TABLE 1. Patterns of behavior in covering food stores, and the location of storage places observed for the White-breasted Nuthatch.

Patterns of behavior	No. of observations
(1) Seized 1–6 bits of closely adjacent bark or lichen without moving from storage place	18
(2) Moved 10–12 cm away to get pieces of bark	3
(3) Flew to another tree or stub to get bark	2
Locations of storage places	
(1) Rotten branch of live paper birch (used rotten wood to cover stores)	2
(2) Trunk or branch of hemlock	2
(3) Maple with rough bark, grown with lichens	6
(4) Bark of dead or live elm	10

ing with mixed flocks. I have seen both Hairy (*Dendrocopos villosus*) and Downy (*D. pubescens*) Woodpeckers supplant White-breasted Nuthatches at food stores. The Red-breasted Nuthatch, which can travel head down, peer in the same places as *S. carolinensis* and, one would suppose, even recognize covered stores, appears to be a main competitor of the larger species. It is conceivable, however, that matters would balance out if each species of *Sitta* robbed the other. Both may conceal their stores in maples, but *S. carolinensis* stores particularly in dead or living elms (table 1).

In most instances neither species of nuthatch attempts to cover stored food, but simply hammers it into a crevice or pushes it well under a flake of bark. The Crested Tit (*Parus cristatus*) in contrast, according to a most thorough study by Haftorn (1954) in Norway, covers its stores in a far more systematic fashion. Red-headed Woodpeckers (*Melanerpes erythrocephalus*) likewise cover stores of food, but use shreds of wet, rotten wood that harden on drying, as well as bark (Kilham 1958).

It might be noted in conclusion that bits of bark or other material used to cover stores may also serve as markers, aiding nuthatches of both species in relocating stores later on.

Of the four Red-breasted Nuthatches I observed, two were males and two were females. All but 3 of the 23 White-breasted Nuthatches were males. This sex distribution, however, may have been an artifact, for I have noted in year-round observations (Kilham 1972) that male White-breasted Nuthatches are more vocal and wide-ranging than females and hence are easier to locate.

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SELECTED PHYSIOLOGICAL RESPONSES OF PHEASANTS TO MINERALS IN CORN

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For reasons that still remain obscure, Ring-necked Pheasants (*Phasianus colchicus*) have never become established south of the 39th parallel in the eastern half of the United States. Leopold (1931:125), upon noting that successful releases of pheasants in the North Central states were confined to soils that originated from recent glacial activity, suggested that "some plant growing on these soils, or some substance, such as a kind of lime or gravel, contained in them, was necessary to the welfare and breeding vigor of exotics of this region." In recent studies (Harper and Labisky 1964; Nelson et al. 1966; Jones et al. 1968; Anderson and Stewart 1969), elemental analyses of pheasant tissues were conducted to determine whether mineral imbalances were prevalent among pheasants subsisting on areas where these gallinaceous birds have consistently failed to establish thriving populations. Basic to these studies was the assumption that mineral deficiencies or excesses on a particular area would be mirrored in the mineral makeup of the resident pheasants.

Corn (*Zea mays*) is recognized as an important, if not the most important, food for pheasants in the Midwest (Korschgen 1964:171). In Illinois, at least 80% of the food eaten by pheasants during the fall and winter months is corn (Anderson and Stewart 1969:261; R. F. Labisky, unpubl. data). Yet, corn is deficient in several inorganic and organic nutrients; the ash content of this grain is low, ranging from 1.3 to 2.1% (Korschgen 1964:164; Jones et al. 1968:6; Anderson and Stewart 1969:260).

The purpose of this study was to determine mineralogically oriented responses of juvenile hen pheasants, as measured by the mineral profile of their livers and by the weights of their parathyroid glands and femurs, to exclusive diets of corn. Two types of corn, normal hybrid (Pioneer 3306) and high-lysine (*opaque-2*), were used in this experiment. Endosperms of the *opaque-2* mutant contain about 70% more lysine, an essential amino acid, than the endosperms of normal hybrids (Mertz et al. 1964:279). Organic aspects of this study—the responses of our experimental birds to organic nutrients in normal

TABLE 1. Mean concentrations (micrograms per gram of dry weight) of 13 chemical elements in FMC, in normal corn, and in high-lysine corn; each was fed as an exclusive diet to juvenile hen pheasants for an 8-week period, 20 October–15 December 1966. Means underscored by the same kind of line are significantly different ($P < 0.05$).

