TRANSFER OF DDT AND LINDANE FROM EWE TO LAMB

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Summary

DDT and lindane were administered to separate groups of ewes in mid-pregnancy for a period of ten days at daily dose rates of 1 or 5 mg/kg body-weight.

Lindane accumulated in ewes at approximately twice the rate of DDT but was released from storage much more rapidly than DDT. Very low levels of lindane were present in the ewes after lambing, and lindane residues in lambs did not exceed the levels found in their dams at corresponding times.

DDT residues in ewes persisted at a similar level from mid- to late-pregnancy until one month after lambing and then decreased progressively with time. At similar points in time, DDT residues in lambs and in their dams were of a similar order. Some transfer of DDT took place from ewe to foetus but most of the DDT in the lambs was apparently derived from the ewes via the milk fat in which the concentration of DDT was about half that in the body fat of the ewes. Relationships between insecticide levels in the blood and fat of both ewes and lambs are discussed.

INTRODUCTION

DURING 1966-7, ewes and lambs from a few farms in mid-Canterbury were found to contain residues of DDT and its metabolites in excess of 7 ppm although DDT in pelleted form had been used on these farms apparently in accordance with current regulations (Anon., 1964). Although high residues in sheep at the time of slaughter would rarely be expected following the recommended usage of DDT (Harrison, 1966), it is recognized that, for persistent insecticides, the observance of fixed withholding periods is not an absolute guarantee that tolerances will never be exceeded (Harrison, 1962).

Possible explanations for the residues found in the mid-Canterbury sheep were that slow growth of pasture during a dry period following DDT topdressing resulted in unusually persistent DDT residues on pasture and subsequently in stock, or that the practice of feeding-out supplementary rations on almost bare paddocks recently topdressed with DDT may have resulted in the uptake by stock of DDT from the soil. Another possibility was that the DDT in the lambs was derived from DDT-contaminated ewes before weaning. These possible sources of DDT contamination were assessed in trials during 1967 at Winchmore Irrigation Research Station (Harrison, Rudman and Mol, unpublished data) and at Wallaceville Animal Research Centre. This paper presents preliminary findings from a Wallaceville trial in which ewes were exposed pre-partum to DDT and lindane and the resulting residues were determined in the tissues of both ewes and lambs. When this work is completed, a full account will be published elsewhere.

EXPERIMENTAL

Twenty 2- to 3-year-old ewes in mid-pregnancy were bled and biopsied* on June 20, 1967. The animals were then drenched daily with insecticide for 10 days from June 22 to July 1 and again bled and biopsied on July 6, two weeks after the start of dosing.

TABLE 1: INSECTICIDE DOSING SCHEDULE
(4 sheep per group)

<i>Treatment</i>	<i>Daily Dose† Rate over 10-day Period</i>	<i>Equivalent Intake of Insecticide on Feed Dry Matter* (ppm)</i>
Nil	Nil	Nil
pp' - DDT	1	60
pp' - DDT	5	300
lindane	1	60
lindane	5	300

* Based on the average body-weight of the ewes of 60 kg at the time of dosing and a dry matter feed intake of 1 kg/day.

† mg/kg body-weight.

Both insecticides were administered by capsule as 10% solutions in peanut oil. Doses were given over a 10-day period to ensure a reasonably high build-up of insecticide in the fat and to avoid toxic effects that may have occurred, with possible loss of lambs, if the insecticides had been administered in single massive doses.

The ewes lambed from 7 to 11 weeks after the start of dosing, except for one control ewe which had a stillborn lamb 14 weeks after the start of the experiment. Each lamb was bled at one and two weeks after birth and afterwards was bled and biopsied when it was 4 and 9 weeks old. Blood and fat samples were taken from all lambs at slaughter when their ages ranged from 14 to 19 weeks. Each ewe was bled and milked one week after lambing and afterwards was bled, milked and biopsied at 2, 4 and 9 weeks after lambing. At slaughter, milk, blood and fat samples were taken from all ewes, 26 weeks after they were first exposed to the insecticides.

