The Effects of DDT on Energetics of the Short-tailed Shrew, *Blarina brevicauda*

by HOWARD W. BRAHAM and CHARLES M. NEAL

Department of Zoology
The College of Biological Sciences
The Ohio State University
Columbus, Ohio 43210

Documentation as to the persistence of DDT is well established, however, the physiological effects on vertebrates have only recently been under investigation. LUSTICK et al. (1971) suggest that DDT causes an increased metabolic rate in quail (Colinus virginianus). Laboratory rats (Rattus norvegicus) fed DDT show signs of decreased cold tolerance (DEFREITAS et al. 1969). PETERLE and PETERLE (1971) have demonstrated decreased aggression in laboratory mice (Mus musculus) fed 7.0 ppm DDT. These and other studies, outlined by PETERLE and PETERLE (1971) have depended upon the artificial addition of DDT to laboratory food preparations. Physiological changes in vertebrates feeding on prey items which have accumulated DDT from the environment have as yet not been reported.

DDT is known to accumulate in invertebrates and invertebrate predators (DIMOND and SHERBURNE 1969). Earthworms are reported to accumulate high quantities of DDT in the range of 1-45 ppm (DAVIS 1971). Tissues of the short-tailed shrew (Blarina brevicauda) contain DDT as long as nine years after application of DDT to a forest habitat (DIMOND and SHERBURNE 1969). FORSYTH and PETERLE (1973) have also detected no apparent decline in Blarina DDT levels four years after a DDT application to an old-field ecosystem. WHITAKER and MUMFORD (1972) found that 35.7% of the diet of Blarina consisted of earthworms.

Short-tailed shrews have a standard metabolic rate twice as high as can be predicted on the basis of weight (NEAL and LUSTICK 1973). Therefore, any increase in shrew metabolic rate due to DDT might be more significant in terms of survival than in other small mammals with lower standard metabolic rates. The intent of this study, then, was to determine if any changes occur in the metabolic rate of the short-tailed shrew fed earthworms (Lumbricus terrestris) which were obtained from an old-field sprayed with DDT.

Materials and Methods

Experimental Animals and Analysis

A total of 10 male short-tailed shrews were used in this investigation (sex was determined at the time of dissection). All animals were trapped within a two hour period on the evening of March 2, 1973, in Sherman live-traps baited with peanut-butter. The shrews were maintained in the laboratory in individual cages at

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20-25° C on a 12-hour photoperiod (0700-1900). All animals were acclimated to the laboratory for a period of one week before any experiments were performed; each was fed bait-store raised worms for this period. All appeared to adjust well, each gaining weight slightly.

Five experimental shrews were fed approximately 10-12 grams of earthworms daily. The worms were collected from an old-field located at the Urbana Wildlife Area Refuge, Urbana, Ohio. This area was treated with Chlorine-36 labeled DDT by helicopter in June, 1969. Earthworms came from that portion of the study area where the soil radioactive disintegrations per minute from the ^{36}Cl were 10,000-15,000 (1320-1984 ppm DDT) at the time of application. For details of the preparation and application of the DDT see BANDY (1971).

Control animals were fed the same diet of earthworms except these worms came from a commercial bait store. The earthworm diet was sparingly supplemented with Alpo chicken and chicken parts dog food (Allen Products Co., Inc., Allentown, Pa.), and sunflower seeds.

Liver and fat tissue from control shrews, and whole control worms were analyzed for DDT by means of gas chromatography (UEBELHARDT 1973). DDT levels in experimental shrew livers and fat, and earthworms collected from the Urbana Wildlife Area were analyzed by liquid scintillation counting (replicate runs, N=32), according to the procedure described by DINDAL and PETERLE (1967). DDT metabolites (DDE, TDE, DDA) were not differentiated for this study, and any reference to DDT is understood to include both DDT and DDT metabolites.

