Dieldrin Accumulation in Tissues of the Sheep

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One hundred thirty-five sheep were fed dieldrin at levels of 0, 0.5, 1.0, 2.0, and 4.0 mg per kg body weight for up to 32 weeks, and accumulation of dieldrin in the tissues was measured. Four mg dieldrin per kg was lethal to most sheep in less than 4 weeks. Correlations of dieldrin in fat of bone, brain, carcass, adipose tissue, heart, muscle, and spinal cord with that in blood were high. Correlations of dieldrin accumulated in blood with that in plasma or kidneys were low. Dieldrin accumulation in the tissues was readily affected by level of dieldrin in the ration, but it was not affected by the level or source of energy in the ration. It is suggested that samples of bone would be suitable for monitoring chlorinated hydrocarbon insecticides in marketable meats.

While it is known that chlorinated hydrocarbon insecticides such as dieldrin accumulate in body fat, systematic studies of the influence of diet and level of insecticide eaten upon this accumulation over relatively long periods of time are lacking. Many experiments have been conducted in which pesticide accumulation in body fat was determined by biopsy techniques (Laben *et al.*, 1965; Radeleff, 1964). Similarly, in some studies the amount of pesticides in brain has been compared with that residual in other parts of the carcass (Robinson *et al.*, 1967; Stickel *et al.*, 1966, 1969). However, in many cases the pesticide was not given in the food; or, if given in the food, the concentration was specified but the amount of food eaten was not controlled or reported.

It seemed reasonable to determine patterns of dieldrin accumulation in tissues of sheep fed a constant diet, and whether or not these patterns were appreciably altered by the amount of energy and fat consumed.

MATERIALS AND METHODS

Animal Treatment. One hundred thirty-five crossbred wethers weighing 30 to 40 kg were randomly divided among 15 dietary groups, as shown in Table I. The sheep were penned individually and fed 400 g pelleted alfalfa hay and 100 g ground supplement twice daily (Davison, 1970). The variables studied were five levels of dieldrin and two levels of energy, with the higher level of energy supplied by either carbohydrates or fat.

The experiment was conducted in two replicates 1 year apart. Dieldrin levels in the first replicate were 0, 1, 2, and 4 mg per kg body weight per day. But 10 of 12 sheep fed the 4-mg level of dieldrin died within 4 weeks, so this level was discontinued. Levels of 0, 0.5, 1, and 2 mg dieldrin per kg body weight were fed in the second replicate. To maintain orthogonality, 10 sheep were fed the 0.5-mg level. Thus, 60 sheep were used in the first replicate and 75 were used in the second.

Technical dieldrin was dissolved in acetone and a premix was made by mixing the acetone solution into a portion of the supplement. After the acetone had evaporated, supplements containing appropriate amounts of dieldrin were prepared from the premix. Then samples of these supplements were assayed to verify their dieldrin content before they were fed to the sheep. Dieldrin intake was adjusted to body weight at biweekly intervals. Energy intake was increased by adding 20% cornstarch and 5% corn syrup or 12% corn oil to the pelleted hay. Dieldrin was not detected as a contaminant in any of the feeds (0.01 μg per g detectable).

With exception of sheep fed 4 mg dieldrin per kg, two sheep from each cell were slaughtered initially and at 4, 8, 16, and 32 weeks. The entire adrenals, brain, heart, kidneys, liver, and spinal cord were collected, and bone, adipose, and muscle tissues were sampled. Bone was represented by the proximal one-half of a femur; adipose tissue was collected from the omentum; and muscle tissue was collected as a cross section on the posterior of a rear leg. After removing the gastrointestinal contents and samples of tissues, the carcass remains and intestines from sheep in the second replicate were ground and sampled (adequate grinding facilities were not available in the first replicate). All tissues and samples were ground and freeze-dried, and the dried material stored in sealed glass jars. Freeze-drying was accomplished in flasks attached externally on a Virtis Model 10-146 MR-VA freeze-drier.