All sheep were kept on one paddock throughout the trial period of six months. Supplementary feed, contained in raised hoppers, was offered to the ewes in early spring when the pasture became scarce but otherwise the main feed was the available pasture.

SAMPLING AND ANALYSIS

Residues of DDT and lindane in fat, milk, blood, soil, pasture and supplementary feed were determined by gas chromatography after the samples had been prepared for analysis by methods appropriate for the various materials. Residues are expressed on a dry matter basis in food-stuffs and on a fresh tissue basis in fat and whole blood. Recoveries of lindane, DDE, DDD and DDT added to control samples were consistently in the range of 90 to 110%. Details of these procedures will be published elsewhere.

* The term biopsy in this paper refers to the surgical removal of omental fat from the live animal.

RESULTS AND DISCUSSION

One ewe was infertile and four lambs were stillborn, three of the latter being from ewes in the untreated control group. All ewes in the high dose-rate groups of both DDT and lindane produced normal lambs including one set of twins in each group. One lamb and one ewe died from peritonitis following surgery but otherwise exposure to these insecticides and the considerable amount of handling and surgery had no harmful effects on either the ewes or the lambs.

The results of analyses of fat, blood and milk for DDT and lindane are presented in Tables 2 to 5. Except where otherwise indicated, values for DDT comprise the sum of DDE, DDD and DDT. Because the ewes lambed on different dates, for samples taken after lambing, individual results both within and between groups are not strictly comparable. However, for the sake of brevity, results are given in the tables as group means since this procedure does not affect the interpretation of results.

The supplementary feed was a mixture of chopped lucerne hay and commercial sheep pellets, a representative sample of which contained only a trace of DDT (less than 0.05 ppm). Pasture sampled towards the end of the trial on December 20, 1967, contained a negligible amount of DDT. Topsoil on the paddock contained 2.7 ppm total DDT (0 to 1 in. depth) which would be equivalent to about 1 lb DDT/acre.

During the trial, DDT was invariably found in the tissues of the sheep that were not dosed experimentally with DDT — *i.e.*, the control group of sheep and the sheep treated with lindane. Recent research indicates that DDT can be derived from topsoil that is ingested in varying quantities with the pasture and the term "background" DDT is used to denote this type of contamination. It is apparent that, in trials such as the present one in which pasture is grazed by the same stock over a prolonged period, the analysis of pre-trial fat samples will indicate the DDT status of the stock at the time of sampling only. Residues in the animals resulting from subsequent exposure to DDT will be superimposed upon varying background levels of DDT. Measurement of this background factor has been possible only since older chemical methods have been superseded by methods based on gas chromatography.

Table 2 compares the levels of each insecticide, at the two dosage levels, in the fat of ewes sampled at two weeks after the groups were first exposed to insecticide (Time 1) and again at four weeks after each ewe had lambed (Time 2) — the interval between Time 1 and Time 2 being 9 to 13 weeks.

It is evident from these results that lindane accumulated in the ewes at approximately twice the rate of DDT but that it was released from storage much more rapidly than was DDT.

TABLE 2: COMPARABLE RESIDUES IN EWE FAT

Dose Rate	Insecticide	Residues in Omental Fat (ppm) (Mean Value for 4 Sheep on Each Treatment)	
		Time 1*	Time 2†
1 mg/kg body-weight	DDT	4.3	4.3
	lindane	10.3	0.3
5 mg/kg body-weight	DDT	25.3	19.6
	lindane	54.4	0.6

* Time 1-2 weeks after the start of dosing.

† Time 2-4 weeks after lambing.

