of the 12-week period during which the cows were on dieldrin intake, ratios of dieldrin in fat to dieldrin in milk ranged between 12 and 18 to 1 and averaged 15.7 to 1 rather than 25 to 1. This phenomenon has also been reported by Kiigemagi *et al.* (*6*) who used endrin. When the dieldrin intake was discontinued, however, and the amount of dieldrin appearing in milk became dependent upon only one source—the existing concentration in the fat of the animal—the ratios became greater than the accepted figure of 25 to 1. The per cent decline in fat residues after the animals had been off dieldrin for 6 weeks was only about 30%, while the decline in dieldrin in milk was greater than 80%. This is borne out also in related work with other insecticides (*4*).

Table III gives dieldrin residues in various cow tissues at the end of 12 weeks of dieldrin intake and after an additional 6-week feed-off period. Concentrations in the various tissues are roughly proportional to the fat content of the tissues.

Steaks and roasts from cows which had been fed high dosages of dieldrin were cooked and compared for dieldrin content with similar raw cuts. No significant losses of dieldrin due to cooking were evident.

Weight gains of treated cows were comparable to those of checks. During the experiment and at slaughter, animals showed no evidence of pathology. Milk production throughout was consistent with that which could be expected.

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PESTICIDE RESIDUES IN MEAT

Storage of Dieldrin in Tissues of Steers, Hogs, Lambs, and Poultry Fed Dieldrin in Their Diets

NORMAN GANNON, R. P. LINK, and G. C. DECKER

Illinois Natural History Survey, University of Illinois College of Veterinary Medicine, and Illinois Agricultural Experiment Station, Urbana, Ill.

Dieldrin was fed in the diet to various animals for 12 weeks at levels of 0.1, 0.25, 0.75, 2.25 p.p.m. Samples of tissues were then analyzed for dieldrin. It was detectable in the fat of all animals fed on the various intake levels. When detectable in other tissues, residues were proportional to the fat content of the tissues. For each species the amount of dieldrin stored appeared to be proportional to the rate of intake. Laying hens stored the greatest quantity of all, but their eggs contained very little dieldrin. Steers stored more dieldrin in their tissues in terms of parts per million than did hogs, while lambs stored less than hogs.

DIELDRIN, AN INSECTICIDAL MATERIAL consisting of not less than 85% 1,2,3,4,10,10 - hexachloro - 6,7 - epoxy-1,4,4a,5,6,7,8,8a - octahydro - 1,4-*endo* - *exo* - 5,8 - dimethanonaphthalene (HEOD), for several years has been a very effective insecticide on a large variety of insects attacking many different crops. It has consequently been registered and approved for use on many of these crops. As a chlorinated hydrocarbon, it is known to be stored in animal fat as a result of ingestion or contact (*1–3*). Therefore, the extent of its usage on forage to be used as animal feed will to a considerable degree be determined by its propensity for storage in animal tissues. Studies reported in this paper were initiated to develop data considered a prerequisite to the possible establishment of tolerances for dieldrin on forage and in animal fat.

Methods

Animals under test were fairly uniform in age, breed, and weight. They consisted of Black Angus steers, Yorkshire hogs, Shropshire lambs, White Rock fryers, and Leghorn laying hens.

Rations for the various breeds were as follows—steers: ground shelled corn and alfalfa hay; hogs: ground shelled corn, dehydrated alfalfa meal, soybean oil meal, ground limestone, and steamed bone meal; lambs: shelled corn, linseed meal, and alfalfa hay; fryers: growing mash; and hens: laying mash. All rations were obtained from the University of Illinois feed storage. Prior to the start of feeding, they were analyzed to ensure that they bore no dieldrin residues.

Before the experiment was started, efforts were made to estimate the ap-

Table I. Dosage Rates and Number of Animals on Test

Dieldrin in Diet, P.P.M.	No. of Animals per Dosage				
	Steers	Hogs	Lambs	Fryers	Hens
0	2	2	2	6	4
0.1	3	3	3	6	5
0.25	3	3	3	6	5
0.75	3	2	2	6	5
2.25	2	2	2	...	...

Table II. Dieldrin Residues in Tissues of Test Animals after 12 Weeks of Dieldrin Intake and after an Additional 6 Weeks of Feed-off