Ash and elements	FMC ($n = 3$)	Normal corn ($n = 3$)	High-lysine corn ($n = 3$)
% ash	9.20 ± 0.23	1.57 ± 0.11	1.64 ± 0.02
Major elements			
Ca	14,443 ± 1,469	41 ± 3	38 ± 1
K	7,997 ± 159	3,249 ± 138	3,924 ± 184
Mg	1,833 ± 24	1,166 ± 48	972 ± 37
Na	2,785 ± 49	204 ± 9	195 ± 4
P	5,327 ± 220	2,183 ± 250[a]	2,264 ± 202[a]
Trace elements			
Co	0.55 ± 0.10	0.11 ± 0.01	0.08 ± 0.02
Cu	19.9 ± 1.0	3.2 ± 0.2	3.5 ± 0.2
Fe	157 ± 18	43 ± 3	36 ± 1
Mn	92.0 ± 2.3	3.7 ± 0.7	4.9 ± 0.8
Mo	0.40 ± 0.04	0.26 ± 0.05	0.41 ± 0.01
Zn	134 ± 7	64 ± 19	51 ± 8
Cd	1.36 ± 0.29	1.19 ± 0.73	0.26 ± 0.03
Sr	36.80 ± 0.92	0.12 ± 0.02	0.14 ± 0.10

[a] About 70% of the phosphorus in plant material is in the form of phytin phosphorus, which is poorly utilized by birds (Titus 1961:89–90; National Research Council 1971:17).

TABLE 2. Mean concentrations (micrograms per gram of wet weight) of 13 chemical elements in livers from juvenile hen pheasants fed exclusive diets of FMC, of normal corn, or of high-lysine corn for an 8-week period, 20 October–15 December 1966. Means underscored by the same kind of line are significantly different ($P < 0.05$).

Ash and elements	FMC ($n = 7$)	Normal corn ($n = 6$)[a]	High-lysine corn ($n = 7$)
% ash	1.44 ± 0.03	1.52 ± 0.14	1.64 ± 0.07
Major elements			
Ca	82 ± 9	84 ± 9	94 ± 11
K	1,556 ± 208	1,847 ± 138	1,694 ± 173
Mg	146 ± 12	170 ± 15	121 ± 15
Na	756 ± 62	885 ± 67	756 ± 60
P	946 ± 204	1,637 ± 179	739 ± 74
Trace elements			
Co	0.07 ± 0.01	0.09 ± 0.03	0.05 ± 0.01
Cu	3.6 ± 0.5	3.9 ± 0.7	4.8 ± 0.7
Fe	74 ± 11	96 ± 11	77 ± 12
Mn	2.2 ± 0.4	1.1 ± 0.1	1.3 ± 0.2
Mo	0.63 ± 0.05	0.76 ± 0.12	0.74 ± 0.14
Zn	28 ± 2	33 ± 4	28 ± 2
Cd	0.63 ± 0.04	0.73 ± 0.09	0.43 ± 0.02
Sr	0.46 ± 0.19	0.13 ± 0.04	0.08 ± 0.02

[a] One pheasant died before the study was completed.

corn and high-lysine corn—are reported in another publication (Labisky and Anderson 1973). In the present paper, emphasis is placed on differences between pheasants fed the corn diets and those fed a balanced ration, and not on the merits of high-lysine corn versus those of normal corn.

MATERIALS AND METHODS

The 21 juvenile hens used in this experiment hatched on 20 June 1966, at the Illinois State Game Farm, Yorkville. The hens were transported to Urbana on 13 September 1966, where they were held temporarily in wire-bottomed pens (3.0 × 3.9 × 1.8 m) and were fed a commercial flight and maintenance chow (FMC). On 3 October, the birds were placed at random in cages (70 × 60 × 34 cm) made of fiber glass (sides, top, bottom, and back) and stainless steel (front, false floor, feeder, and waterer). We recognize that the stainless steel might have been a source of contamination for some of the trace elements included in this study (Bowen 1966:62). The cages, with their fronts facing to the east, were located under a low, shed-like building throughout the experiment. The building had a cement floor and was open on the east and south sides. To acquaint the birds with corn, one-third of their diet of FMC was replaced with whole-kernel normal corn from 3–14 October.

The experiment was begun on 20 October, when groups of seven hens each were randomly selected to be fed exclusive diets of FMC, of normal corn, or of high-lysine corn, and water ad libitum. The hens were maintained on these diets for 8 weeks. At the termination of the experiment on 15 December, the birds were sacrificed by decapitation.