Twenty-four hours before slaughter, all sheep being fed 2 mg dieldrin per kg were put in metabolism cages (Hedde *et al.*, 1970) and given 50 to 100 μCi dieldrin-^{14}C, specific activity 25 to 190 μCi per mg. Urine and feces were collected, and after slaughter, feces, tissues, and carcasses were handled as above.

Dieldrin Analysis. Portions of dried material, generally 2 g, were extracted for 24 hours with petroleum ether on a Soxhlet extractor. Portions of this extract were then chromatographed on Florisil (Johnson, 1965). The efficiency with which dieldrin was eluted from Florisil was checked on all samples. A small amount of dieldrin-^{14}C was added to the extract of nonradioactive samples before chromatography. Dieldrin in the eluate was then corrected to 100% recovery, based upon the recovery of radioactivity. Portions of the Florisil eluate were dried under a stream of nitrogen at 37° C and the residue dissolved in hexane. Dieldrin in this hexane solution was measured by electron capture gas chromatography.

Blood and plasma were extracted with hexane and assayed according to the procedure of Crosby and Archer (1966).

Assay procedures for dieldrin-^{14}C in tissues and excretions were those described by Hedde *et al.* (1970).

Fat and Dry Matter Determination. Fat was determined by loss in weight during Soxhlet extraction, and dry matter was determined by loss in weight during freeze-drying.

Statistical Analyses. The data were analyzed statistically by analysis of variance. Least squares analysis was used where loss of animals or data caused unequal subclass numbers. Ration (energy levels), dieldrin levels, and slaughter periods (time) were treated as discrete effects, with exception

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Table I. Experimental Details of Sheep-Feeding Experiment

HEOD[a] Per Day (mg/kg body wt.)	Number of Sheep in Each Group		
		Energy Fortification in Ration	
	Control	Added CHO[b]	Added fat[c]
0	10	10	10
0.5	10	10	10
1.0	10	10	10
2.0	10	10	10
4.0	5	5	5

[a] Supplied as technical dieldrin containing 85 to 87% of 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). [b] 160 g cornstarch and 40 g corn syrup added to the control ration daily. [c] 96 g corn oil added to the control ration daily.

of the blood data, where time was treated as a continuous effect.

Statistical significance was assessed at probabilities of 5% or less. Data not statistically significant are not discussed as treatment-related.

RESULTS

Tremors occurred intermittently in some of the sheep fed 2 mg dieldrin per kg, and two deaths occurred (Davison, 1970). The two surviving sheep fed the 4-mg level of dieldrin exhibited tremors and were killed on the 4th week.

