0662

11/11/1988

POULTRY SCIENCE

FEBRUARY 1990
VOLUME 69, NUMBER 2

THE UNIVERSITY
OF MICHIGAN

APR 13 1990

NATURAL SCIENCE
LIBRARY

Karl E. Nestor, *Editor-in-Chief* (1992)
Robert E. Smith, *Technical Editor*
Phillip E. Plumart, *Index Editor*
Ralph A. Ernst, *Newsletter Editor*

SECTION EDITORS

P. B. Siegel, *Breeding and Genetics* (1992)
F. V. Muir, *Education and Production* (1991)
W. E. Huff, *Environment and Health* (1992)
R. Click, *Immunology* (1992)
D. M. Janky, *Processing and Products* (1992)
L. S. Jensen, *Metabolism and Nutrition* (1992)
J. L. Sell, *Metabolism and Nutrition* (1992)
L. B. Crittenden, *Molecular Biology* (1992)
J. A. Renden, *Physiology and Reproduction* (1992)

OFFICIAL JOURNAL
of the
POULTRY SCIENCE ASSOCIATION, INC.

Poscal 69 (2) 205-364 (1990)

9485

bursal lymphocytes. Pages 1–14
nity: Mechanisms. R. G. Crispen,
L.
1983. The influence of age on the
hypersensitivity to human gamma
i. 62:563–564.
Bulow, 1987. Development of
for lymphokine production by
s. Vet. Immunol. Immunopathol.
einder, H. G. Remold, and J. R.
s on human migration inhibitory
ion of three molecular species. J.
–1962.
and S. Cohen, 1973. The produc-
ibition factor by B and T cells of
Exp. Med. 138:784–797.

0662

METABOLISM AND NUTRITION

Breeding-Hen and Progeny Performance When Hens Are Fed Excessive Dietary Zinc[1]

J. L. STAHL, J. L. GREGER, and M. E. COOK[2]

Departments of Poultry and Nutritional Sciences, University of Wisconsin, Madison, Wisconsin 53706

(Received for publication November 11, 1988)

ABSTRACT Short-term (12 wk) and long-term (44 wk) studies were conducted to observe the effects of excessive Zn supplementation on the performance of breeding hens and their progeny. Zinc sulfate was added to a corn-soybean meal diet containing 28 mg of Zn/kg in order to provide Zn supplementation at 0, 20, 200, and 2,000 mg/kg. Each dietary treatment was fed to two groups of 20, Single Comb White Leghorn hens and one New Hampshire rooster. The hens were 56-wk old at the start of the short-term study and 24-wk old when the long-term study began. Determinations were made for: fertility, hatchability, progeny growth to 3 wk of age, Zn-related feather-fraying among the progeny as well as Zn, Cu, and Fe in the liver, pancreas, and right tibiotarsus. The Zn treatments had no effect on hen performance or on reproductive performance. Even though Zn was considerably elevated and Cu was reduced in the eggs collected from hens fed the highest level of Zn, chick performance and the tissue content of Zn, Cu, and Fe were not influenced by the maternal Zn nutritional status .

(*Key words*: zinc, copper, iron, progeny, trace-mineral content)

1990 Poultry Science 69:259–263

INTRODUCTION

For three decades, poultry scientists have recognized that the chick can consume 1,000 to 2,000 mg of Zn/kg of diet without gross signs of toxicity (Mehring *et al.*, 1956; Klussendorf and Pensack, 1958; Roberson and Schaible, 1960; Kincaid *et al.*, 1976; Southern and Baker, 1983; Stahl *et al.*, 1989a). More recently, studies have revealed that while the laying hen will show signs of decreased production when fed 4,000 to 6,000 mg of Zn/kg of diet (Gentle *et al.*, 1982; Stevenson *et al.*, 1987), the consumption of 1,000 mg of Zn/kg of diet has resulted in no overt signs of toxicity in hens for a period of up to 5 mo (Jackson *et al.*, 1986).

