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Effect of Sodium Bentonite or Hydrated Sodium Calcium Aluminosilicate on Growth Performance and Tibia Mineral Concentrations in Broiler Chicks Fed Nutrient-Deficient Diets[1]

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ABSTRACT An experiment was conducted to determine whether sodium bentonite (NaB) or hydrated sodium calcium aluminosilicate (HSCA) would affect growth performance and tibia mineral concentrations in chicks fed nutrient-deficient diets. Two identical trials were conducted; each using 240 5- to 19-d-old broiler chicks (4 replicates of 5 chicks each) in a completely random design. A factorial arrangement of treatments consisted of four types of nutrient deficiencies [nutritionally complete basal (C), macromineral-deficient (–MM), trace mineral- and vitamin-deficient (–TMV), and crude protein-deficient (–CP)], and three types of additive (none, .5% NaB, and .5% HSCA). The –MM and –TMV diets reduced ($P < .01$) gain, feed intake, and gain:feed. The –CP diet decreased ($P < .01$) gain and gain:feed but did not affect ($P > .10$) feed intake. Sodium bentonite increased feed intake ($P < .01$) of all diets, resulting in an increase in gain ($P < .09$). Sodium bentonite increased gain:feed in chicks fed the –MM diet but did not affect gain:feed in chicks fed the C, –TMV, or –CP diets (NaB × –MM interaction, $P < .02$). The –MM and –TMV diets decreased ($P < .01$) tibia ash, but the –CP diet increased ($P < .01$) tibia ash. The –MM diet decreased ($P < .01$) tibia Ca but increased ($P < .01$) tibia P. Neither NaB nor HSCA affected percentage of tibia ash, Ca, or P. Tibia Zn and Mn concentrations were increased ($P < .01$) by the –MM diet and decreased ($P < .01$) by the –TMV diet. Tibia Mn concentration was increased ($P < .01$) by the –CP diet. Sodium bentonite and HSCA did not adversely affect growth performance or tibia mineral concentrations of chicks fed nutrient-deficient diets.

(*Key words*: chick, aluminosilicate, sodium bentonite, growth, tibia minerals)

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INTRODUCTION

Sodium bentonite (NaB) and some forms of hydrated sodium calcium aluminosilicate (HSCA), as well as other similar dietary additives, have been shown to decrease the severity of aflatoxicosis and other mycotoxicoses in pigs (Smith, 1984; Colvin *et al.*, 1989; Schell *et al.*, 1993) and chickens (Phillips *et al.*, 1988; Kubena *et al.*, 1990a,b; Huff *et al.*, 1992; Scheideler, 1993). Some of these additives bind aflatoxin B_1 *in vitro* (Phillips *et al.*, 1988; Scheideler, 1993). Thus, the efficacy of these additives probably resides in their ability to bind aflatoxin in the intestine, rendering the toxin unavailable for absorption.

Many of the feed additives used to diminish aflatoxicosis are naturally occurring and relatively inexpensive. Because of the inexpensive nature of these products, their efficacy in preventing aflatoxicosis, and the fairly frequent occurrence and detrimental effects of aflatoxin, these feed additives are becoming common additions to pig and poultry diets. Many nutrients

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are large molecular weight charged compounds that also could be rendered unavailable by these feed additives. Chung *et al.* (1990) reported that a HSCA (NovaSil™) did not affect liver vitamin A concentrations, tibia Mn or Zn concentrations, or the utilization of riboflavin. Schell *et al.* (1993), however, reported that NaB decreased the absorption and retention of some minerals in pigs, and high levels of dietary NaB have been shown to decrease the availability of vitamin A in chicks (Briggs and Fox, 1956; Laughland and Phillips, 1956). Therefore, the purpose of our study was to evaluate the effect of NaB and HSCA in chicks fed nutrient-deficient diets, which should provide a sensitive response surface for detecting detrimental effects on nutrients. Specifically, this investigation was designed to determine the effect of NaB and a naturally occurring HSCA on growth and tibia mineral concentrations in chicks fed diets deficient in macrominerals, vitamins and microminerals, or crude protein.