Composition of Tissues. Table II gives the % fat and dry

Table II. Mean Composition of the Tissues and Carcasses of Sheep Fed Dieldrin

	Adrenals	Bone	Brain	Carcass	Adipose	Heart	Kidneys	Liver	Muscle	Spinal Cord
	% Dry Matter									
Ration[a]										
Control	21.5	76.1	22.5	35.4	68.0	31.5	20.0	29.2	24.9	32.3
Starch	22.5	78.7	22.6	38.7	73.9	31.2	20.3	29.1	24.9	32.1
Corn oil	21.7	80.1	22.8	40.9	81.7	34.0	20.7	29.5	26.2	32.6
Dieldrin Level[b]										
0 mg/kg	21.4	78.1	23.0	39.0	78.2	33.3	20.3	29.3	25.5	32.7
0.5 mg/kg	22.5	78.6	22.5	37.9	76.4	32.5	20.1	29.2	25.4	32.5
1.0 mg/kg	21.1	78.8	22.6	40.2	75.3	32.3	20.1	29.1	25.2	31.9
2.0 mg/kg	22.5	77.8	22.5	36.7	68.1	30.8	20.7	29.4	25.3	32.3
Slaughter Period[c]										
Week 0	21.9	74.6	22.3	32.1	56.0	30.7	20.0	29.0	24.3	32.0
Week 4	22.2	73.4	22.5	33.5	67.2	31.4	20.2	28.9	24.2	31.8
Week 8	21.3	78.0	23.1	36.3	73.3	31.2	19.7	28.8	25.1	32.6
Week 16	21.5	81.7	22.5	42.6	84.1	33.0	20.7	29.7	25.5	33.2
Week 32	22.6	84.1	22.7	47.2	92.2	34.8	20.9	29.8	27.3	32.2
	Total Dry Matter, g									
Ration										
Control	0.63		22.2	9629		55.6	21.2	196		12.3
Starch	0.65		22.6	11109		56.1	21.7	208		12.5
Corn oil	0.62		22.1	13065		63.7	22.2	212		12.7
Dieldrin Level										
0 mg/kg	0.62		21.7	11386		60.1	21.9	177		12.1
0.5 mg/kg	0.61		22.0	11774		61.1	21.4	201		12.9
1.0 mg/kg	0.55		22.3	12025		56.7	21.2	215		12.4
2.0 mg/kg	0.76		23.1	9379		56.1	22.2	228		12.6
Slaughter Period										
Week 0	0.61		21.2	7612		49.3	21.5	169		11.4
Week 4	0.67		21.4	8473		55.7	21.2	198		12.0
Week 8	0.59		22.3	9870		55.6	20.6	205		12.8
Week 16	0.62		22.7	13010		61.3	21.0	215		13.3
Week 32	0.68		23.6	17374		70.5	24.2	240		13.0
	% Fat in Dry Matter									
Ration										
Control	22.3	31.1	39.2	38.8	88.8	52.6	17.6	11.7	19.3	60.1
Starch	22.8	32.5	38.4	44.8	92.7	51.4	17.3	11.5	17.7	60.2
Corn oil	24.6	34.1	38.9	51.2	95.7	56.0	18.6	13.1	21.5	59.1
Dieldrin Level										
0 mg/kg	21.6	32.0	39.7	46.9	93.8	55.6	19.2	12.1	21.0	62.7
0.5 mg/kg	23.1	33.8	42.8	45.6	94.4	56.0	18.9	13.6	20.2	60.2
1.0 mg/kg	22.5	32.5	37.4	46.8	93.0	52.5	17.4	11.3	18.8	58.4
2.0 mg/kg	25.8	31.9	35.5	39.8	88.4	49.4	15.8	11.4	18.2	57 9
Slaughter Period										
Week 0	23.6	29.9	37.6	32.8	84.4	49.6	17.5	11.3	17.7	58.8
Week 4	22.2	30.1	38.6	35.4	89.6	51.9	17.7	13.3	17.4	59.6
Week 8	24.7	31.1	40.3	43.5	92.2	52:6	18.5	12.4	21.5	58.9
Week 16	23.8	36.5	38.6	52.8	97.1	54.8	17.5	11.1	18.4	60.8
Week 32	21.8	35.2	39.0	60.2	98.7	54.9	17.8	12.3	22.7	60.9

[a] Each mean represents main effects of ration at all dieldrin levels and slaughter periods. [b] Each mean represents main effects of dieldrin level at all ration energy levels and slaughter periods. [c] Each mean represents main effects of slaughter period at all ration energy levels and dieldrin levels.

Table III. Mean Total Dry Weight of Liver per Unit Live Weight of Sheep Fed Dieldrin

	Slaughter Period, Week					
	0	4	8	16	32	Mean
	Liver Dry Matter, g/kg Live Weight					
Ration						
Control	4.68	5.44	5.59	5.44	5.15	5.26
Starch	4.65	5.32	5.28	5.32	4.94	5.10
Corn oil	4.53	5.36	5.23	5.04	4.96	5.02
Dieldrin Level[a]						
0 mg/kg	4.48	4.49	4.18	4.46	3.94	4.31
0.5 mg/kg	4.93	5.04	5.49	5.20	4.86	5.10
1.0 mg/kg	4.72	5.50	5.38	5.28	5.30	5.24
2.0 mg/kg	4.36	6.46	6.42	6.11	5.98	5.86

[a] Interaction of dieldrin level X slaughter period was significant, $P < 0.05$

matter for all tissues collected, and the total dry matter for those tissues which were collected in total. Percent dry matter was increased in bone, carcass, and adipose tissue of sheep fed added starch or corn oil compared with that of sheep fed the control ration; and the percent dry matter of these tissues, plus that in heart and muscle, increased in all sheep with each successive slaughter period. Percent dry matter in bone, carcass, fat, and heart was lower in sheep fed 2 mg dieldrin per kg body weight than in sheep fed lower levels of dieldrin.