Oxygen Consumption

Oxygen consumption was measured at an ambient temperature of 10° C with an open-circuit system connected to a Beckman F-3 oxygen analyzer and Heath recorder. The respiration chambers were made from gallon jars with airtight lids having an air intake, air outlet, and an opening for a thermocouple. The respiration chambers were placed in a water bath that maintained temperature within one degree of the desired ambient temperature. Oxygen consumption was calculated based on a flow rate of 1,000 cc/min of air, and all gas volumes were corrected to STP.

Each measurement of oxygen consumption was obtained on animals that had not eaten for two hours. All measurements were made during normal daylight hours in a darkened chamber. Oxygen consumption of experimental and control shrews was measured prior to the initiation of the DDT feeding program and at one week intervals for three weeks.

The shrews were allowed to adjust to the respirometer chamber for at least one-half hour prior to any measurement. The value used for calculating metabolic rate was that obtained after the shrew had reached a minimum steady state of oxygen consumption and maintained it for 20 to 30 minutes. Animals were weighed to the nearest 0.1 gram prior to each run.

At the conclusion of this experiment, two experimental and two control shrews were fasted for 18 hours and their metabolic rates at 10^{o} C T_A determined.

Results

DDT Tissue Residue Analysis

Experimental shrews were found to have a mean DDT residue level of 7.59 ± S.E. 0.99 ppm (N=10) in liver tissue, and 14.70 ± S.E. 1.63 ppm (N=10) DDT in fat four weeks after the experiment was initiated. Experimental earthworm levels of DDT were found to be 16.55 ± S.E. 9.96 ppm DDT (N=6). Control shrews were found to contain no DDT in either fat or liver, nor was DDT detected in control earthworms. Mean weights of both experimental and control shrews increased significantly ($P < 0.05$) during the course of the investigation. There was no significant difference ($P > 0.05$) between experimental and control shrew liver and testes weight at the conclusion of the experiment.