No. of Animals	Dieldrin in Feed, P.P.M.	Av. Total Dieldrin Intake, Mg./Kg.	Dieldrin Content, P.P.M.											
			Renal Fat		Body Fat		Liver		Kidney		Steak[a]		Roast	
			12 wk.	18 wk.	12 wk.	18 wk.	12 wk.	18 wk.	12 wk.	18 wk.	12 wk.	18 wk.	12 wk.	18 wk.
							Steers							
2	0	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
3	0.1	0.221	0.5	0.3	0.3	0.3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
3	0.25	0.543	0.9	0.5	0.8	0.7	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
3	0.75	1.596	4.0	1.2	3.0	3.4	0.2	0.1	<0.1	<0.1	0.4	<0.1	0.7	0.5
2	2.25	4.739	9.7	3.3	7.8	4.9	0.7	0.1	0.2	<0.1	1.0	0.3	2.3	0.4
							Hogs							
2	0	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
3	0.1	0.246	0.4	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.1	<0.1
3	0.25	0.622	0.3	0.8	0.4	0.7	<0.1	<0.1	0.1	<0.1	0.1	<0.1	0.3	0.2
2	0.75	1.786	2.5	1.5	3.0	1.4	0.3	<0.1	0.3	<0.1	0.7	<0.1	0.5	0.2
2	2.25	5.160	5.2	2.5	3.5	2.2	0.2	0.4	0.5	0.4	1.9	0.2	1.2	0.3
							Lambs							
2	0	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
3	0.1	0.356	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.2	<0.1
3	0.25	0.915	0.4	<0.1	0.4	0.2	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.2	<0.1
2	0.75	2.649	0.3	0.2	0.9	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1
2	2.25	9.021	1.9	0.3	1.5	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1

[a] Chops for hogs and lambs.

proximate daily feed intake for each animal or group of animals. During the experiment, the amount of feed provided for each animal or group was kept essentially at these predetermined levels. This practice reduced to a minimum the amount of unconsumed feeds.

The toxicant used was undiluted technical dieldrin containing 85% hexachloroepoxyoctahydro-*endo*-*exo*-dimethanonaphthalene. It was formulated at various concentrations in acetone, so that 1 ml. of the solution was sufficient to add the desired amount of dieldrin, in parts per million, to 1 pound of feed. The total ration was pipetted in this manner each day prior to feeding.

Each steer and hog was confined to an individual stall during feeding periods. The same stall was used to house the same animal throughout the experiment. After daily rations have been consumed, the animals were released and allowed to range in small corrals. Lambs and fryers were fed in groups, while laying hens were fed in individual compartments. Deep troughs were used for chickens to minimize the amount of feed wasted. Records on feed consumption and increases in weight were kept for all animals.

Dosages of dieldrin, in terms of parts per million on the rations, and the number of each species on the various dosages are shown in Table I.

All animals except the fryers were fed dieldrin at the various levels indicated for 12 weeks. At that time, all of the steers, hogs, and lambs except one in each group were slaughtered. The remaining animals were fed on uncontaminated rations for 6 more weeks to determine the decline in residues in the tissues. Eggs were collected from laying hens over the 12-week period, after which both the eggs and the fat of the hens were analyzed. Four-week old fryers were fed for 6 weeks and then tissues were analyzed. At the time of slaughtering, tissue samples were collected, sealed in Pliofilm bags, and stored at 0° F. until analysis.

Table III. Relation of Intake of Dieldrin to Deposition in Fat of Various Animals after 12 Weeks of Feeding

Animal	P.P.M. in Diet	Av. P.P.M. in Renal and Body Fat	P.P.M. Stored per P.P.M. Intake	Av. Total Dieldrin Intake, Mg./Kg.	Ratio P.P.M. in Fat to Total Intake
Hens	0.10	4.1	41.0	0.461	8.89
	0.25	10.2	40.8	1.152	8.85
	0.75	35.7	47.6	3.456	10.33
			Av. 43.1		Av. 9.36
Steers	0.1	0.4	4.0	0.221	1.81
	0.25	0.8	3.2	0.543	1.47
	0.75	3.5	4.7	1.596	2.19
	2.25	8.7	3.9	4.739	1.84
			Av. 3.95		Av. 1.83
Hogs	0.1	0.4	4.0	0.246	1.63
	0.25	0.4	2.0	0.622	0.65
	0.75	2.8	3.7	1.786	1.57
	2.25	4.3	1.9	5.160	0.83
			Av. 2.90		Av. 1.17
Lambs	0.1	0.1	1.0	0.356	0.28
	0.25	0.4	1.6	0.915	0.44
	0.75	0.6	0.8	2.649	0.23
	2.25	1.7	0.8	0.021	0.19
			Av. 1.05		Av. 0.29
Cows[a]	0.1	0.2	2.0	0.30	0.67
	0.25	0.9	3.6	0.55	1.64
	0.75	1.3	1.7	2.17	0.60
	2.25	5.5	2.4	6.15	0.89
			Av. 2.43		Av. 0.95

[a] Data from related experiment (*4*).

The specific colorimetric method of O'Donnell, Johnson, and Weiss (*5*) as modified by the Shell method series (*6*) was used to determine microgram quantities of dieldrin in the tissues. The method was sensitive to 0.1 p.p.m. Samples were first ground in a meat grinder, saponified with ethanolic potassium hydroxide, extracted with redistilled Skellysolve B, and chromatographed on activated magnesium oxide–Celite (2 to 1) followed by the development of color specific for dieldrin. Recoveries, added to check samples, consistently fell between 80 and 120% of the expected.