MATERIALS AND METHODS

Unsexed Arbor Acres × Arbor Acres broiler chicks from a commercial hatchery[3] were used in two identical trials. From hatching to 4 d posthatching, the chicks were fed a corn-soybean meal diet containing 23% CP, devoid of supplemental trace minerals and vitamins, supplemented with .2% salt, and formulated to provide 70% of the NRC (1984) requirement for Ca and P. After the chicks were deprived of feed overnight, they were weighed and randomly assigned to treatment groups on the basis of body weight (average initial weight was 70.5 g in Trial 1 and 69.9 g in Trial 2). Chicks were provided continuous fluorescent lighting and penned in heated, thermostatically controlled (mean temperature 35 C) stainless steel brooder batteries with raised wire floors. Four replicates of five chicks each were assigned to each treatment, and the chicks were fed their experimental diets from 5 to 15 d posthatching. Chicks were allowed *ad libitum* access to feed and water.

Four diets (Table 1) and three dietary feed additives in 3 × 4 factorial arrangement were used in this experiment (the treatment diets and arrangement were identical for each trial). Diet 1 (Complete) was formulated to be adequate in all nutrients (NRC, 1984). Diet 2 (–MM) was formulated to be deficient in the macrominerals Ca, P, Na, and Cl. Diet 3 (–TMV) was devoid of trace mineral and vitamin supplementation. Diet 4 (–CP) was similar to Diet 1 except that it was diluted with 40% cornstarch, resulting in a diet that was deficient in protein and relatively higher in ME, and that contained levels of minerals and vitamins greater than or equal to the levels present in the Complete diet. The diets contained less than 1 ppb aflatoxin. Each of the diets was supplemented with .50% silica flour, .50% NaB,[4] or .50% HSCA.[5] The NaB contained 53 ppm of Zn and 160 ppm of Mn, and the HSCA contained 38 ppm of Zn and 330 ppm of Mn.

At the termination of each trial, individual chick weights and pen feed consumption were determined. All chicks were killed by cervical dislocation and the left tibia was removed for mineral analyses. Tibias were cleaned of adherent tissue, extracted (Soxhlet) continuously for 48 h in 90% ethanol and then for 48 h in anhydrous diethyl ether, and dried at 100 C for 12 h. The dry fat-free tibias were weighed and dry ashed at 550 C for 20 h.

The Ca, Zn, and Mn content of the tibia ash and diets was determined by flame atomic absorption spectroscopy.[6] The P content of the tibia ash and diets was determined spectrophotometrically (Association of Official Analytical Chemists, 1984). The mineral content of the NaB and HSCA was determined using an inductively coupled plasma spectrophotometer.[7]

[3]Sanderson Farms, Laurel, MS 39440.

[4]Astra Ben 20A (AB 20A), Prince Agri Products Inc., Quincy, IL 62301.

[5]Azomite (granulated), Peak Minerals—Azomite, Inc., Colorado Springs, CO 80903.

[6]Model 3030B, Perkin-Elmer Corp., Norwalk, CT 06859.

[7]Series 800 Plasma AtomComp Direct-Reading Spectrometer, Thermo-Ash Jarrell Corp., Franklin, MA 02038.

TABLE 1. Composition of experimental diets[1]

Ingredients and composition	Complete	–MM	–TMV	–CP
	(%)			
Corn	46.70	46.70	46.70	27.01
Soybean meal, 44% CP	42.50	42.50	42.50	24.86
Cornstarch	. . .	. . .	. . .	40.00
Alfalfa leaf meal	2.00	2.00	2.00	1.17
Corn oil	5.00	5.00	5.00	2.92
Defluorinated rock phosphate	2.10	. . .	2.10	2.40
Oyster shell flour	.40	. . .	.40	.40
Salt	.40	. . .	.40	.40
Vitamin-mineral premix[2]	.25	.25	. . .	.25
DL-methionine	.15	.15	.15	.09
Silica flour or feed additives	.50	2.90	.75	.50
Composition[3]				
CP	23.5	23.3	23.7	16.6
Methionine + cystine	.89	.89	.89	.52
Lysine	1.37	1.37	1.37	.80
Arginine	1.64	1.64	1.64	.96
Calcium	.92	.32	.85	1.05
Total phosphorus	.80	.43	.79	.79
Zinc, mg/kg diet	70	69	33	66
Manganese, mg/kg diet	98	84	38	102
Metabolizable energy, kcal/kg	2,980	2,980	2,980	3,191

[1]Complete = nutritionally adequate diet; –MM = deficient in sodium, chloride, calcium, and phosphorus; –TMV = deficient in trace minerals and vitamins; –CP = deficient in CP.