Total dry matter in carcass, heart, and liver was increased by feeding additional energy, while total dry weight of all tissues except adrenals was increased with time. Carcasses of sheep fed 2 mg, dieldrin per kg, were lighter than those of sheep fed lower levels of dieldrin.

Significant interactions of ration and dieldrin level with time occurred in dry weight of liver, suggesting that liver increased in weight at different rates across some treatment combinations. Livers of sheep fed corn oil or starch increased in weight at a faster rate than did livers of control sheep. Livers from sheep fed 0.5 or 1.0 mg dieldrin per kg increased in weight at similar rates, but these rates were faster than those of sheep given no dieldrin. Livers of sheep fed 2 mg dieldrin per kg increased in weight at a faster rate than did those of sheep fed 0.5 or 1.0 mg dieldrin per kg. When liver weight was corrected for body weight (Table III), livers from sheep fed additional energy were smaller than those from control sheep, and livers from sheep fed the 2-mg level of dieldrin were comparatively larger than livers from sheep fed the 0.5- and 1.0-mg levels.

Percent fat in adrenals, brain, liver, kidneys, and spinal cord remained constant across all treatment combinations, while % fat in bone, carcass, adipose tissue, heart, and muscle increased with higher energy intake and with time (Table II). Percent fat in bone, carcass, adipose tissue, and heart was decreased by feeding the 2-mg level of dieldrin.

Dieldrin Accumulation. Accumulation of dieldrin in the fat of the various tissues is shown in Table IV. In the case of tissues, the limit of the dieldrin determination was 0.1 μg per g. Some contamination of control tissues occurred during freeze-drying, and, in at least one case, a control sheep was accidentally fed a ration containing dieldrin. Very small losses of dieldrin occurred during lyophilization. However, by

Table IV. Mean Accumulation of Dieldrin in Tissues of Sheep Fed Dieldrin

	Adrenals	Bone	Brain	Carcass	Adipose	Heart	Kidneys	Liver	Muscle	Spinal Cord
	Dieldrin Concentration in Fat of Dry Tissue, μg/g									
Ration[a]										
Control	68.4	185.0	37.7	151.0	199.0	182.0	113.0	330.0	148.0	38.6
Starch	60.2	175.0	43.6	119.0	147.0	144.0	170.0	325.0	112.0	36.4
Corn oil	45.2	105.0	26.8	101.0	125.0	116.0	87.0	250.0	104.0	29.5
Dieldrin,[b] 0 mg/kg										
Week 0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Week 4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Week 8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Week 16	5.0	2.9	0.1	3.6	2.6	1.1	1.0	7.9	2.7	0.5
Week 32	7.1	0.1	0.0	0.5	0.2	0.0	0.0	4.1	0.0	0.3
Dieldrin,[b] 0.5 mg/kg										
Week 0	8.0	0.5	0.7	0.9	0.3	0.5	0.8	2.8	3.0	0.9
Week 4	41.2	37.5	14.1	57.9	72.1	52.6	40.2	153.0	48.7	15.3
Week 8	57.3	59.4	15.7	72.6	120.0	68.1	43.1	180.0	53.9	20.9
Week 16	39.4	66.3	16.2	63.8	126.0	62.0	56.1	218.0	63.8	15.7
Week 32	65.9	98.6	20.5	110.0	126.0	107.0	80.0	323.0	104.0	18.9
Dieldrin,[b] 1.0 mg/kg										
Week 0	12.1	0.2	0.5	0.7	0.0	0.0	0.0	0.9	0.0	0.7
Week 4	78.6	165.0	37.7	130.0	162.0	151.0	96.4	454.0	105.0	25.9
Week 8	61.1	102.0	28.7	126.0	177.0	133.0	124.0	381.0	142.0	43.7
Week 16	91.3	176.0	28.4	147.0	197.0	153.0	137.0	464.0	173.0	42.8
Week 32	111.0	172.0	55.1	203.0	186.0	206.0	169.0	509.0	212.0	48.2
Dieldrin,[b] 2.0 mg/kg										
Week 0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Week 4	172.0	634.0	109.0	271.0	373.0	350.0	195.0	510.0	227.0	85.5
Week 8	99.8	486.0	105.0	430.0	513.0	447.0	253.0	702.0	319.0	93.9
Week 16	87.7	566.0	138.0	428.0	465.0	569.0	638.0	966.0	445.0	150.0
Week 32	225.0	610.0	151.0	752.0	677.0	649.0	629.0	1157.0	522.0	133.0
Dieldrin,[b] 4.0 mg/kg										
	150.0	358.0	102.0		603.0	411.0	305.0	786.0	438.0	105.0