TABLE 3: DDT AND LINDANE RESIDUES IN EWE FAT, MILK FAT AND LAMB FAT

(Each figure is the mean value for 4 animals on the same treatment)

Group Treatment	Gestation Period		Period from Dosing to Lambing in Aug./Sept. (weeks)	Type of Fat	Period after Lambing (weeks)				
	Pre-trial Residues June 1967	Residues after Dosing July 1967			1	2	4	9	16-19
Control	0.4	0.4	6-12	ewe milk lamb*	1.2	1.2 1.6	1.8 1.6 3.3	1.1 1.0 2.2	0.6 1.2 1.4
DDT 1 mg/kg	0.3	4.3	7-9	ewe milk lamb	2.6	5.6 3.0	4.3 2.6 5.2	3.3 1.9 3.6	2.0 1.9 1.8
DDT 5 mg/kg	0.4	25.3	6-9	ewe milk lamb*	11.7	20.3 10.8	19.6 11.6 17.9	8.9 6.4 9.1	5.6 3.4 4.6
lindane 1 mg/kg	—	10.3	7-8	ewe milk lamb*	0.8	0.7 0.6	0.3 0.1 0.2	tr† tr tr	— tr tr
lindane 5 mg/kg	—	54.4	5-9	ewe milk lamb*	2.5	1.5 2.5	0.6 0.5 0.4	tr tr tr	— tr —
					DDT Residues in Lindane-treated Groups				
			lindane 1 mg/kg	ewe milk lamb	1.1	0.9 1.1	1.2 1.0 2.0	0.8 1.0 1.7	0.6 0.8 1.9
			lindane 5 mg/kg	ewe milk lamb	0.7	1.0 1.1	1.1 1.2 1.8	0.8 1.1 2.0	0.6 0.7 1.3

* Includes one set of twins

† Lindane residue <0.05 ppm

While most of the lindane had been eliminated from ewe fat by the fourth week after lambing, DDT at this time was still present at levels similar to those found just after dosing ceased 9 to 13 weeks previously. In contrast to the steady elimination pattern of DDT following the cessation of dosing reported for meat stock (Claborn *et al.*, 1960) the persistence of DDT in ewe fat from the latter part of gestation through to early lactation was most striking. This effect is possibly due to the particular conditions of fat metabolism that take place during this period. Subsequently the DDT residues in ewe fat decreased slowly but progressively until the animals were killed at six months after exposure to the insecticide.

For the two DDT-dosed groups, DDT residues in lambs were of a similar order to residues in their ewes at comparable points of time (Table 3). In general, where comparisons were possible, the concentrations of DDT in milk fat were about half the concentrations in ewe fat or lamb fat.

Background levels of DDT both in lambs from the control groups of ewes and from the lindane-treated ewes were about twice the levels of their ewes at 4 and 9 weeks after lambing and at the time of slaughter (Table 3). In these particular animals, DDE was the major component of the total DDT residue in the milk fat and in the lambs. This finding is believed to be of significance. For example, it has recently been reported that calves can accumulate DDE in the fat at a much higher rate than DDT (Fries and Kane, 1967). The same could be true for lambs.

Lindane residues in the body fat and in the milk fat of all ewes dosed with this insecticide were very low following lambing. Lindane residues in the lambs did not exceed the residues in their ewes at corresponding times. From the limited data available, it appears that lindane residues in milk fat were of a similar order to residues in both ewe and lamb fat.

Three lambs from control ewes and one lamb from a ewe in the low DDT-dose group were stillborn. These lambs had no depot fat but liver fat and muscle fat from three of these lambs were analysed for DDT and the relevant data are given in Table 4. By comparing these results with the figures for other lambs in the same groups (Table 3), it can be deduced that, while some transfer of DDT from ewe to foetus took place through the placenta, the bulk of the DDT in the depot fat of surviving lambs was derived from the ewes via the milk fat after birth.

