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RESPONSE OF AMERICAN BLACK DUCKS TO DIETARY URANIUM: A PROPOSED SUBSTITUTE FOR LEAD SHOT

SUSAN D. HASELTINE and LOUIS SILEO, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708.

Lead (Pb) shot has been associated with mortality in waterfowl (Trainer and Hunt 1965, Anderson 1975, Stout and Cornwell 1976) and other avian species (Benson et al. 1974, Kaiser et al. 1980, Pattee et al. 1981). Bellrose (1959) indicated that between 2 and 3% of waterfowl populations may be lost yearly to lead poisoning. Incidence of lead shot in waterfowl and estimates of mortality from lead poisoning have decreased slightly (Trost 1980) or not at all (Longcore et al. 1982) in local areas since 1976, when the U.S. Fish and Wild-

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daily for any sign of debility. A 5-ml heparinized blood sample was taken from either the jugular or deep ulnar vein after 3 and 6 weeks on dosage. Ducks were sacrificed with halothane (Halocarbon Laboratories, Inc., Hackensack, N.J.) or CO_2. The proventriculus and duodenum were immediately injected with neutral-buffered formalin to prevent auto-digestion and the carcasses were examined. Carcass, liver, and kidney weights and descriptions of any gross lesions were recorded. Representative samples of kidney tissue from 38 ducks were fixed in 10% neutral-buffered formalin. Segments of heart, proventriculus, gizzard, intestine, liver, lung, spleen, and brain from 5 ducks fed the control diet and 8 ducks fed 1,600 ppm U were also fixed. Formalinized tissues were submitted to American Histolabs, Inc. (Rockville, Md.) for routine histologic processing and staining with hematoxylin and eosin. All slides were scanned at 2.5 and 10× with a light microscope.

Blood samples were stored on ice until centrifugation for separation of plasma from packed cells. Packed cell volume (PCV) was determined by the microhematocrit method. Delta-aminolevulinic acid dehydratase (ALAD) activity was measured with a spectrophotometer in whole blood (Burch and Siegel 1971), as was hemoglobin concentration using the cyanomethemoglobin procedure (Hycel, Inc., Houston, Tex.). Uric acid, aspartate aminotransferase (AST, EC 2.6.1.1), and alanine aminotransferase (AAT, EC 2.6.1.2) were assayed in plasma on a centrifugal analyzer (Centrifichem® Union Carbide Corp., Rye, N.Y.) according to manufacturer's specifications.

Weight data were compared by repeated measure analysis of variance (Winer 1971) separating sex and treatment level interactions; all other measurements were compared using 1- or 2-way ANOVA.

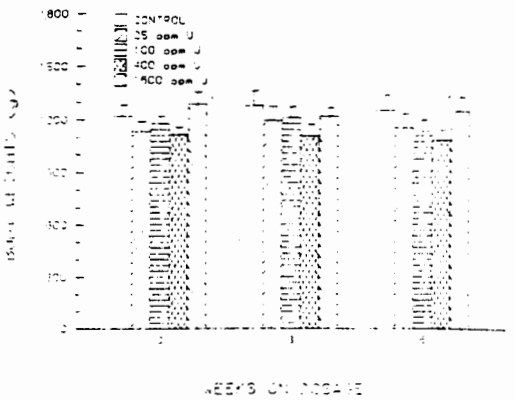

Fig. 1. Body weights (g) of adult black ducks fed 0, 25, 100, 400, or 1,600 ppm U in the diet for a 6-week period. Bar height represents $\bar{x} \pm$ SE for males and females in each group.

RESULTS AND DISCUSSION

Only 1 black duck died while on U dosage. One male in the 100 ppm dietary U dosage group weakened and was harassed by other birds in the pen. It was found dead in the 6th week of the study; necropsy revealed trauma lesions, but no indication of disease or pathological changes in the kidney that are associated with U-induced mortality in mammals (Durbin and Wrenn 1975).

Birds that survived through the dosage period exhibited little indication of treatment-related weight change (Fig. 1). Weight gain and/or loss occurred in all treatment groups, but in no pattern that reflected treatment level or time on dosage. There were transitory treatment effects ($P < 0.05$) in body weight change; these were attributed to the normal fluctuations in weight within any group of birds and were not considered biologically significant or U-induced. Body weights of females were lower ($P < 0.01$) than body weights of males throughout the study in all treatments. No sex-treatment interaction was revealed by the analysis. Males and females did not show the same weight

toxicity. First, the species sensitivities among laboratory mammals dosed with U salts may vary by as much as 100-fold. Dogs are generally the most sensitive and strains of white mice are the least sensitive (J. Ruedy, unpubl. rep., 1980). Although most of these studies have used water, not food, as the vehicle of U presentation, the amount of U that caused effects in the laboratory studies was in the range fed to the black ducks (Novikov and Yudina 1970). Waterfowl may thus be relatively insensitive to the chemical toxicity of U. Second, Durbin and Wrenn (1975) considered elemental U to be biologically inert. Only the U salt forms were capable of being absorbed and biologically incorporated. Even dosing with the uranyl oxide form, potentially the most prevalent in aquatic systems (Can. Minist. Natl. Health and Welfare 1979), would result in absorption that would only be in the 0.5–3.0% range in most mammals. Poor absorption of elemental U might also explain the low chemical toxicity for U seen in this study. None of the histological (Goel et al. 1980) or physiological (Novikov 1970, Little 1971) damage cited in the literature was apparent in the black ducks during a 6-week-dosage of substantial dietary U levels.

Several questions must still be answered concerning the chemical toxicity to waterfowl of elemental U in shot form. Altered absorption or toxicity may occur if birds are dosed with a U shot or a shot of a U alloy. Likewise, the toxicity of U and U shot must be tested in birds on a nutritionally deficient diet and 1 that contains a high percentage of corn. These questions can be answered only after an alloy shot has been developed.

Aside from the chemical toxicity of U shot to waterfowl and other avian species that ingest pellets, the behavior and persistence of U in shot form in the aquatic environment must be investigated. This can be done only if the technology for U shot and alloy production is developed. Data collected near military installations that test heavy artillery have shown that U is present in algae in aquatic systems (O'Kelley 1976, Garten et al. 1981) and in vegetation, invertebrates, and small mammals at above background levels on terrestrial sites (Hanson and Miera 1976, Miera et al. 1978, Miera 1980). Altered population densities have not been demonstrated in vertebrates or other species in these studies.

These questions concerning the chemical toxicity and environmental fate and effects of U shot must be investigated before sanctioning of U shot can be considered. Ballistic feasibility and cost of manufacture and purchase are other factors that need appraisal. Our preliminary research findings on the toxicity of U to black ducks indicates that further examination of this metal as a substitute for Pb in shot is justified.

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