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Effect of Dietary Sodium Zeolite A and Excess Calcium on Growth and Tibia Calcium and Phosphorus Concentration in Uninfected and *Eimeria acervulina*-Infected Chicks[1]

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ABSTRACT Two identical trials were conducted with 5 to 14-day-old broiler chicks. Sodium zeolite A (NZA, 0 and .75%) and Ca (1.0 and 1.5%) were fed to both uninfected and *Eimeria acervulina*-infected chicks resulting in a 2 × 2 × 2 factorial arrangement of treatments. Coccidial infection reduced weight gain and gain:feed (P<.01), and tibia ash, Ca, and Ca:P ratio (P<.05). Excess dietary Ca reduced (P<.05) weight gain and tibia ash in uninfected chicks but had no effect (P>.10) in coccidiosis-infected chicks (Ca × coccidiosis interaction, P<.05). Addition of NZA to diets with excess Ca further decreased (P<.05) weight gain and tibia ash in both uninfected and *E. acervulina*-infected chicks. Tibia Ca, as a percentage of dry fat-free tibia, was reduced (P<.05) by the addition of NZA. This effect was not observed when tibia Ca was expressed as a percentage of ash. These results suggest that NZA may exacerbate the adverse effects of excess dietary Ca.

(*Key words*: chicks, zeolite, weight gain, bone Ca, coccidiosis)

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INTRODUCTION

Sodium zeolite A[3] (NZA) is a synthetic hydrated sodium aluminosilicate with a crystalline lattice structure having a large surface area and pore value occupied by exchangeable sodium ions and water (Pond and Mumpton, 1984). Calcium and other divalent cations are known to exchange with the Na ions associated with NZA.

The ion exchange property of NZA may be responsible for the reported increase in egg shell weight as measured by specific gravity of eggs when NZA is fed to laying hens (Roland *et al.*, 1985; Miles *et al.*, 1986; Harms and Miles, 1987; Roland, 1988) and broiler breeders (Ingram *et al.*, 1987; Skinner *et al.*, 1988). The effect of NZA on growth, feed efficiency, and mineral balance, however, is less clear. Willis *et al.* (1982) reported that the addition of certain natural zeolites to broiler diets improved weight gain and feed efficiency. Harris *et al.* (1988) reported that addition of .5% NZA to the diet of broilers raised in a hot climate improved weight gain and feed efficiency, whereas broilers raised in a moderate climate did not respond to dietary NZA. Waldroup *et al.* (1984) observed no beneficial effect of dietary zeolite on weight gain or feed utilization of broilers. Similarly, Ballard and Edwards (1988) reported no effect of dietary NZA on weight gain and gain:feed; however, tibia ash was higher, and incidence of tibial dyschondroplasia was lower in chickens fed NZA. The diet used by Ballard and Edwards (1988) contained .65% Ca.

Excess dietary Ca greater than 1.2% reduces growth and percentage of tibia ash in chicks (Smith and Taylor, 1961; Scott *et al.*, 1982; Bafundo *et al.*, 1984; Smith and Kabaija, 1985). If dietary NZA enhances Ca utilization, then inclusion of NZA in diets with excess Ca should further reduce growth and percentage of tibia ash. Coccidial infections, specifically *Eimeria acervulina* infections, reduce Ca absorption (Turk, 1973), tibia Ca content, and tibia Ca:P ratio (Giraldo *et al.*, 1987). Sodium zeolite A may overcome the reduction in Ca utilization that occurs in coccidiosis-infected chickens. Thus, the purpose of this investigation was to assess the effect of NZA on weight

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[3]The abbreviation NZA will be used when referring specifically to synthetic sodium zeolite A. Zeolite will be used when referring to both natural and synthetic zeolites referenced by other authors.

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

Ingredient	(%)
Silica flour	to 100.00
Ground yellow corn	45.07
Soybean meal (44% CP)	42.50
Corn oil	5.00
Dehydrated alfalfa leaf meal	2.00
Defluorinated phosphate	2.10
Oyster shell flour	.40
NaCl	.40
Vitamin mix[2]	.25
DL-Methionine	.15
$MnSO_4 \cdot H_2O$	.05
$ZnCO_3$	.01

[1]Calculated composition of the diet: CP, 23%; lysine, 1.37%; methionine, .52%; cystine, .37%; ME, 3,000 kcal/kg.