Both the normal corn and the high-lysine corn were grown in 1966 on the University of Illinois Agronomy Farm, section 19, T. 19 N., R. 9 E., Champaign County. Soils on this farm are principally silt loams that have a pH of 6.2. Managers of the farm normally treat these soils annually with 100 lb. of N, 50 lb. of P_2O_5, and 50 lb. of K_2O per acre for corn production—no other mineral deficiencies exist (O. G. Oldham, pers. comm.).

The liver, both parathyroid glands, and the right femur were removed from each bird, freed of extraneous material, and weighed. The livers and parathyroids were weighed wet (fresh), but the femurs were immersed for 48 hr in hexane (to extract lipids) and dried for 72 hr in an oven (50°C) before being weighed. Each liver was placed in a polyethylene bag and kept frozen until the analytical work was performed.

The livers and three samples each of FMC, normal corn, and high-lysine corn were analyzed for concentrations of 13 chemical elements by Stewart Laboratories, Inc., Knoxville, Tennessee. Prior to performing the analyses, each liver and each sample of the diets was freeze-dried (at < 1 mm Hg) to remove water, homogenized, and then divided into two fractions. One fraction was further processed by oxygen flask combustion (Schöniger 1955, 1956) and analyzed by atomic absorption spectrophotometry

TABLE 3. Mean weights of both parathyroid glands and of the right femur from juvenile hen pheasants fed exclusive diets of FMC, of normal corn, or of high-lysine corn for an 8-week period, 20 October–15 December 1966. Means underscored by the same kind of line are significantly different ($P < 0.05$).

	FMC ($n = 7$)	Normal corn ($n = 6$)	High-lysine corn ($n = 7$)
		Parathyroids	
Wet weight (mg)	4.1 ± 0.9	9.9 ± 1.5	8.5 ± 0.5
% × 10^{4}[a]	5.9 ± 1.3	12.4 ± 1.8	11.6 ± 0.9
		Femur	
Dry, fat-free weight (g)	1.56 ± 0.06	1.45 ± 0.10	1.38 ± 0.05
% × 10[a]	2.19 ± 0.02	1.96 ± 0.14	1.84 ± 0.05

[a] The percentage values were calculated using the body weights recorded for the hens on 20 October. On that date, the body weights averaged 711 ± 29 g for the hens fed FMC, 742 ± 37 g for the hens fed normal corn, and 753 ± 32 g for the hens fed high-lysine corn. The body weights of the hens fed normal corn or high-lysine corn did not change appreciably during the experimental period whereas those fed FMC increased, on the average, to 810 ± 30 g.

(for Ca, Mg, Zn, and Cd), flame spectrophotometry (for Na and K), and colorimetry (for P). The other fraction was ashed in a muffle furnace (550°C) and analyzed by emission spectrography (for Co, Cu, Fe, Mn, Mo, and Sr). Accuracy of the analyses was ± 5% for the emission spectrographic work and ± 2% for the other procedures. Of the 13 elements, 11 (Cd and Sr excepted) are dietary essentials for higher vertebrates.

The differences among mean values were tested for significance by analysis of variance and, if significance was indicated, by a multiple range test (Duncan 1955; Kramer 1956). We accepted the 95% confidence level as the critical level for significance.

RESULTS

Mean concentrations of 12 of the 13 chemical elements included in this study, Mo excepted, were less in both the normal corn and the high-lysine corn than in the FMC (table 1). The dietary differences for 11 of these 12 elements, when comparing the two types of corn with the FMC, were statistically significant—in this case, Cd was the exception. Differences between mean concentrations of elements in the normal corn and the high-lysine corn were significant for only K, Mg, and Mo (table 1). K and Mo were more abundant in high-lysine corn than in normal corn, whereas the reverse was true for Mg.

In livers, mean concentrations of P, Mn, and Cd exhibited significant differences among pheasants fed the three different diets (table 2). P levels in livers were less for the birds fed exclusive diets of FMC and of high-lysine corn than for those fed normal corn. Mn levels in livers were less for the pheasants fed the two types of corn than for the birds fed FMC. Cd levels in livers were less for the birds fed the high-lysine corn than for those fed the other two diets.

Mean weights of parathyroid glands, both in milligrams and when expressed relative to body weight, were approximately twice as great for the pheasants fed corn as for those fed the FMC (table 3). All of these differences were statistically significant.

Mean weights of femurs were less for the birds fed the two corn diets than for the birds fed the FMC (table 3). The difference between the relative weights of this bone, hens fed FMC versus hens fed normal corn, was statistically significant.