[a] Each mean represents main effects of ration at all dieldrin levels and slaughter periods. [b] Each mean represents the effects of the specified dieldrin level and slaughter period at all ration energy levels.

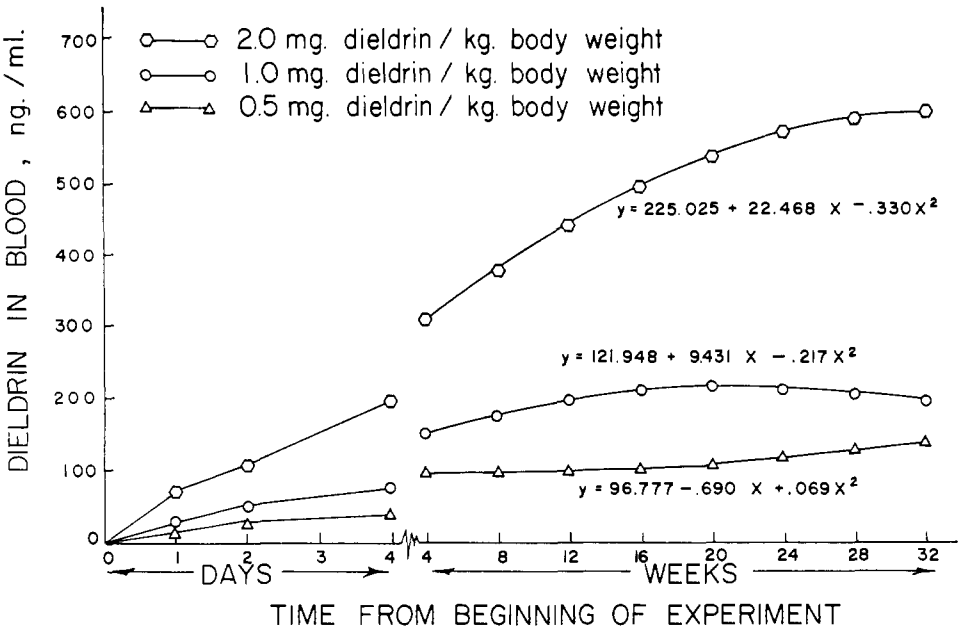

Figure 1. Accumulation of dieldrin in blood of sheep fed dieldrin. Values from days 0 to 4 are experimental means. The equations and values plotted from weeks 4 to 32 are predicted from the data obtained in this time period

monitoring the radioactivity in the tissues of sheep fed dieldrin-^{14}C and in the water evolved during freeze-drying of these tissues it was estimated that less than 1% of the dieldrin was lost in this process.

Dieldrin concentration in adrenals was more erratic than in other tissues. Superficial fat was difficult to trim off the adrenals before processing, and extracts from this tissue contained more substances which interfered with gas chromatography. Very little dieldrin was found in the spleen, so collection of this tissue was discontinued early in the experiment.

Dieldrin accumulated equally in the fat of bone, carcass, adipose tissue, and heart. Accumulation in the fat of muscle tissue and kidneys was slightly less than that in the preceding tissues. Brain and spinal cord accumulated equal amounts of dieldrin, but here accumulation was much less than that in adipose tissue. Per unit of fat, accumulation was higher in liver than in any other tissue.

