.0 and 10.0	1	C		2		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)		
	Turnip, cooked	B	3 yr. = 130; test yr. = 0	1	C		(1)		
						3	21	1	
Chlorthion	Peach, fresh, canned, stored	B	0.0225/tree	1	CH	1	3	2	
DDT	Bean, snap, canned	F	1.0 and 2.0	1	FK		4		
	Bean, Lima, canned	F	5.0 and 10.0	1	FK		4		
	Cabbage, raw, cooked	E	9.0	1	E		2		
	Carrot, frozen, cooked	ED	10.0	3	E	1	1	1	
	Cucumber, raw	E	Reg. 4.0; pur. 16.0	1	E		2		
	Potato, new, stored, baked	EF	10.0 and 20.0	5	CEF	1	6		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)		
						2	19	1	
Diazinon	Bean, snap, canned	F	2.0	1	F		2		
	Broccoli, frozen	F	2 3/4 and 7.0	2	F		3		
	Potato, stored, baked	E	0.7 and 1.575	1	E		2		
	Tomato juice, canned	B	1.0	1	CFK	1	5		
						1	12		
Dibrom (R.E. 4355)	Bean, snap, canned	F	1.0 to 4.0	2	FK		5		
	Bean, Lima, canned	F	1 1/2	1	F		1		
	Broccoli, frozen	F	1.0 and 7.0	2	FK		3	1	
	Cabbage, cooked	F	1.0	1	F		1		
	Egg plant, cooked	F	2 1/4	1	F		1		
	Potato, cooked	F	2.0	1	F		1		
	Tomato juice, canned	F	2.0	1	F		1		
							13	1	
Dieldrin	Potato, new, baked	E	2 1/2	1	E		1		
	Squash, canned	D	1.0	1	D	1			
	Sweet potato, baked	B	1 1/2 and 2 1/2	1	C		3		
	Turnip, cooked	D	0.39 to 6.0	2	D		6		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)		
	Turnip, cooked	B	3 yr. = 65; test yr. = 0	1	C		(1)		
						1	10		
Dilan	Bean, snap, canned	F	1/2 to 1 1/2	4	DEFHK	1	19		
	Potato, cooked	F	2.0	1	F		1		
	Residue								
	Turnip, cooked	B	3 yr. = 130; test yr. = 0	1	C		(1)		
						1	20		
Dylox	Bean, snap, canned	F	1.0	1	FK		2		
	Bean, Lima, canned	F	5.0	1	FK		1	1	
							3	1	
Endrin	Cantaloup, raw	D	2 1/2	1	D	1			
	Carrot, canned	D	3.0	2	DEHK		4	3	
	Cucumber, raw	D	3/4 to 2 1/2	2	D		3		
	Potato, new, baked	E	2 1/4	1	E		1		
	Squash, canned	D	3/4 to 2.0	3	DEFK	2	6	1	
	Sweet potato, baked	B	2 1/2	1	C		1		
	Watermelon, raw	D	2.0	1	D			1	
	Residue								
	Carrot, canned	D	1 yr. = 3.0; test yr. = 0	1	DE		(2)		

