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Eimeria acervulina Infection and the Zinc-Copper Interrelationship in the Chick

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ABSTRACT An experiment was conducted with young chicks to investigate the effect of duodenal coccidiosis caused by *Eimeria acervulina* infection on the interrelationship between dietary copper (Cu) and zinc (Zn). A corn-soybean meal diet (devoid of Zn fortification) was supplemented with Zn (50 mg/kg) or Cu (250 mg/kg), or both; these diets were fed to control or coccidiosis-infected chicks. The coccidial infection depressed rate and efficiency of weight gain. Excess dietary Cu had no effect on performance of control or infected chicks. Zinc supplementation did not affect performance of control chicks, but it improved both rate and efficiency of weight gain in *E. acervulina*-infected chicks. Liver Zn concentration was decreased by coccidiosis, increased by Zn supplementation, but unaffected by excess dietary Cu. Liver Cu concentration was increased by excess dietary Cu and by coccidiosis but decreased by Zn supplementation of the diet. These data indicate that coccidiosis impaired Zn utilization and precipitated Zn deficiency in the chick.

(Key words: coccidiosis, copper, zinc, performance, tissue copper, tissue zinc)

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INTRODUCTION

We reported recently that *Eimeria acervulina* infection (duodenal coccidiosis) increased tissue copper (Cu) accumulation and exacerbated Cu toxicity in chicks (Southern and Baker, 1982). Zinc (Zn), however, appeared to be less toxic during coccidiosis, and tissue Zn levels were decreased, rather than increased, by the coccidial infection (Southern and Baker, 1983). These data suggest that coccidiosis increased Cu absorption but decreased Zn absorption. Practical poultry diets, which may be slightly deficient in Zn (Zeigler *et al.*, 1961), are routinely supplemented with excess Cu. Moreover, Cu and Zn have been shown to be antagonistic to each other (Hill and Matrone, 1962, 1970; Starcher, 1969). Thus, coccidiosis could precipitate Zn deficiency in chicks, especially during high intakes of Cu. This investigation was designed to determine the effect of duodenal coccidiosis and excess dietary Cu on the Zn status of chicks fed corn-soybean meal diets.

MATERIALS AND METHODS

Male chicks resulting from the cross of New Hampshire males and Columbian females were used in this study. Care and handling of the chicks as well as experimental allotment procedures have been described previously (Southern and Baker, 1982). Three replicates of five male chicks each were assigned to each treatment, and the experimental period was 8 to 22 days posthatching. Chicks were allowed *ad libitum* access to experimental diets and water. Weight gain and feed consumption were determined at the end of the experiment.

The basal diet (Table 1) used in this study was a conventional corn-soybean meal diet formulated to meet or exceed nutrient requirements of the growing chick (National Research Council, 1977) except that it contained no Zn supplementation. Dietary additions of Zn and Cu were made to the basal diet at the expense of cornstarch and were provided by $ZnCO_3$ and $CuSO_4 \cdot 5H_2O$, respectively.

Coccidial infections were established by 1-ml crop intubations of an aqueous inoculum containing 4×10^5 sporulated *E. acervulina*

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TABLE 1. *Composition of basal diet*[a]

Ingredient	(%)
Cornstarch	to 100.00
Ground corn (8.5% CP)	50.97
Soybean meal (48% CP)	37.00
Corn oil	4.00
Menhaden fish meal (60% CP)	2.00
Alfalfa meal, dehydrated (17% CP)	1.00
Dicalcium phosphate	2.20
Limestone, ground	1.00
Iodized salt	.40
DL-methionine	.20
Choline chloride (60%)	.10
Vitamin premix[b]	.10
Manganese sulfate (28% Mn)	.05
Lincomycin premix (44 g/kg)	.01

[a]Contained 40 mg/kg Zn.

[b]Southern and Baker (1982).

oocysts.[4] The *E. acervulina* inoculum was prepared in our laboratory and administered as previously described (Willis and Baker, 1981). Uninfected chicks received tap water sham inoculations. Chicks were inoculated on days 0, 3, 6, 9, and 12 of the experiment.

The experiment consisted of a 2 × 2 × 2 factorial arrangement of treatments. Two levels of Zn (0 and 50 mg/kg) and two levels of Cu (0 and 250 mg/kg) were added to the basal diet. The experimental diets were then fed in the presence and absence of induced *E. acervulina* infection.