[2]Provided the following per kilogram of diet: vitamin A (retinyl acetate), 11,000 IU; cholecalciferol (d-activated animal sterol), 1,650 IU; dl-α-tocopheryl acetate, 8 IU; menadione (menadione sodium bisulfite), .72 mg; thiamine (mononitrate), 1 mg; riboflavin, 4.4 mg; niacin, 33 mg; d-pantothenic acid (d-calcium pantothenate), 8.1 mg; folic acid, .33 mg; d-biotin, .055 mg; vitamin B_{12}, .011 mg; choline (as chloride), 382 mg; manganese (oxide), 60 mg; zinc (sulfate), 44 mg; iron (ferrous sulfate), 20 mg; copper (oxide), 2 mg; iodine (ethylenediamine dihydriodide), 1.2 mg; cobalt (carbonate), .2 mg; ethoxyquin, 125 mg.

[3]Nutrient composition was calculated based on NRC (1984) values except for calcium, total phosphorus, zinc, and manganese, which are analyzed values.

Data were analyzed by analysis of variance procedures appropriate for a factorial arrangement of treatments in a completely random design (Steel and Torrie, 1980). Single degree of freedom comparisons were used to test main effects and interactions. The two trials were pooled for statistical analyses after error variances were found to be homogenous ($P > .10$). The treatment by trial interaction was significant ($P < .10$) for the percentage of tibia ash, Ca, and P data. Therefore, the treatment by trial interaction mean square was used as the error term to test treatment effects for these variables (Gill, 1989). The residual error mean square was used to test treatment effects for all other variables. The statistical model included treatment and trial effects, and pen means (eight per treatment) were used as the experimental unit for all data.

RESULTS AND DISCUSSION

Daily gain and efficiency of feed utilization were reduced ($P < .01$) in chicks fed the –MM, –TMV, and –CP diets compared with the Complete diet (Table 2). Feed intake was not affected ($P > .10$) by the –CP diet, but it was reduced ($P < .01$) in chicks fed the –MM and –TMV diets. Feed intake was increased ($P < .01$) by the addition of NaB, which resulted in an increase ($P < .09$) in gain. Addition of NaB did not affect efficiency of feed utilization in chicks fed the Complete, –TMV, and –CP diets, but increased efficiency of feed utilization in chicks fed the –MM diet (NaB by –MM interaction, $P < .02$). The HSCA addition did not affect growth performance ($P > .10$) of chicks.

The changes observed in growth performance in chicks fed diets deficient in

TABLE 2. **Growth performance of chicks fed nutrient-deficient diets containing sodium bentonite (NaB) or hydrated sodium calcium aluminosilicate (HSCA)[1]**

	Daily gain			Daily feed			Gain:feed		
Diet[2]	None	NaB	HSCA	None	NaB	HSCA	None	NaB	HSCA
	(g)						(g:g)		
Complete	32.5	33.3	32.1	45.1	47.4	44.8	.720	.704	.717
–MM	8.6	10.9	8.7	24.2	27.6	25.7	.353	.397	.338
–TMV	17.3	17.9	16.9	28.9	30.5	28.4	.607	.587	.597
–CP	20.9	20.0	20.5	44.3	45.7	46.3	.472	.439	.452
Pooled SEM		.6			.9			.012	
Source of variation	Probability								
NaB[3]		.09			.01			NS	
–MM		.01			.01			.01	
–TMV		.01			.01			.01	
–CP		.01			NS			.01	
NaB × –MM		NS			NS			.02	

[1]Data are means of eight replicates of five chicks each during the period 5 to 19 d posthatching. Average initial weight was 70 g (Trial 1, 71 g; Trial 2, 70 g).

[2]Complete = nutritionally adequate diet; –MM = deficient in sodium, chloride, calcium, and phosphorus; –TMV = deficient in trace minerals and vitamins; –CP = deficient in CP.