Insecticide	Product	Location[a,b]	Total Lb. Actual[c] / Acre	No. of Crop Years	Tested by[b]	Flavor Compared to Standard[d]: Better	Equal	Poorer	Off-flavor
						Number of tests			
	Turnip, cooked	B	3 yr. = 65.0; test yr. = 0	1	C		(1)		
						3	15	5	1
Ethion (1240)	Bean, snap, canned	F	$^1/_2$ and 2.0	2	FK		5		
	Bean, Lima, canned	F	$2^1/_2$ and 3.0	2	FK	1	2		
	Egg plant, cooked	F	$4^1/_2$	1	F		1		
	Potato, cooked	F	$4^1/_4$	1	F		1		
	Tomato juice, canned	F	$4^1/_4$	1	F		1		
						1	10		
Guthion	Peach, fresh, canned	B	0.015 lb./tree	1	CH	1	5		
Heptachlor	Broccoli, fresh, frozen	FM	$1^3/_4$ to 4.0	2	FM		5		
	Cantaloup, raw	D	$4^1/_2$	1	D		1		
	Carrot, raw, cooked, frozen, canned	BDE	$2^1/_2$ to 6.0	5	CEHK	4	10		
	Corn, cooked	M	2.0 and 4.0	1	M		3		
	Parsnip, cooked	B	3.0 and 6.0	1	C		2		
	Potato, cooked	BEM	2.0 to 6.0	3	CEM		6		
	Squash, cooked	D	3.0	1	D		1		
	Sweet potato, baked	B	$2^1/_2$	1	C		1		
	Tomato juice, canned	B	1.0	1	CFK	2	4		
	Turnip, cooked	BD	0.6 to 6.0	3	CD	1	14		
	Watermelon, raw	D	4.5	1	D		1		
	Residue								
	Corn, frozen	K	$^1/_4$ to 1.0; test yr. = 0	1	K	(4)	(5)		
	Turnip, cooked	B	3 yr. = 130; test yr. = 0	1	C			(1)	
						7	48		
Isodrin	Turnip, cooked	D	3.0	1	D		1		
	Residue								
	Turnip, cooked	B	3 yr. = 65; test yr. = 0	1	C		(1)		
Kepone	Cabbage, cooked	F	1.0	1	F		1		
Korlon (Dow Et 14)	Tomato juice, canned	B	$^3/_4$	1	CFK	1	2		
Lead arsenate	Apple juice, frozen	A	3.0/100[f]	2	DEF		4	4	
	Apple sauce, canned	A	3.0/100[f] (4 and 5 app.)	1	DEFHK	2	3		
						2	7	4	
Lindane	Bean, snap, canned	F	0.2 and 0.6	1	DF		2	1	1
	Cantaloup, raw	BD	$1^1/_4$ and 1.4	2	CD		2	1	1
	Potato, new, stored, baked	E	$^3/_4$ to $3^1/_4$	2	E		1	3	
		E	$9^3/_4$	1	E			2	
	Squash, cooked, canned	D	$^3/_4$ and $1^3/_4$	2	DFK	1	1	2	
	Watermelon, raw	D	$1^3/_4$ and $5^1/_2$	2	D	1	1		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C				(1)
						2	7	9	2
Malathion	Apple sauce, canned	A	3.0/100[f]	1	DEFHK		7	2	
	Asparagus, canned, frozen	F	$1^1/_4$	1	F		2		
	Bean, snap, canned	F	$1^1/_4$ to $3^3/_4$	4	DEFHK	1	21	3	1
	Bean, Lima, canned	F	4.0	1	F		1		
	Broccoli, frozen	F	$2^1/_2$ to $13^3/_4$	2	F		4	1	
	Cabbage, raw, cooked	E	9.0	1	E		2		
	Cantaloup, raw	D	5.0 to 10.0	3	D	1	2		
	Cucumber, raw	DE	8.0 and 10.0	2	DE		2		
	Egg plant, cooked	F	9.0	1	F		1		
	Mushroom, canned	B	$1^1/_4$ to 5.0	1	C		3		
	Potato, cooked	F	$8^1/_2$ and $13^3/_4$	2	F		2		
	Squash, cooked, canned	D	4.0 to 7.0	3	DFK	2	1	2	
	Tomato juice, canned	BF	1.0 and $8^1/_2$	1	CFK	1	2	1	
	Watermelon, raw	D	7.0 and 8.0	3	D		2	1	
						5	52	10	1
Methoxychlor (marlate)	Applesauce, canned	A	3.0/100[f]	1	K			1	
	Broccoli, frozen	F	$^3/_4$ and $1^1/_2$	1	F				2
	Cabbage, cooked	F	1.0	1	F		1		
	Cantaloup, raw	D	9.0 and $12^1/_2$	2	D	1		1	
	Cucumber, raw	E	8.0	1	E		1		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)		
						1	2	2	2
Parathion	Bean, snap, canned	F	1.0	1	F		2		
Perthane	Broccoli, frozen	F	11.0 and 14.0	2	F	1	1	1	
Phorate (Thimet)	Bean, snap, canned	F	$^1/_2$	1	F		2		
	Broccoli, frozen	F	$^1/_2$ to 2.0	2	F		3	1	
	Potato, cooked	F	3.0	1	F		1		
							6	1	
Phosdrin	Broccoli, frozen	F	$^1/_2$ and $5^1/_2$	1	F		2		
Ryania	Apple juice, frozen	A	6.0/100[f]	2	DEF		8		

(*Continued on page 218*)

Table I. Flavor Evaluations of Crops Treated with Single Insecticides (continued)