[2]Roche Chemical Division, Nutley, NJ. Provided the following per kilogram of diet: vitamin A acetate, 6,614 IU; vitamin D_3 (D-activated animal sterol), 1,653 IU; dl-α-tocopheryl acetate, 6.6 IU; vitamin B_{12}, 11 μg; riboflavin, 6.6 mg; niacin, 33.1 mg; d-pantothenic acid, 11.0 mg; choline, 551 mg; menadione sodium bisulfite, 4.4 mg; folic acid, .7 mg; pyridoxine, 1.1 mg; thiamin, 1.1 mg; d-biotin, 55 μg.

gain, feed intake, gain:feed, and percentage and composition of tibia ash in uninfected and *E. acervulina*-infected chicks fed 1.0 and 1.5% Ca.

MATERIALS AND METHODS

Unsexed Arbor Acres × Peterson chicks from a commercial hatchery (Sanderson Farms, Laurel, MS) were used in this investigation. From hatching to Day 4 posthatching, all chicks were fed a conventional corn-soybean meal diet (Table 1). After an overnight fast, chicks were inspected for fecal pasting, weighed, wingbanded, and randomly assigned to one of eight experimental treatments. Chicks were provided continuous light and penned in heated, thermostatically controlled (mean temperature 35 C) starter batteries with raised wire floors. Five replicates of five chicks in each of two identical trials (total of 10 replicates of 5 chicks/treatment) were assigned to each treatment and maintained on the experimental diets from Day 5 to Day 14 posthatching. Chicks were allowed *ad libitum* access to feed and water. Average initial weight of chicks was 80.3 and 76.4 g for Trials 1 and 2, respectively.

The basal diet (Table 1) was formulated to meet or exceed the nutrient requirements of growing chicks (National Research Council, 1984). Dietary additions were made to the basal diet at the expense of silica flour (Fisher Chemical Co.).

Coccidial infections were established by crop intubation of 1 ml of an aqueous inoculum containing 4×10^5 sporulated *E. acervulina* oocysts on Days 0, 3, and 6 of the trials. Uninfected chicks received sham inoculations with tap water.

Treatment diets consisting of the basal (B), B + .5% Ca from 1.32% oyster shell flour, B + .75% NZA, and B + .5% Ca + .75% NZA were fed to uninfected and *E. acervulina*-infected chicks resulting in a 2 × 2 × 2 factorial arrangement of treatments. All diets were analyzed to contain .87% P and were calculated to contain approximately .53% available P (National Research Council, 1984). Chemical analysis confirmed that the diets with no excess Ca contained 1.0% Ca, and that the diets with 1.32% excess oyster shell flour contained 1.5% Ca.

At the termination of both trials (Day 14 posthatching), chicks were weighed individually and feed consumption was determined. Following euthanasia by cervical dislocation, the left tibia was removed from each chick. The dry fat-free tibia was dry ashed at 590 C for 20 h. The Ca content of the ash was determined by atomic absorption spectroscopy (Association of Official Analytical Chemists, 1984), and P was determined using an automated (No. 369-75A, Technicon Industrial Systems, Tarrytown, NY) molybdovandate method (Association of Official Analytical Chemists, 1984).

Data for both trials were pooled and analyzed by analysis of variance procedures appropriate for factorially arranged treatments (Steel and Torrie, 1980). Orthogonal single degree of freedom comparisons were used to test treatment differences. Trial × treatment interaction mean squares were used as the error term when $P<.10$. The pen of chicks was used as the experimental unit.