In a continued effort to control the feed intake of laying and breeding hens (Jensen, 1988), attention has focused on the possible use of toxic levels of zinc as an inexpensive way of restricting intake (Dewar *et al.*, 1983). However, hens consuming high levels of Zn (2,000 mg of Zn/kg of diet), have deposited as much as 57% more Zn in the egg (not the shell) (Stahl *et al.*, 1988). In addition, the Cu levels in the eggs have been reduced as much as 34% when the hen was fed 2,000 mg of Zn/kg of diet (Stahl *et al.*, 1988). Although the effects of feeding excessive levels of Zn on the production of laying hens have been documented recently (Scott and Creger, 1976; Hermayer *et al.*, 1977; Palafox and Ho-A, 1980; Gentle *et al.*, 1982; Dewar *et al.*, 1983; Jackson *et al.*, 1986; Stevenson *et al.*, 1987), the effects of changed Zn and Cu levels in the egg on the development of the embryo and the subsequent metabolism of selected trace elements has not been investigated. In the following research, the authors examined the effects of marginal and excessive maternal Zn intake on some measures of progeny development and the concentrations of trace minerals in tissue and also evaluated hen performance.

MATERIALS AND METHODS

Eight groups of 20, Single Comb White Leghorn (SCWL) hens (H&N Nick Chicks) were maintained in floor pens and were mated to New Hampshire roosters in each of two studies. In Study 1, hens 56 wk of age were fed the dietary treatments until 68 wk of age. In Study 2, hens 24 wk of age were placed on the dietary treatments until 68 wk of age. The basal diet (Table 1) and hen maintenance were

[1]Supported in part by the College of Agricultural and Life Sciences, University of Wisconsin, Madison, WI 53706.

[2]To whom correspondence should be addressed.

TABLE 1. *Diet composition, Study 1 and Study 2*

Ingredient	Breeder diet[1]	Chick diet
	(%)	
Ground yellow corn	67.15	56.2
Soybean meal, 44% protein	21.0	39.2
Dehydrated alfalfa meal, 17% protein	3.0	1.0
Dicalcium phosphate	1.3	1.5
Calcium carbonate	6.0	1.2
Iodized salt	1.0	. . .
Vitamin-mineral mix	.5[2]	.9[3]
DL-methionine	.05	. . .
Determined analysis		
Zinc level, mg/kg	28	38

[1]Oyster shell provided free-choice.

[2]Provided per kg of diet: 4,000 IU, vitamin A; 1,000 ICU, vitamin D_3; 500 mg, choline; 11 μg, vitamin B_{12}; 3 mg, riboflavin; 112 mg, MnO; and 22 mg, erythromycin.

[3]Provided per kg of diet: 3,000 IU, vitamin A; 600 ICU, vitamin D_3; 36 IU, vitamin E; 1.5 mg, menadione sodium bisulfite complex; 1.3 g, choline; 27 mg, niacin; 3.6 mg, riboflavin; 7.8 mg, Ca pantothenate; 10.0 μg, vitamin B_{12}; 1.0 g, lysine; 1.0 g, DL-methionine; 4.8 g, NaCl; and 57 mg, MnO.

provided as described by Stahl *et al.* (1986). The basal diet contained 28 mg of Zn/kg of diet, as determined by atomic absorption spectroscopy (Perkin-Elmer model 372, Perkin-Elmer Corp., Norwalk, CT). Zinc, as feed-grade zinc sulfate (Zinc Nacional, Monterrey, Mexico), was added to the basal diet to provide Zn supplementation of: 0, 20, 200, and 2,000 mg of Zn/kg of diet. Each level was fed to two groups of 20 hens.

The hens were trapnested. The hen-day egg production (kilograms of feed consumed per dozen eggs produced) and grams of feed consumed per hen per day were calculated for each hen. The hens were weighed at the end of Study 1 and at 52 wk of age in Study 2.