Insecticide	Product	Location[a,b]	Total Lb. Actual[c]/Acre	No. of Crop Years	Tested by[b]	Flavor Compared to Standard[d]: Better	Equal	Poorer	Off-flavor
						Number of Tests			
Sevin	Bean, snap, canned	F	1.0 to 4.0	2	FK		8	1	
	Bean, Lima, canned	F	$4\frac{3}{4}$ to 10.0	2	FK		7		
	Egg plant, cooked	F	7.0	1	F		1		
	Potato, cooked	F	$6\frac{1}{2}$	1	F		1		
	Tomato juice, canned	F	$6\frac{1}{2}$	1	F		1		
							18	1	
TDE	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)		
Thiodan	Bean, snap, canned	F	1.0 and 2.0	2	FK		5		
	Bean, Lima, canned	F	3.0 and 5.0	2	FK		2	1	
	Broccoli, frozen	F	$\frac{3}{4}$ and $3\frac{1}{2}$	2	FK		4		
	Cabbage, cooked	F	$\frac{3}{4}$	1	F		1		
	Egg plant, cooked	F	$4\frac{1}{2}$	1	F		1		
	Peas, canned	F	$\frac{3}{4}$	1	FK	1	1		
	Potato, cooked	F	$\frac{1}{2}$ to $4\frac{1}{4}$	3	F		5		
	Tomato juice, canned	F	$4\frac{1}{4}$	1	F		1		
	Strawberry, raw	E	2.0	1	E		1		
						1	21	1	
Toxaphene	Broccoli, frozen	F	$1\frac{1}{2}$ to $10\frac{1}{2}$	2	F		2		2
	Potato, new, stored, baked	E	9–11 yr. = 91 to 121; test yr. = 15.0	3	CEF		8	7	3
	Spinach, frozen	F	4.0	1	FK		2		
	Sweet potato, baked	B	15.0	1	C		1		
	Residue								
	Carrot, cooked	B	4 yr. = 190; test yr. = 0	1	C		(1)		
	Corn, cooked	K	$\frac{3}{4}$ to 3.0; test yr. = 0	1	K	(5)	(3)		(1)
	Potato, new, stored, baked	E	9–11 yr. = 91 to 106; test yr. = 0	1	CEF		(12)	(1)	(1)
	Turnip, cooked	B	4 yr. = 130; test yr. = 0	1	C		(1)		
							13	7	5
Trithion (and methyl)	Bean, snap, canned	F	1.0 to 2.0	2	FK		5		
	Bean, Lima, canned	F	$2\frac{3}{4}$ and 5.0	2	FK		3		
	Broccoli, frozen	F	1.0 to 7.0	3	F		5		
	Cabbage, cooked	F	$1\frac{1}{2}$	1	F		1		
	Egg plant, cooked	F	$4\frac{1}{4}$	1	F		1		
	Peas, canned	F	1.0	1	FK		2		
	Potato, cooked	F	$\frac{1}{2}$ to 4.0	2	F		3		
	Tomato juice, canned	F	4.0	1	F		1		
							21		
Systemics									
Dimethoate (Am. Cyan. 12880)	Bean, snap, canned	F	$\frac{1}{4}$ to 2.0	2	FK		11	1	
	Bean, Lima, canned	F	5.0	1	FK		2		
	Broccoli, frozen	F	$\frac{1}{2}$ to 1.0	1	FK		6		
	Peas, canned	F	$\frac{1}{4}$ to 1.0	1	FK	2	4		
	Potato, cooked	F	$\frac{1}{4}$ to 4.0	1	F		5		
						2	28	1	
Phosphamidon	Bean, snap, canned	F	$\frac{1}{2}$ to 2.0	2	FK		10		
	Bean, Lima, canned	F	$2\frac{1}{2}$ and 5.0	1	FK		4		
	Broccoli, frozen	F	$\frac{1}{2}$ and 1.0	1	FK		4		
	Cabbage, cooked	F	$\frac{1}{2}$	1	F		1		
	Peas, canned	F	$\frac{1}{4}$ and $\frac{1}{2}$	1	FK	2	2		
	Potato, cooked	F	$\frac{1}{4}$ and $\frac{1}{2}$	1	F		3		
						2	24		
Systox (demeton)	Bean, snap, canned	F	$\frac{3}{4}$	1	F		2		
	Potato, new, baked	E	0.0312	1	E		2		
							4		
18706 (Am. Cyan.)	Bean, snap, canned	F	1.0	1	FK		4		

[a] Location where grown.
[b] States or agencies responsible for results. A, Conn. Expt. Sta., New Haven. B, Entomology Research Div. or Crops Research Div., U.S.D.A. C, Human Nutrition Research Div., U.S.D.A. D, Mass. Expt. Sta. E, Maine Expt. Sta. F, Md. Expt. Sta. H, N. Y. Expt. Sta. M, R. I. Expt. Sta.
[c] Unless otherwise specified [d] Untreated except apples from Conn. and N. Y., treated with pesticides previously shown not to affect flavor quality.
[e] Parentheses indicate results from residue study, not included in totals. [f] Pounds or quarts/100 gal./ application.