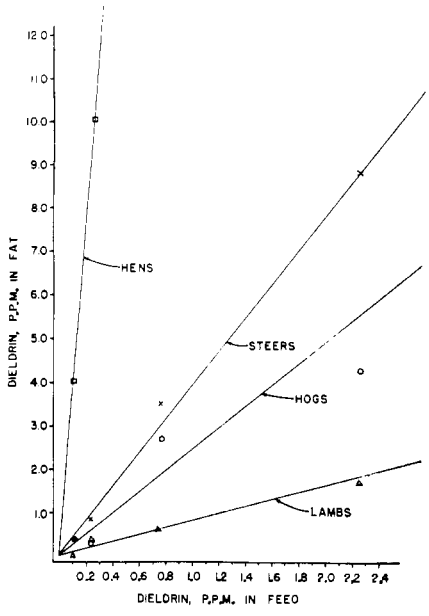

Figure 1. Average dieldrin content of fat of hens, steers, hogs, and lambs receiving 0.1, 0.25, 0.75, and 2.25 p.p.m. of dieldrin in the diet for 12 weeks

Table IV. Dieldrin Residues in Tissues of Fryers after 6 Weeks of Dieldrin Intake

No. of Animals	Dieldrin in Feed, P.P.M.	Av. Total Dieldrin Intake, γ/G.	Dieldrin Constant, P.P.M.	
			Drumstick	Breast
6	0	0	<0.1	<0.1
6	0.1	0.354	<0.1	<0.1
6	0.25	0.846	<0.1	<0.1
6	0.75	2.555	0.1	<0.1

Table V. Dieldrin Residues in Fat of Hens Fed Dieldrin for 12 Weeks and in Eggs Collected over the Feeding Period

Dieldrin in Feed, P.P.M.	Av. Total Dieldrin Intake, Mg./Kg.	Dieldrin Content, P.P.M.							
		Weeks after Start of Intake							Fat of Hens at 12 weeks
		6	7	8	9	10	11	12	
		Eggs							
0	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.1	0.461	0.1	<0.1	<0.1	0.1	0.1	0.1	0.1	4.1
0.25	1.152	0.2	0.1	0.2	0.2	0.4	0.1	0.2	10.2
0.75	3.456	0.2	0.5	0.4	0.4	0.8	0.7	1.2	35.7

Results and Discussion

As indicated in Tables II and III which give the levels of dieldrin residues present in various tissues of steers, hogs, and lambs as a result of feeding various dosages for 12 weeks, the amounts stored are in direct proportion to the fat content of the tissues. In general, amounts in renal fat were slightly higher than those in body fat. This was expected because analyses run to determine the actual fat content of the various tissues indicated that most renal fat samples contained more actual fat and less connective tissue than did body fat. Steak and roast cuts were next in magnitude or storage value, while liver and kidney stored the least. At levels of 0.25 p.p.m. or less in the feed, no dieldrin was measurable in steaks and roasts of steers. Lambs showed no dieldrin in chops over the entire range of dosages, and residues found in roasts were so close to the sensitivity of the method that they are probably insignificant. Of interest is the fact that storage occurred in fat samples at all levels of intake. Considering variations between animals, the amount of storage appeared to be proportional to intake.

Over the feeding period, lambs ingested about twice as much dieldrin per unit of body weight as did the steers, while hogs ingested only slightly more than the steers. Steers, however, stored about twice as much as hogs, and about five times as much as lambs, but only about $^1/_{10}$ the amount found in hen fat. Because the hogs contained a higher percentage of fat in their bodies than the steers, this might be offered as an explanation for the lower residues in the fat of hogs. It cannot explain the differences when lambs are considered, however, because throughout the test the lambs were very lean. Thus it appears that the propensity for the storage of dieldrin in fat may be a characteristic of the species (Figure 1). In a related test, milk cows showed slightly less dieldrin in tissues than did steers (*4*). Losses through lactation may partially account for this.

Six weeks after the feeding of dieldrin was stopped, analyses indicated that the dieldrin content of steer and hog fat had dropped about 40%, while the level in fat from lambs had dropped about 70%.

At the highest level of feeding for fryers (0.75 p.p.m.), only 0.1 p.p.m. of dieldrin was found in drumsticks after 6 weeks of feeding (Table IV). Breast and other drumstick samples gave results below the sensitivity of the method.

In eggs, dieldrin residues were barely measurable after 9 weeks of feeding at 0.1 p.p.m. in the ration. The fat of the hens, analyzed 12 weeks after the start of feeding, showed high residues (Table V).

The weight gains of animals used in this study were consistent with those fed similar amounts of untreated rations. All the animals appeared normal throughout the testing period. At the time of slaughter there was no evidence of pathology in any of the animals.

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