In Study 1, eggs were collected for incubation after the hens had been receiving the diets for 2, 4, 6, and 8 wk, respectively. In Study 2, eggs were collected at 3, 5, 7, and 9 mo after the hens had been receiving the diets. The resulting chicks were grown to 3 wk of age in Jamesway battery brooders (James Manufacturing Co., Ft. Atkinson, WI) and were fed a corn-soybean meal diet (38 mg of Zn/kg of diet and 6 mg of Cu/kg of diet) as well as tap water; the chicks were weighed and scored for Zn-related feather-fraying (Sunde, 1972). Five, 3-wk old chicks per maternal treatment were killed by cervical dislocation. The liver, pancreas, and right tibiotarsus were removed, cleaned of adhering tissue, rinsed with deionized water, weighed, and frozen until analysis. The tissues were analyzed for Zn, Cu, and Fe as described by Johnson and Greger (1984). Bovine liver standards (SRM Number 1577a, National Bureau of Standards, Washington, DC) were used to analyze each set of samples. The liver standards (n = 28) were found to contain 121 ± 1 mg of Zn/kg, 146 ± 1 mg of Cu/kg, and 181 ± 2 mg of Fe/kg. The standards were certified to contain 123 mg of Zn/kg, 158 mg of Cu/kg, and 194 mg of Fe/kg.

Data were subjected to an analysis of variance, using the repeated-measures option available in the General Linear Model Program of the Statistical Analysis System (1985). Protected, least significant differences were used to separate means where appropriate. All the statements of significance were based on a 5% probability. For fertility and hatchability, the experimental unit (four per study) represented each group of eggs collected and set. Thus, the values reported in the tables represent an average for hatchability and fertility throughout each study. Data from the trials on chick growth were pooled within each hen study.

RESULTS AND DISCUSSION

Adding Zn to the hen's diet, even at the very high level of 2,000 mg of Zn/kg, resulted in no significant differences in overall egg production, feed conversion, or feed consumption in either study (Table 2). Also, no significant differences were found for egg

TABLE 2. *Effect on egg production, feed conversion, feed consumption, and hen body weight of adding zinc to a breeder diet of corn-soybean meal*

Added Zn	Study 1[1]				Study 2[2]			
	Egg production	Feed consumed	Feed consumed	Hen weight	Egg production	Feed consumed	Feed consumed	Hen weight
(mg/kg)	(%)[3]	(kg/dozen eggs)	(g/hen/day)	(g)[4]	(%)	(kg/dozen eggs)	(g/hen/day)	(g)
0[5]	57	2.34	104	2,037	74	2.27	125	1,900
20	59	2.39	105	2,037	78	2.14	127	1,963
200	54	2.60	109	2,014	78	2.04	123	1,935
2,000	44	3.05	104	2,057	69	2.16	114	1,766
Pooled SEM	9	.49	6	87	8	.24	5	67

[1]12-wk study. n = 2 pens.

[2]44-wk study. n = 2 pens.

[3]Mean hen-day egg production, percentage.

[4]Hen weights 68 wk of age in Study 1 and at 52 wk of age in Study 2.

[5]Zinc level in the basal diet was 28 mg/kg of diet.

production or feed conversion between hens receiving the control diet and those receiving the Zn-supplemented diets during any 28-day period in either study. No consistent, significant differences in feed consumption were observed during any 28-day period in Study 1 or Study 2. The results for egg production agree with those of Hermayer *et al.* (1977), who found that a diet containing more than 2,000 mg of Zn/kg of diet was necessary in order to depress production. However, Hermayer *et al.* (1977) found that hens consuming diets with only 794 mg of Zn/kg of diet did show a drop in feed intake and that hens consuming 1,585 mg of Zn/kg of diet also had lower body weights. Jackson *et al.* (1986) found that a diet with 2,000 mg of Zn/kg of diet reduced egg production, feed intake, and body weight. These differences among studies could have been due to the number of experimental units per treatment; and, thus, to sensitivity.

In Study 1, there was a significant, linear decrease in egg production and feed consumption across all treatments (data not shown), as might be expected. For all treatments, feed conversion was constant. No interactions for Zn by time were apparent for any of the variables measured.