Table II. Flavor Evaluations of Crops Treated with Single Fungicides

Fungicide	Product	Location[a,b]	Pounds or Quarts / 100 Gal./Application[c]	No. of Crop Yr.	Tested by[b]	Flavor Compared to Standard[d]: Better	Equal	Poorer	Off-flavor
						Number of Tests			
Bordeaux	Potato, stored, baked	E	(8.0 + 4.0)	5	E	5	7	1	
Captan (orthocide 50 or 80)	Apple, raw, stored 1 and $2^1/_2$ mo.	E	2.0	1	E		2		
	Stored $3^1/_2$ mo.	E	2.0	1	E			1	
							2	1	
Cop-o-zink	Potato, stored, baked	E	4.0	1	E	1	1		
Cuprocide	Potato, stored, baked	E	2.0	1	E	2			
Dichlone (phygon)	Potato, stored, baked	E	1.0	1	E	1	1		
Glyodin (Crag 341)	Apple, raw, stored 1 and $2^1/_2$ mo.	E	1.0	1	E	2			
	Stored $3^1/_2$ mo.	E	1.0	1	E		1		
						2	1		
Maneb (dithane M22, manzate)	Potato, stored, baked	E	1.0 and 2.0	2	E	1	1		
PCNB (Terrachlor)	Potato, stored, steamed	E, No. Dak.	50 lb./acre	1	CE			6	5
Tennan	Potato, stored, baked	E	4.0	1	E		2		
Tribasic copper	Potato, stored, baked	E	4.0	5	E	5	8		
Zineb (tank mixed)	Potato, stored, baked	E	(2.0 + 1.0)	5	E	4	9		

[a] Location where grown.
[b] States or agencies responsible for results. A, Conn. Expt. Sta., New Haven. B, Entomology Research Div. or Crops Research Div., U.S.D.A. C, Human Nutrition Research Div., U.S.D.A. D, Mass. Expt. Sta. E, Maine Expt. Sta. F, Md. Expt. Sta. H, N. Y. Expt. Sta. K, Pa. Expt. Sta.
[c] Unless otherwise specified.
[d] Untreated except apples from Conn. and N. Y. treated with pesticides previously shown not to affect flavor quality.

Table III. Flavor Evaluations of Crops Treated with Multiple Pesticides

Pesticide[a]	Product	Location[b,c]	Pounds or Quarts[d] / 100 Gal./Application	No. of Crop Yr.	Tested[c] by	Flavor Compared to Standard[e]: Better	Equal	Poorer	Off-flavor
						Number of Tests			
BHC									
+ Cu	Squash, canned	D	$^3/_4$–$4^1/_2$	1	DEF		3		
Black Leaf 253	Apple juice, frozen	A	$2^1/_2$	2	DEF		2	3	
+ glyodin	Applesauce, canned	A	$2^1/_2$–1.0	1	DEF		3		
							5	3	
DDT									
+ captan	Apple, raw	H	2.0–$1^1/_2$	1	FK		2		
+ captan + PbAs	Apple, raw, cooked	H	2.0–2.0–$1^1/_2$	2	FK		7		
+ Cyprex	Apple, raw	H	2.0–$^1/_2$	1	FK		2		
+ dieldrin	Spinach, frozen	F	$2^1/_2$–0.19[f]	1	FK		1	1	
+ ferbam	Apple, raw	H	2.0–$1^1/_2$	1	FK		2		
+ glyodin	Apple, raw	H	2.0–$1^1/_2$	2	FK		4		
+ parathion	Broccoli, frozen	F	3.0–$^3/_4$[f]	1	F			1	
+ S micronized	Apple, raw	H	2.0–5.0	1	FK		2		
+ thiram	Apple, raw	H	2.0–$1^1/_2$	1	FK		2		
+ thiram + PbAs	Apple, raw, cooked	H	2.0–2.0–$1^1/_2$	2	FK		4	2	
+ toxaphene	Potato, baked	E	9 yr. = 158 – 106;[f] test yr. = 20.0–15.0[f]	2	CE		1	1	2
	Spinach, frozen	F	1.0–1.0[f]	1	FK		1	1	
+ toxaphene + malathion	Spinach, frozen	F	1.0–1.0–$3^3/_4$[f]	1	FK		1	1	
							29	7	2
Diazinon									
+ captan	Apple, raw	H	2.0–$1^1/_2$	1	FK		1	1	
+ dieldrin	Spinach, frozen	F	$2^1/_2$–0.19[f]	1	FK		1	1	
+ ferbam	Apple, raw	H	2.0–$1^1/_2$	1	FK		2		
+ glyodin	Apple, raw	H	2.0–$1^1/_2$	1	FK		2		
+ Niacide M + PbAs	Apple, raw, sauce	B	14.0–1.0–7.0	1	C		2		
+ S micronized	Apple, raw	H	2.0–5.0	1	FK		2		
+ thiram	Apple, raw	H	2.0–$1^1/_2$	1	FK		2		
							12	2	
Dibrom									
+ Thiodan	Broccoli, frozen	F	1.0–$^3/_4$[f]	1	FK		2		
Dieldrin									

(*Continued on page 220*)

Table III. Flavor Evaluations of Crops Treated with Multiple Pesticides (continued from page 219)