TABLE 4: DDT RESIDUES IN STILLBORN LAMBS
(Concentration ppm)

Ewe No.	Insecticide Treatment	Ewe Fat		Stillborn Lambs	
		Before Lambing	2 Weeks after Lambing		
568	Control	0.4	0.7	Liver fat	0.5
				Muscle fat	1.1
571	Control	0.5	1.5	Liver fat	0.4
				Muscle fat	1.0
567	1 mg/kg DDT	4.6	5.7	Liver fat	0.9
				Muscle fat	1.4

Results of blood analyses are shown in Table 5.

TABLE 5: RESIDUES IN WHOLE BLOOD ($\mu\text{g}/\text{kg}$)
(Each figure is the mean value for 4 sheep on the same treatment)

Group Treatment	Pre- trial	Gestation Period		Period after Lambing (weeks)	1	2	4	9	16-19
		5 days after Dosing	3½ weeks after Dosing						
Control	tr†	2	tr	1.5	1	1.5	1	tr	tr
DDT 5 mg/kg	3	20	15	5	4	5	5	2	3
lindane 5 mg/kg	—	152	50	10	6	10	9	5	5
				33	27	33	28	11	4
				4.8	7.3	4.8	2.1	ND	ND
				6.6	10.0	6.6	2.4	1.8	1.8

* Residues of DDT. † DDT residue $<1 \mu\text{g}/\text{kg}$. ND — not detectable.

DDT in whole blood ranged from less than 1 to 20 $\mu\text{g}/\text{kg}$ in ewes (corresponding range in fat was 0.6 to 25.3 ppm) and 2 to 33 $\mu\text{g}/\text{kg}$ in lambs (corresponding to the range in fat of 1.4 to 17.9 ppm). Intermediate residues in blood corresponded to DDT residues in the intermediate range in the fat of both ewes and lambs (Tables 3 and 5).

Before lambing, lindane residues in blood were 0 and 152 $\mu\text{g}/\text{kg}$ (corresponding to 0 and 54.4 ppm in fat). After lambing the residues in corresponding samples of blood and fat ranged from 0 to 4.8 $\mu\text{g}/\text{kg}$ and 0 to 1.5 ppm lindane, respectively. For similar residues in body fat, the residues in lamb blood were consistently higher than in ewe blood and this was true for both insecticides. Overall these findings suggest that DDT and lindane levels in body fat could probably be assessed within limits on the basis of analysis of whole blood from the live animal. The value of such a diagnostic test is obvious.

Both the pasture sampled in December and the supplementary feed given from September onwards contained negligible amounts of DDT. There was, however, DDT in the topsoil resulting from treatment of the experimental area some years previously. It seems probable that the DDT found consistently in all stock not experimentally exposed to this insecticide was derived from topsoil, especially during late winter and early spring when conditions were wet and the pasture was very short.

DDT was administered to the ewes in the form of pp'-DDT. The appearance of DDD and the increase in DDE in the fat of experimental sheep is further confirmation of the conversion of pp'-DDT to these compounds *in vivo*.

This trial has only limited relevance to situations in which ewes, and later their lambs, were exposed continuously to DDT and lindane because of high residues of these insecticides in the topsoil or through grazing root crops growing in insecticide-contaminated soil.

PRACTICAL ASPECTS OF THIS TRIAL

In this trial, ewes in mid-pregnancy were exposed to two levels of DDT or lindane. Similar alternative situations might occur if stock were grazed, without a withholding period, on pasture freshly topdressed with prills (60 ppm residues on pasture, Table 1) or with insecticide/superphosphate dust (300 ppm on pasture). The residues, above background levels, subsequently found in both ewes and lambs would be derived solely from this single period of exposure. In these circumstances, it is apparent from this trial that residues of total DDT in fat lambs at the time of slaughter (and in their ewes) would be below 7 ppm on average although residues in individual animals could exceed this level. Under similar exposure conditions, residue hazards from lindane in the post-lambing period would be very much less than for DDT.

REFERENCES

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* $\mu\text{g}/\text{kg}$ is equivalent to parts per thousand million or ppb (U.S.)