In Study 2, there was a significant, linear decrease in egg production across all treatments and a parallel increase in feed conversion. Feed consumption was constant for all treatments. Again, no interactions for Zn treatment by time were apparent for the variables measured (Table 2).

The fertility and hatchability of the eggs incubated during the two studies were not

TABLE 3. *Effect on fertility and hatchability of adding zinc to a corn-soybean meal breeder diet*

Added Zn	Study 1[1]		Study 2[2]	
	Fertility	Hatchability	Fertility	Hatchability
(mg/kg)	(%)			
0[3]	57.8	81.5	84.0	86.5
20	77.0	92.8	87.0	85.7
200	81.7	90.7	72.8	83.8
2,000	78.2	85.9	82.5	69.8
Pooled SEM	15.5	7.2	13.5	6.3

[1]12-wk study. 160 to 200 eggs set per treatment.

[2]44-wk study. 160 to 200 eggs set per treatment.

[3]Zinc level in the basal diet was 28 mg/kg of diet.

TABLE 4. *Effect on progeny body weight and incidence of progeny feather-fraying at 3 wk of age of adding zinc to a corn-soybean meal breeder diet*

	Study 1[1]		Study 2[2]	
Added Zn	Body weight	Frayed feathers	Body weight	Frayed feathers
(mg/kg)	(g)	(%)	(g)	(%)
0[3]	170	14	170	3
20	172	0	167	2
200	180	1	175	0
2,000	184	0	179	0
Pooled SEM	4	8	10	3

[1]12-wk study. n = 60 to 100 chicks per group.
[2]44-wk study. n = 60 to 100 chicks per group.
[3]Zinc level in basal diet was 28 mg/kg of diet.

affected significantly by the level of Zn in the diet (Table 3). In another study, a decline in hatchability was observed for eggs from a different strain of SCWL hens fed a diet containing 178 mg of Zn/kg (Stahl, 1984). Palafox and Ho-A (1980) recorded a drop in the fertility of eggs collected 14 to 28 days after the hens were fed and then removed from a diet with an acute Zn toxicity (20,000 mg of Zn/kg of diet); the hatchability of fertile eggs was not affected. Palafox and Ho-A (1980) also reported that the eggs in their study had lower-than-normal concentrations of Zn and Cu. By contrast, in yet another study, hens continually ingesting the very high Zn diet produced eggs with concentrations of Zn up to 57% higher than those from control hens (Stahl *et al.*, 1988); the amount of Cu in the eggs was reduced by as much as 34% (Stahl *et al.*, 1988).

In the present study, the maternal, dietary treatments had no effect on the body weight of the progeny at 3 wk of age (Table 4). This observation is consistent with an earlier one by Stahl *et al.* (1986). Progeny from dams fed the basal diet did not have increased feather-fraying, as previously described by Stahl *et al.* (1986). In the present investigation, the lack of feather-fraying could be the result of using a different strain of hens (H&N versus Shaver or Babcock), or possibly an unknown change in other factors. Feather-fraying can be affected by the dietary Zn level for mother and progeny; but it appears that other factors can also have an influence (Stahl, 1984; Cook *et al.*, 1984). Because the status of trace-element nutrients during gestation (Beach *et al.*, 1982) and possibly embryogenesis (Kienholz *et al.*, 1961; Stahl *et al.*, 1986, 1989b) may affect subsequent biological functions in animals (i.e., immunity and feather-fraying) and since the availability of trace elements for the developing embryo apparently was altered by the high Zn treatment, the tissue levels of Zn,

TABLE 5. *Effect on the mineral concentration in progeny tissue of adding zinc to a corn-soybean meal breeder diet, Study 1*