Pesticide[a]	Product	Location[b,c]	Pounds or Quarts[d] / 100 Gal./Application	No. of Crop Yr.	Tested by	Flavor Compared to Standard[d]: Better	Equal	Poorer	Off-flavor
						Number of Tests			
+ DDT	Spinach, frozen	F	0.19–2½[f]	1	FK		1	1	
+ diazinon	Spinach, frozen	F	0.19–2½[f]	1	FK		1	1	
+ malathion	Spinach, frozen	F	0.19–6¼[f]	1	FK		2		
							4	2	
Guthion									
+ captan	Apple, raw	H	1¾–1½	1	FK		2		
+ ferbam	Apple, raw	H	1¾–1½	1	FK		2		
+ glyodin	Apple, raw	H	1¾–1½	1	FK		2		
+ S micronized	Apple, raw	H	1¾–5.0	1	FK		1	1	
+ thiram	Apple, raw	H	1¾–1½	1	FK		1	1	
							8	2	
Lead arsenate									
+ DDT + captan	Apple, raw, cooked	H	2.0–2.0–1½	2	FK		7		
+ DDT + thiram	Apple, raw, cooked	H	2.0–2.0–1½	2	FK		4	2	
+ diazinon + Niacide M	Apple, raw, sauce	B	1.0–14.0–7.0	1	C		2		
+ malathion + captan	Applesauce, canned	A	3.0–2.0–2.0	1	DEF		3		
							16	2	
Malathion									
+ captan	Cantaloup, raw	D	5.0–9.0[f]	1	D		1		
	Squash, cooked, canned	D	7.0–12.0[f]	2	DEF		1	2	1
	Watermelon, raw	D	7.0–12.0[f]	1	D	1			
+ captan + PbAs	Applesauce, canned	A	2.0–3.0–2.0	1	DEF		3		
+ dieldrin	Spinach, frozen	F	6¼–0.19[f]	1	FK		2		
+ maneb	Cantaloup, raw	D	5.0–10.0[f]	1	D		1		
	Squash, cooked	D	7.0–14.0[f]	1	D			1	
	Watermelon, raw	D	7.0–14.0[f]	1	D		1		
+ methoxychlor	Apple juice, frozen	A	2.0–3.0	1	DEF		3		
+ methoxychlor + captan	Apple juice, frozen	A	2.0–3.0–2.0	2	DEF		5	3	
+ methoxychlor + captan + TDE	Applesauce, canned	A	2.0–1½–2.0–1½	1	DEF		3		
+ perthane	Broccoli, frozen	F	8¾–7.0[f]	1	F		2		
+ ryania + captan	Apple juice, frozen	A	2.0–6.0–2.0	1	EF			2	
+ ryania + glyodin	Applesauce, canned	A	2.0–6.0–1.0	1	DEF		3		
+ Thiodan	Broccoli, frozen	F	1¼–¾[f]	1	FK		2		
+ toxaphene	Broccoli, frozen	F	25.0–30.0[f]	2	F		2	2	
+ toxaphene	Spinach, frozen	F	6¼–4.0[f]	1	FK		2		
+ toxaphene + DDT	Spinach, frozen	F	3¾–1.0–1.0[f]	1	FK		1	1	
						1	32	11	1
Methoxychlor									
+ malathion	Apple juice, frozen	A	3.0–2.0	1	DEF		3		
+ malathion + captan	Apple juice, frozen	A	3.0–2.0–2.0	2	DEF		5	3	
+ malathion + captan + TDE	Applesauce, canned	A	1½–2.0–2.0–1½	1	DEF		3		
+ maneb	Squash, cooked	D	4.0–6.0	1	D	1			
+ zineb	Cucumber, raw	D	12½–25.0[f]	1	D			1	
	Squash, cooked	D	7½–15.0[f]	1	D		1		
	Watermelon, raw	D	10.0–20.0[f]	1	D		1		
						1	13	4	
Parathion									
+ DDT	Broccoli, frozen	F	¾–3.0[f]	1	F			1	
Perthane									
+ malathion	Broccoli, frozen	F	7.0–8¾[f]	1	F		2		
Rotenone									
+ copper	Cantaloup, raw	D	1¾–10½[f]	2	D		2		
	Squash, cooked	D	1¾–10½[f]	2	D		1	1	
	Watermelon, raw	D	2.0–12.0[f]	2	D		2		
+ maneb	Cantaloup, raw	D	1¾–14.0[f]	1	D		1		
	Squash, cooked	D	1½–12.0[f]	1	D		1		
	Watermelon, raw	D	2.0–16.0[f]	1	D		1		
							8	1	
Ryania									
+ malathion + captan	Apple juice, frozen	A	6.0–2.0–2.0	1	EF			2	
+ malathion + glyodin	Applesauce, canned	A	6.0–2.0–1.0	1	DEF		3		
							3	2	

