Eggshell Thinning as Influenced by Method of DDT Exposure

by RICHARD K. TUCKER and H. A. HAEGELE
Bureau of Sport Fisheries and Wildlife, Denver Wildlife Research Center
Denver, Colorado

When Ratcliffe (1) in England found that certain birds of prey had displayed a dramatic decrease in eggshell thickness since 1946, workers in the United States began looking for, and finding, thin-shelled eggs among American raptors and avian fish predators (2). The species in which eggshell thinning has occurred are among those receiving the highest exposure to DDT. Attempts have been made to correlate residues of DDT and its metabolites in eggs with the degree of shell thinning, but often low residues have been found in eggs with thin shells and high residues are commonly found in eggs with shells of normal thickness.

In attempting to understand how, or indeed if, DDT or other chlorinated organic residues in the environment could be responsible for the thin-eggshell phenomenon, workers have been seriously handicapped by an inability to duplicate in the laboratory the degree of shell thinning found in the wild. While documented cases of over 50% thinning have occurred in wild birds (3), most laboratory studies to date have used chronic treatments with moderate to high levels of chlorinated organics and produced only on the order of 10% thinning (4, 5, 6), often less. In the course of such a chronic study with DDT, we found in a side experiment that shell thinning of 25% or more could be produced in mallard ducks by a different method of administration.

Chronic study

Groups of 2-year-old bobwhite quail (Colinus virginianus) and 1-year-old mallard ducks (Anas platyrhynchos) were placed on diets of a non-calcareous quartz grit and breeder rations containing various levels of technical DDT and calcium. Limestone containing 40% calcium was added to obtain the desired calcium levels. Each of nine diet combinations was given to three groups of quail (one male and three females per group) and one group of mallards (one male and four females). The mallards were kept in outdoor pens and the quail in an air-conditioned room.

Birds on all diets laid an average of about 0.5 eggs per hen per day. The following tabulation gives the mean shell thickness in microns for quail eggs laid during the 69th through 96th day of feeding, the period of maximum egg production. Each eggshell was measured at four points around the girth.

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	3.0% calcium (control)	1.73% calcium	1.0% calcium
0 ppm DDT (control)	204	204	186
10 ppm DDT	208	200	183
30 ppm DDT	195	196	181

Lower calcium and the addition of DDT both caused some decline in shell thickness. Thinning averaged 1.1% at the 1.73% calcium level and 9.3% at the 1.0% calcium level, when the figures were compared with their appropriate controls (3.0% calcium, same DDT level). Similarly, thinning averaged 0.5% for 10 ppm DDT and 3.7% for 30 ppm DDT.

The results with mallards were similar. The following tabulation gives the mean shell thickness in microns for mallard eggs laid the 14th through the 68th day of feeding.

	3.0% calcium (control)	1.73% calcium	1.0% calcium
0 ppm DDT (control)	374	344	327
10 ppm DDT	369	354	308
30 ppm DDT	346	334	313

In mallards, 1.73% and 1.0% calcium caused 5.2% and 12.9% thinning, and 10 and 30 ppm DDT caused 1.4% and 4.9% thinning, respectively.

Residue analyses confirmed the dietary DDT levels and showed that an average of 25.8% of the DDT that the mallards consumed was eliminated through their eggs. Mean DDT residues in weekly pools of eggs from each mallard group varied as much as 15-fold

between weeks and reached as high as 64 ppm (wet-weight basis) without any concomitant variation in shell thickness in any given week.

The results of this chronic study are essentially similar to others described in the literature. The shell thickness data have not yet been statistically analyzed, but whether or not the DDT-related thinning is statistically significant, it is probably not reproductively significant, and surely does not compare with the far greater thinning seen in some wild populations.

Acute studies

Because the above results did not demonstrate the degree of eggshell thinning seen in the wild, we investigated the effect on eggshells of single oral administration of DDT. In one test, doses of 1000 mg/kg technical DDT were administered by gelatin capsule to four 2-year-old mallard hens. No feed was offered for 2 days following treatment. Eggs laid by our mallards normally average 373 microns in thickness. On the day of treatment, before dosing, hens in the test group laid two eggs with shells that measured 390 and 391 microns. However, during the 2 days following treatment, they laid three eggs with shells that measured 270, 294, and 274 microns. This averaged 25% thinner than the 373-micron norm and 28% thinner than the eggs laid the day of treatment. Shell thickness increased somewhat from the third day after treatment until the birds were sacrificed at 16 days; the average for this period was 339 microns, or 9% thinner than the norm.

To determine whether fasting contributed to the production of thin-shelled eggs, single oral doses of 1000 mg/kg DDT were next administered to two groups of five 1-year-old mallard hens. One group was fasted for 23 hours after treatment and the other group was allowed free access to feed. During the 2 days after treatment, the fasted and non-fasted groups each laid four eggs of 292 microns average thickness (22% thinner than the norm). From the third day until sacrifice 2 weeks later, the mean shell thickness was 333 microns (11% thinner than the norm) for the fasted group and 307 microns (18% thinner) for the nonfasted group. Fasting after dosing did not appear to contribute to eggshell thinning.

In a concurrent experiment, four 2-year-old mallard hens were given 1000 mg/kg of another chlorinated organic, Arochlor 1268. No feed was offered for 3 days following treatment. The shell of one egg laid the day after treatment was 18% thinner than the norm, but eggs laid from this time until

these hens were sacrificed 16 days later averaged a nearly normal 369 microns. However, egg production was noticeably reduced during the first week. (The temporary reduction of egg laying was probably due to the fasting, since it also occurred, though to a lesser extent, in other fasted mallards.) Controls treated with distilled water to simulate the handling of dosed birds showed negligible eggshell thinning (less than 2 microns).

Discussion

The finding that 25% thinning in the shells of mallard eggs can be produced by rather high acute oral doses of DDT makes it more plausible that DDT or similar compounds could cause the drastic eggshell thinning seen in wild bird populations. While it seems unlikely that entire breeding populations could ingest acute oral doses of this magnitude, it is possible that massive mobilization of body residues caused by fasting and stress during reproduction could produce the same effect. It is also possible that much smaller acute dosages could result in significant thinning. Final judgments will have to await additional tests and mode-of-action studies.

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