	Liver			Pancreas			Tibiotarsus		
Added Zn	Zn	Cu	Fe	Zn	Cu	Fe	Zn	Cu	Fe
(mg/kg)	Wet tissue (μg/g)								
0[1]	19.3[2]	4.3	63.8	34.0	2.1	22.1	89.9	3.7	91.6
20	19.9	4.6	72.0	32.5	1.9	19.5	93.6	3.4	87.5
200	21.6	4.6	67.2	29.0	1.9	22.6	92.5	3.4	84.8
2,000	19.4	3.7	69.3	33.3	2.5	22.6	95.3	3.7	94.2
Pooled SEM	1.3	.5	6.1	2.8	.4	2.1	6.3	.4	6.3

[1]Zinc level in basal diet was 28 mg/kg of diet.
[2]n = 20.

f progeny feather-fraying
neal breeder diet

Study 2[2]	
/ weight	Frayed feathers
	(%)
	3
	2
	0
	0
	3

at 3 wk of age (Table 4). This
s consistent with an earlier one by
986). Progeny from dams fed the
id not have increased feather-
eviously described by Stahl *et al.*
present investigation, the lack of
g could be the result of using a
n of hens (H&N versus Shaver or
possibly an unknown change in
Feather-fraying can be affected
ary Zn level for mother and
it appears that other factors can
influence (Stahl, 1984; Cook *et*
cause the status of trace-element
ng gestation (Beach *et al.*, 1982)
embryogenesis (Kienholz *et al.*,
et al., 1986, 1989b) may affect
biological functions in animals
y and feather-fraying) and since
ty of trace elements for the
nbryo apparently was altered by
reatment, the tissue levels of Zn,

tissue of adding zinc
dy 1

	Tibiotarsus		
	Zn	Cu	Fe
	89.9	3.7	91.6
	93.6	3.4	87.5
	92.5	3.4	84.8
	95.3	3.7	94.2
	6.3	.4	6.3

Cu, and Fe were determined for the progeny. Zinc, copper, and iron concentrations in the tissues of the progeny were not affected by maternal supplementation (Table 5). Dewar *et al.* (1974) demonstrated that the amount of Zn in the egg does not correlate with the amount of Zn transferred to the embryo. If any differences between chicks occurred at hatch, such differences could disappear by 3 wk of age. Since hens ingesting the very high Zn diet for 40 wk did not produce eggs with concentrations of Zn greater than those in eggs produced after ingesting the diet for only 8 wk, the chick tissues from Study 2 were not analyzed.

The present studies showed that long-term supplementation of Zn up to 2,000 mg/kg in the diet of breeder hens resulted in no apparent alteration in the Zn, Cu, or Fe metabolism based on the mineral concentrations in the tissue of the chicks. The present findings suggest that observed changes in the biological functions of progeny (immunity and feather-fraying, although not observed or tested in the current studies) resulted from changes in maternal Zn intake (Sunde, 1972; Beach *et al.*, 1982; Stahl *et al.*, 1989b) and were not a direct consequence of an altered, trace-mineral metabolism in the progeny.

ACKNOWLEDGMENT

The authors thank B. Yandell of the College of Agricultural and Life Sciences Statistical Consulting Service for his assistance with the analyses of repeated measures.

REFERENCES

Beach, R. S., M. E. Gershwin, and L. S. Hurley, 1982. Gestational zinc deprivation in mice: Persistence of immunodeficiency for three generations. Science 218: 469–471.

Cook, M. E., M. L. Sunde, J. L. Stahl, and L. E. Hanson, 1984. Zinc deficiency lesions in pheasant chicks fed practical diets. Avian Dis. 28:1102–1109.

Dewar, W. A., P. W. Teague, and J. N. Downie, 1974. The transfer of minerals from the egg to the chick embryo from the 5th to 18th days of incubation. Br. Poult. Sci. 15:119–129.

Dewar, W. A., P.A.L. Wight, R. A. Pearson, and M. J. Gentle, 1983. Toxic effects of high concentrations of zinc oxide in the diet of the chick and laying hen. Br. Poult. Sci. 24:397–404.

Gentle, M. L., W. A. Dewar, P.A.L. Wight, and K. M. Dick, 1982. The effects of high dietary zinc on food intake in the domestic fowl appetite. J. Intake Res. 3:53–60.