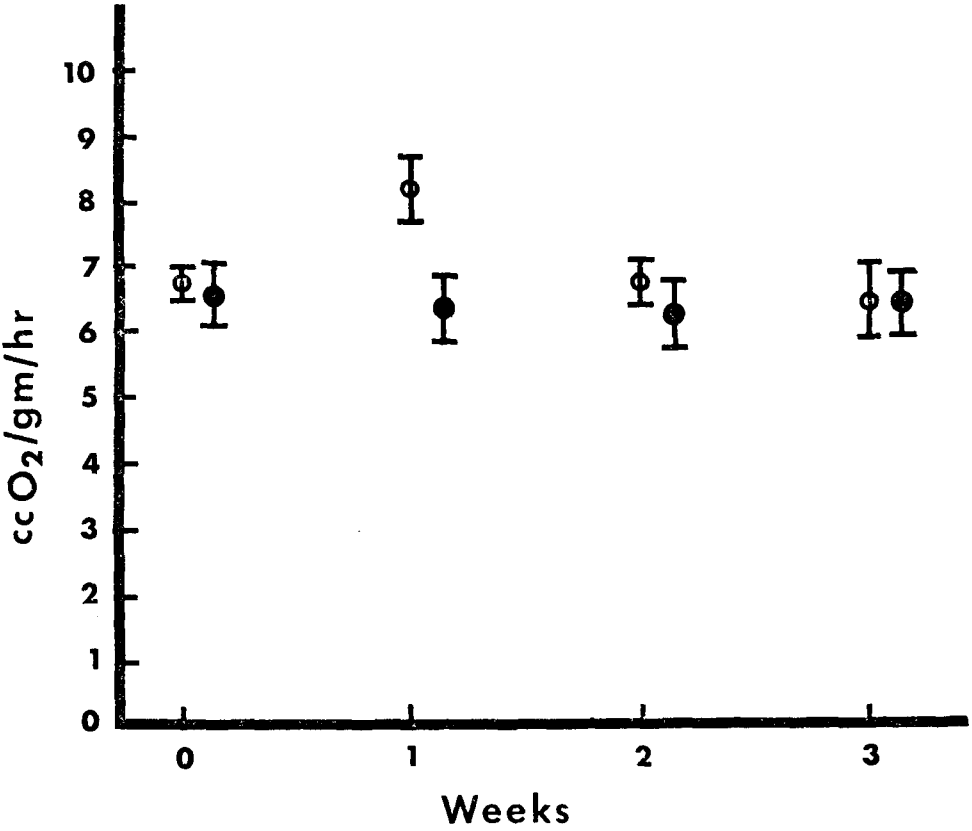

Figure 1. The oxygen consumption of five experimental short-tailed shrews fed earthworms containing DDT (unshaded circles) for three weeks, and five control shrews (shaded circles). Circles represent means, horizontal lines represent the 95% confidence limits (t times S.E.M.). Control data is shifted slightly to the right to avoid confusion.

Oxygen Consumption

The metabolic rates of the experimental group were significantly higher ($P < 0.02$), after being fed DDT earthworms for one week, than the metabolic rate of the control shrews (8.91 ± 0.73 and 6.32 ± 0.26 cc O_2/gm/hr respectively). The metabolic rates of both groups were not, however, significantly different ($P > 0.05$) after the second and third weeks of feeding. Control shrews showed no significant change in metabolic rate ($P > 0.05$) at the 10° C temperature during the period of this investigation (Figure 1).

Two experimental shrews fasted for 18 hours showed an average of 12.3% increase in metabolic rate, while control shrews fasted for the same period had an average decrease of 8.3% in metabolic rate (Table 1).

TABLE 1

Changes in the metabolic rate of two experimental and two control short-tailed shrews (Blarina brevicauda) after being starved for 18 hours.

	DDT Shrews		Control Shrews	
cc O_2/gm/hr	No. 1	No. 2	No. 1	No. 2
before	6.24	7.36	5.90	7.35
after	7.14	8.37	5.38	6.76
% change	+12.6	+12.1	-8.7	-8.0
weight loss (gms)	2.2	1.9	2.7	2.3

Discussion

Feeding 10-12 gm/day of earthworms that had accumulated DDT caused a significant increase in the metabolic rate of Blarina brevicauda after the first week of the feeding program but not after the second or third week. Other investigators (LUSTICK et al. 1971) have shown increased oxygen consumption in quail (Colinus virginianus) using artificial addition of DDT to food. The increased metabolic rate at 10° C for experimental shrews was equal to a non-DDT fed shrew's metabolic rate of approximately 5° C (NEAL and LUSTICK 1973). It is apparent that initial exposures to DDT laden food, simulating naturally occurring levels, alters the metabolic activity of this mammal. It is possible that initially the metabolic rate increase was due to high circulating levels of the insecticide in the bloodstream. The later decrease in metabolic rate could have resulted from liver enzyme induction (SANCHEZ 1967) and more efficient removal of DDT from the blood.

The decrease in 18-hour fasted control animals' metabolic rate indicates lack of specific dynamic effect (KLEIBER 1961) and, therefore, metabolism of fats. The fact that two experimental shrews fasted for 18 hours showed an increase in metabolic rate lends support to the conclusion that metabolic rate is increased when DDT is released from metabolized fat tissue into the blood stream. When fats are metabolized, 1 cc of O_2 is approximately equal to 4.7 calories (KLEIBER 1961). Based on a mean difference between experimental and control shrews of 1.68 cc O_2/gm/hr and a mean weight of 23.2 g, the fasted experimental shrews were expending approximately 4.4 Kcal/day more energy than fasted control shrews. It is interesting to note that the two fasted DDT shrews died shortly after the metabolic tests, the controls did not. As fat becomes mobilized under stress conditions, as in lowered ambient temperatures or limited food supply, release of DDT from fat may be an important factor in short-tailed shrew survival.

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