At the termination of the experiment, three uniform chicks within a replicate were bled by cardiac puncture. The blood was pooled by replicate and analyzed immediately for hemoglobin content (Crosby *et al.*, 1954) and hematocrit value (Cohen, 1967). The chicks were then killed by cervical dislocation and the gallbladder-free half of the liver and the right tibia removed and pooled by replicate. The liver segment was analyzed for Zn and Cu, and each tibia was measured to determine length-to-width ratio (Southern and Baker, 1983).

Data were analyzed by analysis of variance procedures (Steel and Torrie, 1980). Orthogonal single degree-of-freedom comparisons were used to test treatment differences.

[4]Microscopic examination of the inoculum prior to intubation was carried out to enumerate the population of sporulated oocysts. Coccidiosis was verified by intestinal lesion scoring and periodic examination of fecal excreta for shed oocysts.

RESULTS AND DISCUSSION

The coccidial infection depressed both rate and efficiency of weight gain (Table 2). Dietary Zn supplementation did not affect performance of healthy chicks, but it dramatically improved both gain and gain/feed of *E. acervulina*-infected chicks. Thus, significant coccidiosis × Zn interactions were observed in gain and gain/feed data. Excess Cu addition to the diet did not affect performance of healthy or coccidiosis-infected chicks.

Liver Zn concentration was increased slightly by dietary Zn supplementation, but it was decreased by coccidiosis, regardless of whether the diet was supplemented with Zn. Excess dietary Cu did not affect liver Zn levels. The excess Cu addition, however, dramatically increased liver Cu concentration, and coccidiosis, in the presence of excess dietary Cu, quadrupled liver Cu. Zinc supplementation of the diet, however, reduced liver Cu in both healthy and coccidiosis-infected chicks receiving excess Cu.

Blood hemoglobin and hemotocrit values, as well as tibia length-to-width ratio, were determined (data not shown) as a means of assessing Zn deficiency in chicks (O'Dell *et al.*, 1968). No significant differences associated with Zn deficiency were observed in any of these parameters. This is not surprising, because we have recently shown that performance is more indicative of Zn status than either blood or bone measurements, especially in chicks not severely deficient in Zn (Southern and Baker, 1983).

The results of this study indicate that duodenal coccidiosis impairs Zn utilization to the point of precipitating Zn deficiency. A signficant growth response to Zn supplementation was observed in coccidiosis-infected chicks but not in healthy chicks. Excess dietary Cu did not affect performance of uninfected or infected chicks, nor did it impair Zn utilization. Zinc supplementation of the diet, however, dramatically reduced liver Cu levels in chicks fed excess Cu. This agrees with earlier research with rats (O'Dell *et al.*, 1976) and chicks (Southern and Baker, 1983) showing that Zn interferes with Cu absorption but that Cu does not interfere with Zn absorption.

TABLE 2. *Performance and liver analyses of control (–) and E. acervulina infected (+) chicks fed a corn-soybean meal diet with or without Z supplementation, or excess Cu addition,[a] or both*

Dietary addition		Gain[b,d]		Gain/feed[b,d]		Liver Zn[c,e]		Live
Zn[g]	Cu[h]	–	+	–	+	–	+	–
(mg/kg)		(g)		(g/kg)		(μg/g dry tissue)		
0	0	255	176	655	576	97	93	11
50	0	260	204	671	622	108	102	12
0	250	252	187	659	556	108	100	88
50	250	262	210	657	617	109	104	64
Pooled SEM		5.9		10.1		4.4		

[a] Infected chicks (+) were inoculated with 4×10^5 sporulated *E. acervulina* oocysts on days 0, 3, 6, 9, and 12 of the experiment.

[b] Data are mean values per chick of three replicates of five male chicks during the assay period 8 to 22 days posthatching; average initial weight was 72 g

[c] Data are means of three samples, each sample representing pooled tissue from three uniform chicks within a replicate.

[d] Coccidiosis × Zn interaction significant ($P<.04$).

[e] Coccidosis and Zn main effects significant ($P<.08$).

[f] Coccidiosis × Cu ($P<.01$) and Cu × Zn ($P<.08$) interactions significant.

[g] Provided by $ZnCO_3$.

[h] Provided by $CuSO_4 \cdot 5H_2O$.

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