Linear correlation indicated that, when all 20 pheasants were considered, a significant inverse relationship existed between the actual weights of the parathyroids and the actual weights of the femurs ($r = -0.51$). The correlation for the relative weights of these tissues was not significant ($r = -0.23$).

DISCUSSION

We recognize that the use of corn as an experimental diet for inducing mineralogically oriented responses in pheasants was not the ultimate in research design. Corn is deficient in several nutrients, organic as well as mineral. In theory, a different experiment should have been conducted for each chemical element in question, and each experimental diet should have contained adequate levels of all nutrients except one of these elements. However, in practice, the above approach is quite remote as regards the nutritional responses of pheasants in the wild. Consequently, we believe the results of this study are worthy of serious consideration—the mineral content of the corn diets and of the FMC were *grossly* different, and the responses of the experimental birds were clear-cut.

A comparison of mean concentrations of chemical elements in the diets used in this study with the minimum requirements young, growing pheasants and chickens have for minerals (National Research Council 1971:17; Underwood 1971:45, 97, 197, 239; Scott et al. 1958:1421, 1422, 1959:1348, 1960:282; Higgens et al. 1956:542) suggests to us that the corn diets were deficient in Ca by a factor of 243, in Mn by a factor of 8, in Na by a factor of 4, and in P and Fe by a factor of 2. Although it is probable that the mineral needs of pheasants diminish considerably as they approach the age of our experimental birds (14–22 weeks), the magnitude of some of these apparent deficiences is overwhelming. The pheasants maintained on normal corn or high-lysine corn were, at the very least, in a negative balance for Ca.

Surprisingly, with one exception, the mineral concentrations in the livers from the hen pheasants did not mirror the differences in the mineral levels that existed between the two types of corn and the FMC (table 2). The exception was Mn, which was relatively low and possibly deficient in the corn diets and was also relatively low in the livers from the birds fed the corn (tables 1, 2). It is perhaps significant that, except for Fe, Mn was the only *trace element* that appeared to be deficient in the two corns. The other minerals that were potentially deficient in the corns—Ca, Na, and P—were *major elements.*

Although the factor or factors that contributed to the relatively heavy weights of the parathyroid glands and the relatively light weights of the femurs in the pheasants fed the corn diets (table 3) cannot be specifically identified, we believe that the above-described symptoms were precipitated by the low intake of Ca. The normal corn and high-lysine corn contained only 0.03% as much Ca as the FMC (table 1). The parathyroid hormone regulates the level of ionized Ca in the extracellular fluid (Sturkie 1965: 652; Ganong 1965:312). When the level of circulating Ca decreases, secretion of the hormone is increased and Ca is mobilized from bones. Bloom et al. (1960:207) reported that the parathyroids of laying chickens were twice as large in hens on a diet low in Ca as in hens on a diet adequate in this element—findings that concur with ours on pheasants.

The evidence obtained during this study leads us to conclude that (1) there is reason to doubt the adequacy of the liver for study when attempting to detect low intakes of major elements such as Ca, Na, and P in pheasants, and (2) weights of the parathyroid glands and of femurs might be useful indicators of low intake of Ca in these gallinaceous birds.

SUMMARY

Mineralogically oriented responses of juvenile hen pheasants fed exclusive diets of normal hybrid (Pioneer 3306) corn, of high-lysine (*opaque-2*) corn, or of commercial flight and maintenance chow (FMC), from 20 October 1966 to 15 December 1966, were measured by determining the concentrations of 13 chemical elements (Ca, K, Mg, Na, P, Cd, Co, Cu, Fe, Mn, Mo, Sr, and Zn) in their diets and livers and by weighing their parathyroid glands and femurs. The two diets of corn contained lesser amounts of 11 of the 13 elements, Cd and Mo excepted, than the FMC; the corns appeared to be deficient in the essential elements Ca, Mn, Na, P, and Fe. With the exception of Mn, the mineral concentrations in the livers from the hens did not mirror the differences in the mineral levels that existed between the two types of corn and the FMC. Mean weights of parathyroids were approximately twice as great for the hens fed the normal corn or the high-lysine corn as for the hens fed the FMC. However, femurs from the corn-fed hens were relatively light in weight. We concluded that (1) there is reason to doubt that mineral levels in the liver indicate whether pheasants are on low intakes of Ca, Na, and P, but that (2) weights of the parathyroid glands and of femurs might be useful indicators of low intake of Ca.

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