The level of dieldrin accumulated in all tissues was directly related to the level of dieldrin fed. This is shown graphically for blood in Figure 1. Also, dieldrin accumulated to higher concentrations in all tissues of sheep fed the 2-mg level of dieldrin than in corresponding tissues of sheep fed the 4-mg level.

The accumulation of dieldrin in all tissues tended to plateau with time at all levels of dieldrin fed. However, this observation should be viewed cautiously at this time because the sheep fattened considerably by the end of the experiment (Davison, 1970). Fat deposition would dilute the dieldrin accumulated in the tissues and could, in this case, give a false plateau. Long-term balance studies with dieldrin-^{14}C are in progress to study this problem.

Distribution of Dieldrin-^{14}C. Distribution of dieldrin-^{14}C is given in Table V. Radioactivity in adipose tissue, heart, muscle, brain, and spinal cord was readily extracted with petroleum ether, and this material behaved as dieldrin during cleanup and gas chromatography. Not all of the radioactivity in the liver, kidneys, or digestive tract extracted with petroleum ether, but that which did extract behaved as dieldrin. Radioactivity that could not be extracted with petroleum ether could be extracted with methanol. These extraction characteristics have been used for separating dieldrin from its metabolites, the metabolites being more soluble in more polar solvents (Hedde *et al.*, 1970; Korte and Arent, 1965; Matthews and Matsumura, 1969).

Highest radioactivity per unit dry matter appeared in the gall bladder. Virtually none of this radioactivity extracted with petroleum ether, but it all dissolved in methanol, along with most of the dried bile. Very little dieldrin was present in urine. The excretion of dieldrin metabolites in urine has been discussed elsewhere (Hedde *et al.*, 1970).

The radioactivity was equally distributed in the extractable fat of adipose tissue, bone, and heart, further verifying the relationship observed with the cold dieldrin. Although the number of sheep involved in this portion of the study was small, the distribution of the radioactivity among the various tissues did not appear to be affected by previous exposure to dieldrin.

Correlations. Correlations of dieldrin in the blood, plasma,

Table V. Mean Distribution of Radioactivity in Sheep 24 Hr Following Dosing with Dieldrin-^{14}C

Tissue	Recovery,[a] %	Extractable with Petroleum Ether,[b] %
Adipose	(1.1)	102.3
Heart	0.4	102.3
Muscle	(0.1)	105.4
Brain	0.1	100.9
Spinal cord	0.05	97.5
Carcass	55.5	91.8
Liver	3.0	78.5
Kidneys	0.1	64.3
Rumen contents	17.4	63.9
Gastrointestinal contents	7.0	66.1
Feces	3.2	61.7
Urine	4.4	
Total	92.35	

[a] Data in this column were obtained by combusting portions of the various samples. The ^{14}C so obtained as CO_2 is expressed as a % of the dose. [b] Data in this column were obtained by extracting the various samples with petroleum ether. The radioactivity obtained is expressed as a % of that obtained by combustion.

Table VI. Correlations of Dieldrin in Plasma, Blood, and Fat of Various Tissues of Sheep Fed Dieldrin[a]

	Adrenals	Bone	Brain	Adipose	Heart	Kidney	Liver	Muscle	Spinal Cord	Plasma	Carcass	Blood
Adrenals	1.00000	0.73853	0.86420	0.80596	0.86752	0.63750	0.76898	0.84838	0.84975	0.46011	0.83333	0.58871
Bone		1.00000	0.87831	0.67408	0.79069	0.61098	0.68160	0.68439	0.80236	0.43674	0.70491	0.75606
Brain			1.00000	0.81020	0.93130	0.81094	0.87526	0.85005	0.92397	0.51056	0.87203	0.76434
Adipose				1.00000	0.82826	0.65208	0.80074	0.83015	0.82514	0.56864	0.93034	0.83494
Heart					1.00000	0.76877	0.89453	0.93236	0.94318	0.55889	0.95532	0.85649
Kidney						1.00000	0.85833	0.68099	0.75873	0.40151	0.70475	0.47716
Liver							1.00000	0.85655	0.85454	0.51793	0.85055	0.68477
Muscle								1.00000	0.89470	0.55651	0.96230	0.75504
Spinal cord									1.00000	0.61031	0.93331	0.81469
Plasma										1.00000	0.52306	0.48913
Carcass											1.00000	0.79734
Blood												1.00000