Pesticide[a]	Product	Location[b,c]	Pounds or Quarts[d] / 100 Gal./Application	No. of Crop Yr.	Tested by	Flavor Compared to Standard[d]: Better	Equal	Poorer	Off-flavor
						Number of Tests			
Sevin									
+ captan	Apple, raw, cooked	H	2.0–2.0	2	FK		5	3	
+ Cyprex	Apple, raw	H	2.0–1/2	1	FK		2		
+ glyodin	Apple, raw	H	2.0–1 1/2	1	FK	1	1		
+ thiram	Apple, raw, cooked	H	2.0–1 1/2	2	FK		4	2	
						1	12	5	
TDE									
+ malathion + methoxychlor + captan	Applesauce, canned	A	1 1/2–2.0–1 1/2–2.0	1	DEF		3		
Thiodan									
+ Dibrom	Broccoli, frozen	F	3/4–1.0[f]	1	FK		2		
+ malathion	Broccoli, frozen	F	3/4–1 1/4[f]	1	FK		2		
							4		
Toxaphene									
+ DDT	Spinach, frozen	F	1.0–1.0[f]	1	FK		1	1	
	Potato, baked	E	9 yr. = 106–158[f]; test yr. = 15–20[f]	2	CE		1	1	2
+ DDT + malathion	Spinach, frozen	F	1.0–1.0–3 3/4[f]	1	FK		1	1	
+ malathion	Broccoli, frozen	F	30.0–25.0[f]	2	F		2	2	
	Spinach, frozen	F	4.0–6 1/4[f]	1	FK		2		
							7	5	2
Fungicides									
Captan (orthocide 50 or 80)									
+ DDT	Apple, raw	H	1 1/2–2.0	1	FK		2		
+ DDT + PbAs	Apple, raw, cooked	H	1 1/2–2.0–2.0	2	FK		7		
+ diazinon	Apple, raw	H	1 1/2–2.0	1	FK		2		
+ Guthion	Apple, raw	H	1 1/2–1 3/4	1	FK		2		
+ malathion	Cantaloup, raw	D	9.0–5.0[f]	1	D		1		
	Squash, canned, cooked	D	12.0–7.0[f]	2	DEF		1	2	1
	Watermelon, raw	D	12.0–7.0[f]	1	D	1			
+ malathion + PbAs	Applesauce, canned	A	2.0–3.0–2.0	1	DEF		3		
+ malathion + methoxychlor	Apple juice	A	2.0-2.0–3.0	2	DEF		5	3	
+ malathion + methoxychlor + TDE	Applesauce	A	2.0–2.0–1 1/2–1 1/2	1	DEF		3		
+ malathion + ryania	Apple juice	A	2.0–2.0–6.0	1	EF		2		
+ Sevin	Apple, raw, cooked	H	2.0–2.0	2	FK		5	3	
						1	33	8	1
Copper									
+ BHC	Squash, canned	D	4 1/2–3/4[f]	1	DEF		3		
+ rotenone	Watermelon, raw	D	12.0–2.0[f]	2	D		2		
	Cantaloup, raw	D	10 1/2–1 3/4[f]	2	D		2		
	Squash, cooked	D	10 1/2–1 3/4[f]	2	D		1	1	
							8	1	
Cyprex									
+ DDT	Apple, raw	H	1/2–2.0	1	FK		2		
+ Sevin	Apple, raw	H	1/2–2.0	1	FK		2		
							4		
Ferbam									
+ DDT	Apple, raw	H	1 1/2–2.0	1	FK		2		
+ diazinon	Apple, raw	H	1 1/2–2.0	1	FK		2		
+ Guthion	Apple, raw	H	1 1/2–1 3/4	1	FK		2		
							6		
Glyodin									
+ Bl. Leaf 253	Applesauce, canned	A	1.0–2 1/2	1	DEF		3		
+ DDT	Apple, raw	H	1 1/2–2.0	2	FK		4		
+ diazinon	Apple, raw	H	1 1/2–2.0	1	FK		2		
+ Guthion	Apple, raw	H	1 1/2–1 3/4	1	FK		2		
+ malathion + ryania	Applesauce	A	1.0–2.0–6.0	1	DEF		3		
+ Sevin	Apple, raw	H	1 1/2–2.0	1	FK	1	1		
						1	15		
Maneb									
+ malathion	Cantaloup, raw	D	10.0–5.0[f]	1	D		1		
	Squash, cooked	D	14.0–7.0[f]	1	D			1	
	Watermelon, raw	D	14.0–7.0[f]	1	D		1		

(*Continued on page 222*)

Table III. Flavor Evaluations of Crops Treated with Multiple Pesticides **(continued from page 221)**