Hermayer, K. L., P. E. Stake, and R. L. Shippe, 1977. Evaluation of dietary zinc, cadmium, tin, lead, bismuth and arsenic toxicity in hens. Poult. Sci. 56:1721–1722. (Abstr.)

Jackson, N., S. W. Gibson, and M. H. Stevenson, 1986. Effects of short- and long-term feeding of zinc oxide-supplemented diets on the mature, female domestic fowl with special reference to tissue mineral content. Br. J. Nutr. 55:333–349.

Jensen, L. S., 1988. Control of feed intake in poultry by the hydroxy analogue of glycine. Pages 35–40 *in*: Proc. Maryland Nutr. Conf. March 10–11, Baltimore, MD.

Johnson, M. A., and J. L. Greger, 1984. Absorption, distribution and endogenous excretion of zinc by rats fed various dietary levels of inorganic tin and zinc. J. Nutr. 114:1843–1852.

Kienholz, W. E., P. E. Turk, M. L. Sunde, and W. G. Hoekstra, 1961. Effects of zinc deficiency in the diet of hens. J. Nutr. 75:211–221.

Kincaid, R. L., W. J. Miller, L. S. Jensen, D. L. Hampton, M. W. Neathery, and R. P. Gentry, 1976. Effect of high amounts of dietary zinc and age upon tissue zinc in young chicks. Poultry Sci. 55:1954–1957.

Klussendorf, R. D., and J. Pensak, 1958. Newer aspects of zinc metabolism. J. Am. Vet. Med. Assoc. 132: 446–450.

Nehring, A. L., J. H. Brumbaugh, and H. W. Titus, 1956. A comparison of the growth of chicks fed diets containing different quantities of zinc. Poultry Sci. 35: 956–958.

Palafox, A. L., and E. Ho-A, 1980. Effect of zinc toxicity in laying white leghorn pullets and hens. Poultry Sci. 59: 2024–2028.

Roberson, R. H., and P. J. Schaible, 1960. The tolerance of growing chicks for high levels of different forms of zinc. Poultry Sci. 39:893–896.

SAS Institute Inc., 1985. Pages 433–506 *in*: SAS User's Guide: Statistics, Version 5 ed. SAS Inst. Inc., Cary, NC.

Scott, J. T., and C. R. Creger, 1976. The use of zinc as an effective molting agent in laying hens. Poultry Sci. 55: 2089. (Abstr.)

Southern, L. L., and D. H. Baker, 1983. Zinc toxicity, zinc deficiency and zinc-copper interrelationship in *Eimeria acervulina*-infected chicks. J. Nutr. 113: 688–696.

Stahl, J. L., 1984. Zinc requirements for laying hens for normal egg and chick production. M.S. thesis, Univ. Wisconsin, Madison, WI.

Stahl, J. L., M. E. Cook, and J. L. Greger, 1988. Zinc, iron and copper content of eggs from hens fed varying levels of zinc. J. Food Comp. Anal. 1:309–315.

Stahl, J. L., M. E. Cook, and M. L. Sunde, 1986. Zinc supplementation: Its effect on egg production, feed conversion, fertility, and hatchability. Poultry Sci. 65: 2104–2109.

Stahl, J. L., M. E. Cook, M. L. Sunde, and J. L. Greger, 1989b. Enhanced humoral immunity in progeny chicks from hens fed practical diets supplemented with zinc. Appl. Agric. Res. 4:86–89.

Stahl, J. L., J. L. Greger, and M. E. Cook, 1989a. Effect of variations in zinc intake on zinc, copper and iron utilization in chicks. Br. Poult. Sci. 30:123–134.

Stevenson, M. H., S. W. Gibson, and N. Jackson, 1987. Withdrawal of zinc oxide-containing diets from mature, female domestic fowl: Effects on selected tissue mineral contents. Br. Poult. Sci. 28:449–459.

Sunde, M. L., 1972. Zinc requirement for normal feathering of commercial Leghorn-type pullets. Poultry Sci. 51: 1316–1322.