[a] The correlations were derived from all data, including all rations, dieldrin levels, and slaughter periods.

and fat of various tissues are given in Table VI. Correlations of dieldrin in plasma and kidney were generally lower than those for the remaining tissues. Interestingly, correlations for dieldrin in blood with other tissues were much higher than those for plasma.

DISCUSSION

From the data reported here and in a previous paper (Davison, 1970), it appears that 2 mg dieldrin per kg body weight was the maximum daily intake that could be tolerated by sheep for prolonged periods. This level of feeding equaled 80 to 100 ppm of dieldrin in the diet. Evidence for chronic poisoning at this level included tremors, reduced growth and fattening, and increased dry mass of the liver.

As the experiment progressed, it became increasingly difficult to avoid contamination of tissues from control animals with dieldrin while the tissues were being processed. Very small amounts of dieldrin distilled with water on the freeze-dryer. And the cross-contamination of control samples that occurred was not anticipated, since they were dried in flasks attached externally.

It was assumed that some of the information obtained from feeding dieldrin to sheep could be extended generally to include other chlorinated hydrocarbon insecticides. Although the amount of energy fed per day was increased from about 3000 kcal per sheep to 4000 kcal, by adding carbohydrates or fat, the accumulation of dieldrin in the tissues was not significantly affected. Therefore, manipulation of dietary energy or fat to reduce accumulation of chlorinated hydrocarbon insecticides in body tissue would be of little value.

The use of dieldrin-^{14}C in some of the sheep proved to be quite useful for detecting loss of dieldrin during sample processing and analysis. It also provided a means of determining where metabolites of dieldrin might be present in appreciable quantities. This includes the liver, gall bladder, kidneys, rumen, and gastrointestinal contents, and the excretions.

Those doing research with birds have suggested that DDT or dieldrin levels in the brain were better indicators of death by these pesticides than were levels in other tissues (Robinson *et al.*, 1967; Stickel *et al.*, 1966, 1969). However, the observations reported herein do not support this hypothesis. Since dieldrin concentrations in nervous tissue, adipose tissue, heart, bone, muscle, and blood were highly correlated, concentration in any one of these could be predicted from concentration in another by using appropriate constants. Also, sheep fed 2 mg dieldrin per kg body weight accumulated higher concentrations of dieldrin in all tissues measured than did sheep fed 4 mg dieldrin per kg, even though this latter dosage proved highly lethal. While this research does not reveal the specific target organ for poisoning by dieldrin, it does emphasize that rate of intake or accumulation is an important factor in inducing poisoning.

Since correlation of dieldrin in blood with that in body fat was higher than correlation of dieldrin in plasma with fat, dieldrin in blood would be a better indicator of dieldrin residues in the body of living animals than would level of dieldrin in plasma. Laben *et al.* (1965) observed that level of DDT in blood was a good indicator of residues of that insecticide in body fat. These measures would become useless at extremely low residue levels, however, because limits of detection are about 10 ppb, and residues in blood are several hundredfold less than those in fat.

Residues in fat of bone were highly correlated with residues in both carcass and fat tissue. Concentrations of radioactivity in fat extracted from bone of sheep given dieldrin-^{14}C were identical to those in fat of adipose tissue, further verifying this correlation. Since bone tissue is easy to obtain and has a relatively low market value, it would be a potential sample for measuring residues of chlorinated hydrocarbon pesticides in marketable meats.

ACKNOWLEDGMENT

I thank the Shell Chemical Company, 110 West 51st Street, New York, N.Y., 10020, for supplying the dieldrin, Alice Nolin for technical assistance, and E. J. Thacker for helpful advice and criticism.

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