Pesticide[a]	Product	Location[b,c]	Pounds or Quarts[d] 100 Gal./Application	No. of Crop Yr.	Tested by[c]	Flavor Compared to Standard[e] Better	Equal	Poorer	Off-flavor
						Number of Tests			
+ methoxychlor	Squash, cooked	D	6.0–4.0[f]	1	D	1			
+ rotenone	Cantaloup, raw	D	14.0–$1^{3}/_{4}$[f]	1	D		1		
	Squash, cooked	D	12.0–$1^{1}/_{2}$[f]	1	D		1		
	Watermelon, raw	D	16.0–2.0[f]	1	D		1		
						1	5	1	
Niacide M									
+ diazinon + PbAs	Apple, raw, sauce	B	1.0–2.0–1.0	1	C		2		
Sulfur micronized									
+ DDT	Apple, raw	H	5.0–2.0	1	FK		2		
+ diazinon	Apple, raw	H	5.0–2.0	1	FK		2		
+ Guthion	Apple, raw	H	5.0–$1^{3}/_{4}$	1	FK		1	1	
							5	1	
Thiram									
+ DDT	Apple, raw	H	$1^{1}/_{2}$–2.0	1	FK		2		
+ DDT + PbAs	Apple, raw, cooked	H	$1^{1}/_{2}$–2.0–2.0	2	FK		4	2	
+ diazinon	Apple, raw	H	$1^{1}/_{2}$–2.0	1	FK		2		
+ Guthion	Apple, raw	H	$1^{1}/_{2}$–$1^{3}/_{4}$	1	FK		1	1	
+ Sevin	Apple, raw, cooked	H	$1^{1}/_{2}$–1.0	1	FK		4		
	Apple, raw	H	$1^{1}/_{2}$–2.0	1	FK			2	
							13	5	
Tribasic Cu									
+ zineb	Potato, stored, baked	E	4.0–(2.0 + 1.0)	1	E	1	1		
Zineb									
+ methoxychlor	Cucumber, raw	D	25.0–$12^{1}/_{2}$[f]	1	D			1	
	Squash, cooked	D	15.0–$7^{1}/_{2}$[f]	1	D		1		
	Watermelon, raw	D	20.0–10.0[f]	1	D		1		
(tank mixed)									
+ tribasic Cu	Potato, stored, baked	E	(2.0 + 1.0)–4.0	1	E	1	1		
						1	3	1	

[a] Pesticides cross-indexed. [b] Location where grown.
[c] States or agencies responsible for results. A, Conn. Expt. Sta., New Haven. B, Entomology Research Div. or Crops Research Div., U.S.D.A. C, Human Nutrition Research Div., U.S.D.A. D, Mass. Expt. Sta. E, Maine Expt. Sta. F, Md. Expt. Sta. H, N. Y. Expt. Sta. K, Pa. Expt. Sta.
[d] Unless otherwise specified. [e] Untreated except apples from Conn. and N. Y., treated with pesticides previously shown not to affect flavor quality. [f] Total actual pounds per acre.

i.e., application to the crop of two or more insecticides, fungicides, or a combination of the two. Pesticides in Table III are cross-indexed to make the information useful to both pathologists and entomologists, even though this involves repetition of the data.

On some pesticides, relatively few observations were made. A few of these involved new and/or experimental materials. Others were discarded after brief testing because of discontinuance of the use of the pesticide, the introduction of new and more effective materials to supersede the old, or limited applicability. It was decided to release all of the findings for the benefit of the users and manufacturers of the materials as well as to stimulate other investigators to fill the gaps where more data are needed. The data reported here were combined from all cooperating laboratories. They were verified independently by each investigator, who interpreted his own results.

The tables include some information on the actual amounts of pesticidal materials applied. For sprays, this is presented as pounds or quarts per 100 gallons per application as necessary in area of production. The pesticides in dust form are recorded as total pounds of actual ingredient per acre for soil or foliar applications or a combination of the two. An insecticide applied at 1 pound per acre nine times is recorded as 9 pounds. In a few experiments, excessive dosages were applied to simulate careless use of pesticides or to telescope the effect of long-term applications—e.g., 20 pounds per acre of chlordan or 15 pounds per acre of toxaphene per year for several years. Possible relevant details as to dates of application, nearness to harvest, depth and distribution of soil-applied chemicals, soil type, etc., are omitted. The locations of the field trials are labeled, and the reader may obtain the treatment schedules in greater detail from these sources.

Fifteen of the 36 single insecticides were represented by 14 to 68 evaluations and seven of the 17 combined insecticides by 14 to 45 tests. Fungicides were not so widely tested. Three of the 11 single fungicides were tested 13 times and three of 11 combinations were evaluated 16 to 43 times. Many of the data have been or will be published in greater detail as separate studies.

Average scores of treated samples showing "slight off-flavor" were infrequent and "definite off-flavor" average scores were rare enough to be ignored. Both off-flavor categories are tabulated and discussed together.

Discussion is generally limited to those pesticides or combinations of pesticides on which a sufficient number of evaluations were made to give some conception of distribution.

Discussion

About 21, 10, and 20% of the samples treated with BHC, lindane, and toxaphene, respectively, were judged to be off-flavor. The multiple pesticide treatments including toxaphene were judged off-flavor in 14% of the samples.