RESULTS

Experimental coccidial infection reduced ($P<.01$) weight gain, feed intake and gain:feed (Table 2). The coccidial infection also reduced tibia ash ($P<.01$), Ca as a percentage of tibia ash ($P<.05$), Ca as a percentage of dry fat-free tibia ($P<.01$), and tibia Ca:P ratio ($P<.05$)

TABLE 2. *Weight gain, feed intake, and feed efficiency of control (–) and Eimeria acervulina-infected (+) chicks fed excess Ca or sodium zeolite A (NZA) or both*[1]

Dietary additions	Weight gain[2] –	Weight gain[2] +	Feed intake[3] –	Feed intake[3] +	Gain:feed[4] –	Gain:feed[4] +
	(g)				(g/g)	
Basal (B)	281	165	368	266	.763	.619
B + .5% Ca	265	167	350	258	.755	.645
B + .75% NZA	275	168	365	266	.752	.633
B + Ca + NZA	252	154	342	247	.738	.624
Pooled SEM	4.7		8.5		.012	

[1]Data are means of ten replicates of five chicks each. Average initial chick weight was 78.4 g (Trial 1, 80.3 g; Trial 2, 76.4 g).

[2]Coccidiosis (P<.001), Ca (P<.01), and NZA effects (P<.04) and coccidiosis × Ca (P<.05) and coccidiosis × NZA (P<.08) interactions.

[3]Coccidiosis (P<.001) and Ca effects (P<.02).

[4]Coccidiosis effect (P<.001).

compared with uninfected chicks (Table 3). Tibia P as a percentage of ash, however, was increased (P<.05) in coccidiosis-infected chicks.

Excess dietary Ca reduced weight gain in uninfected chicks but had no effect in coccidiosis-infected chicks (coccidiosis × Ca interaction, P<.05); however, excess Ca reduced (P<.02) feed intake in both uninfected and coccidiosis-infected chicks (Table 2). Excess Ca also reduced tibia ash and Ca content (percentage of dry fat-free tibia) in uninfected chicks but not in coccidiosis-infected chicks (coccidiosis × Ca interaction, P<.02, Table 3).

The addition of NZA to the basal diet had no effect on weight gain, feed intake, or gain: feed of chicks fed 1.0% Ca. However, the addition of NZA to diets with excess Ca resulted in a further reduction (P<.05) in weight gain and tibia ash. This resulted in Ca × NZA interactions for tibia ash (P<.02) and weight gain (P<.08). There were no Ca or NZA main effects on tibia Ca or P content when these minerals were expressed as a percentage of ash (Table 3). However, when tibia Ca was expressed as a percentage of dry fat-free tibia, dietary NZA addition reduced (P<.05) tibia Ca in uninfected chicks fed excess Ca and in coccidiosis-infected chicks irrespective of Ca level. Tibia P expressed as a percentage of dry fat-free tibia was not affected by dietary Ca or NZA.

DISCUSSION

Experimental coccidial infection reduced weight gain, feed intake, gain:feed, and tibia ash and Ca content, and increased tibia P content. These effects are well documented characteristics of *E. acervulina*-infected chicks (Turk, 1973; Stephens *et al.*, 1974; Willis and Baker, 1981; Southern and Baker, 1983; Giraldo *et al.*, 1987).

Research has indicated that feeding high levels of Ca reduces weight gain and feed consumption and delays sexual maturity in pullets. It is recommended that chicks should not be fed diets containing more than 1.2% Ca until 18 to 20 wk of age (Smith and Taylor, 1961; Scott *et al.*, 1982; Bafundo *et al.*, 1984; Smith and Kabaija, 1985). The growth reduction observed in the present experiment was most likely the result of a decreased feed intake, because excess Ca had no effect on gain:feed. Although chicks fed 1.5% Ca had lower feed intakes than chicks fed 1.0% Ca, their daily Ca intake was still 52% greater. Smith and Taylor (1961) observed that broilers from 0 to 6 wk of age fed 1.3% Ca had reduced weight gain and feed efficiency; however, feed intake was identical to that of chicks fed .8% Ca. The authors suggested that the reduction in growth was due to the excess of Ca interfering with the utilization of other nutrients. Bafundo *et al.* (1984) found that .9 and 1.8% excess Ca reduced weight gain and tissue Zn in growing chicks. Smith and Kabaija (1985) reported that high dietary Ca