Five single insecticides indicated a noteworthy degree of adverse effect on flavor quality (significantly "poorer than standard" plus off-flavor). BHC, lindane, and toxaphene treatments induced poor flavor quality in 57, 55, and 48% of 14, 20, and 25 samples, respectively. The high level of ill effects from toxaphene was mainly for potato samples grown on soil treated with 15 pounds per acre applied in alternate years for 9 to 11 years as well as in the test year, a relatively high dosage (probably three to five times the amount necessary for insect control). Twenty-five per cent of the 24 samples treated with endrin and 16% of the 68 samples treated with malathion were judged to be in the poorer flavor category.

Single insecticides which in general did not induce poor flavor quality as based on 14 or more evaluations were: chlordan, DDT, Dibrom, Dilan, dimethoate, heptachlor, phosphamidon, Sevin, Thiodan, and Trithion.

Improved flavor quality was observed in 10 to 13% of the samples treated with chlordan, heptachlor, lindane, and endrin. Two of these—lindane and endrin—also showed an appreciable degree of poorer flavor.

Samples treated with toxaphene in combination with other insecticides had poor flavor quality in 50% of 14 tests, reflecting the results with potatoes (three of seven poor samples). About 28% of 18 samples treated with Sevin in combination with other pesticides were evaluated as poorer than standard, seemingly because of the interaction of pesticides. Samples treated with the combination of DDT with other pesticides showed quality loss in 24% of 38 samples, demonstrating the influence of toxaphene (five of nine poor samples). The single effect of Sevin and DDT was negative. Malathion in combination induced adverse flavor effects in 27% of 45 samples as compared with its single influence on 16% of 68 samples.

Three of the 11 single fungicides—Bordeaux, tribasic copper, and zineb, with 13 tests each on potatoes only—showed no ill effects on flavor and induced better flavor quality in approximately one third of the 13 tests. Although the PCNB treatments involved potatoes only in one crop year, in 11 tests (by two laboratories on two varieties from North Dakota and one from Maine) five of the samples were judged off-flavor and the other six poorer than standard.

None of the fungicides in combination resulted in mean scores showing slight or definite off-flavor. Poorer samples were evident, however, in nine of 43 (21%) captan-treated, and five of 18 (28%) thiram-treated samples. Of these 14 poorer samples, six were in combination with malathion and five others involved Sevin.

With multiple pesticides, it is difficult to ascribe poor flavor quality to a single component of the treatment, and the possibility of interaction should not be ignored.

There was no evidence of improved flavor quality associated with multiple treatments.

In the data shown some contradictory results are noted, in that the use of certain pesticides resulted in better as well as poorer flavor. These aberrant situations may be related to specific crop response, to soil type, to crop years with their varying macro- or micro-climate, to pesticidal carriers, to method, time, and distribution of the pesticides, or to unknown factors. The data presented from the NE-15 long-term study admirably demonstrate the need for continued and multiple observations before dogmatic interpretations may be made.

New Jersey was a member of the NE-15 project for three years with emphasis on instrumentation. The New Jersey Food Technology Department pursued taste panel evaluations on samples grown, treated, and tested in New Jersey. More ill effects were evident in the New Jersey tests than among all of the others—e.g., aldrin, chlordan, and dieldrin were classified as poorer than standard (*1*). The New Jersey results were omitted from the tables and the general discussion because they did not represent the group findings and because no samples were exchanged with other members. The validity of the New Jersey tests is recognized, and it is deemed that neither methodology nor panel acuity is responsible for the lack of agreement. Possible factors which may be related to the discrepancy between the New Jersey and the other samples are soil type, product form, formualtion of the pesticides, and other extraneous influences as discussed above. The NE-15 study was not designed to examine these possible interacting agents and any *a posteriori* conclusions would be of dubious validity.

Conclusions

Coordinated through the NE-15 regional project, seven state experiment Stations and the U. S. Department of Agriculture examined by organoleptic methods crops treated with pesticides to determine their influence on flavor quality.

During six years, 528 evaluations on 36 single insecticides, 152 on 18 combinations of insecticides, 66 on 11 single fungicides, and 118 on 11 fungicide combinations were made. Each average score represented the opinion of a trained or experienced panel ranging from five to 40 members and was based on a minimum of 20 judgments.

Insecticide evaluations involved 23 crops (20 vegetables and three fruits). Fungicide treatments were used on six crops (five vegetables and one fruit).

Five of the single insecticides and one of the single fungicides were associated with a notable degree of poor flavor quality. Six combinations of pesticides had adverse effects on flavor. Some of these seemed to be related to specific components of the multiple treatments while others were ascribed to interaction.

The committee does not condemn nor endorse any particular pesticide or combination of pesticides. Both known and unknown influences may alter the picture and vitiate any blanket conclusions. We suggest rather that these data be considered a reference summary for the reader to consult according to his own interest as to crop, amount of pesticide, number of crop years tested, and degree of accord among analysts.

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