TABLE 3. *Mineral content of the tibia of control (–) and Eimeria acervulina-infected (+) chicks fed excess Ca or sodium zeolite A (NZA) or both*[1]

Dietary additions	$Ca^{2,3}$ –	$Ca^{2,3}$ +	$Ca^{2,4}$ –	$Ca^{2,4}$ +	$P^{2,3}$ –	$P^{2,3}$ +	P^{2} –	P^{2} +	Ash^{5} –	Ash^{5} +	$Ca{:}P^{3}$ –	$Ca{:}P^{3}$ +
	(% of ash)		(% of tibia)		(% of ash)		(% of tibia)		(%)			
Basal (B)	36.82	34.86	19.02	16.79	18.97	20.68	9.80	9.94	51.65	48.12	1.94	1.70
B + .5% Ca	36.66	34.51	18.74	17.63	18.72	19.95	9.57	9.90	51.11	49.65	1.96	1.79
B + .75% NZA	37.10	33.27	19.34	16.02	19.41	20.14	10.12	9.70	52.14	48.18	1.91	1.66
B + Ca + NZA	35.25	34.64	17.29	16.60	19.20	19.26	9.42	9.25	49.08	47.97	1.84	1.82
Pooled SEM	.91		.43		.53		.27		.47		.08	

[1]Data are means of ten replicates of five chicks each.

[2]Tibia Ca and P concentration expressed as a percentage of ash and as a percentage of dry fat-free tibia.

[3]Coccidiosis effect ($P \leq .05$).

[4]Coccidiosis ($P \leq .01$) and NZA ($P \leq .05$) effects and coccidiosis × Ca interaction ($P \leq .02$).

[5]Coccidiosis ($P \leq .01$) and NZA ($P \leq .05$) effects and coccidiosis × Ca ($P \leq .01$) and Ca × NZA ($P \leq .02$) interactions.

had no effect on weight gain, feed intake, feed efficiency, or mortality in broilers from 3 to 42 days posthatching. However, tibia volume increased and tibia ash decreased as dietary Ca was increased from 1 to 3% and dietary P was held constant at .6%. As increasing dietary P to 1.2% removed the negative effects of excess Ca on tibia, Smith and Taylor (1961) concluded that these effects could be attributed to an imbalance of Ca and P.

Coccidiosis-infected chicks were less susceptible to the adverse effects of excess Ca (decreased weight gain and tibia ash) than were uninfected chicks. This diminished susceptibility can probably be attributed to a reduced efficiency of Ca utilization and absorption by coccidiosis-infected chicks (Turk, 1973; Giraldo *et al.*, 1987).

Results of the present study indicate that NZA influences Ca utilization. Sodium zeolite A accentuated the adverse effects of excess Ca and further reduced growth, feed intake, and tibia ash in chicks fed excess Ca. Ballard and Edwards (1988) have also reported that male broiler chicks fed diets containing 1.0% NZA had increased absorption and day zero retention of orally and intramuscularly administered ^{47}Ca.

The means by which NZA affects Ca utilization is not known. However, NZA contains approximately 15% Al (.1125% dietary Al), and NZA is hydrolyzed to various silicate and aluminate compounds at pH 5 or less (Cook *et al.*, 1982). Therefore, it is possible that the observed effects could be in part attributed to the well documented (Ondreicka *et al.*, 1966; Venugopal and Luckey, 1978; Spencer and Lender, 1979) inhibition of P absorption by various Al compounds. Edwards (1988) reported that 1.0% dietary NZA decreased total and phytate P retention in male chicks. Storer and Nelson (1968) reported that aluminum sulfate and aluminum chloride (.01 to .08% dietary Al) reduced weight gain, feed efficiency, and bone ash when fed to chicks 1 to 15 days of age. They concluded that Al can impair chick growth if supplied in soluble form. The only criterion used in the present investigation that could be used to evaluate P utilization would be tibia P content, which was not affected by NZA. Little or no effect on growth or tibia composition was observed when NZA was included in the diets of chicks fed 1.0% Ca.

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