[3]The NaB effect is the contrast of all diets containing no additive (None) vs all diets containing NaB, regardless of nutritional adequacy. The –MM, –TMV, or –CP effects are the contrasts of the Complete diets (with and without feed additives) vs the –MM, –TMV, or –CP diets (with and without feed additives), respectively. The NaB × –MM interaction was estimated using the product of the coefficients for the NaB and –MM effects.

macrominerals, Zn, Mn, vitamins, and CP were expected and have been reported previously (Blair and Stevens, 1983; Southern and Baker, 1983a,b; March, 1984; Summers *et al.*, 1984; Proudfoot *et al.*, 1985; Pimentel and Cook, 1987; Abawi and Sullivan, 1989). The –CP diet did not affect feed intake, a response that also has been reported (Welch *et al.*, 1988; Summers *et al.*, 1992).

Sodium bentonite increased feed intake and growth of chicks in this experiment. Sodium bentonite previously has been shown to have a positive effect on certain production criteria in hens (Olver, 1989), ducks (Hollister and Kienholz, 1980), and turkeys (Salmon, 1985). Sellers *et al.* (1980) reported a trend [effect was not significant, ($P > .05$)] for increased feed intake in broilers fed 2.5 and 5% NaB, but growth rate was not affected. Schell *et al.* (1993) reported that NaB increased growth and feed intake of nursery pigs, but that the response was much more pronounced in pigs fed diets containing aflatoxin. Generally, the positive responses from NaB were an increased growth rate and feed intake.

The HSCA used in this experiment did not affect growth performance. Although we are not aware of prior research with this HSCA, zeolites have been shown to either increase, decrease, or have no effect on growth of broilers (Watkins and Southern, 1992, 1993).

Tibia ash was lower ($P < .01$) in chicks fed the –MM and –TMV diets, but it was increased ($P < .01$) in chicks fed the –CP diet compared with the Complete diet (Table 3). Tibia Ca was lower ($P < .01$) and tibia P higher ($P < .01$) in chicks fed the –MM diet. Tibia ash, Ca, and P were not affected ($P > .10$) by NaB or by HSCA, and tibia Ca and P were not affected ($P > .10$) by the –TMV or –CP diets. The decrease in tibia ash percentage is consistent with previous reports of chicks (or poults) fed diets deficient in Ca (Watkins and Southern, 1992), P (Watkins and Southern, 1992), or NaCl (Egwuatu *et al.*, 1983). The decrease in tibia ash in chicks fed the –TMV diet was likely due to vitamin deficiency (Edwards *et al.*, 1992) and not to either Zn or Mn deficiency, because moderate deficiencies of these trace minerals previously have not affected tibia ash (Southern and Baker, 1983a,b). The decrease in tibia ash in chicks fed the –TMV

TABLE 3. Tibia ash, calcium, and phosphorus of chicks fed nutrient-deficient diets containing sodium bentonite (NaB) or hydrated sodium calcium aluminosilicate (HSCA)[1]

	Tibia ash			Tibia calcium			Tibia phosphorus		
Diet[2]	None	NaB	HSCA	None	NaB	HSCA	None	NaB	HSCA
	(%)			(% of ash)					
Complete	53.4	53.2	53.2	36.6	38.1	37.7	19.6	19.7	18.8
-MM	39.5	41.0	40.9	33.5	33.9	34.3	21.1	20.8	20.5
-TMV	48.7	49.5	49.8	37.7	36.8	36.7	19.6	19.0	19.3
–CP	54.8	54.3	55.3	35.9	38.0	37.1	19.7	19.0	19.2
Pooled SEM		.8			1.1			.7	
Source of variation	Probability								
-MM[3]		.01			.01			.01	
-TMV		.01			NS			NS	
–CP		.01			NS			NS	

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

[2]Complete = nutritionally adequate diet; -MM = deficient in sodium, chloride, calcium, and phosphorus; -TMV = deficient in trace minerals and vitamins; –CP = deficient in CP.

[3]The -MM, -TMV, or –CP effects are the contrasts of the Complete diets (with and without feed additives) vs the -MM, -TMV, or –CP diets (with and without feed additives), respectively.

diet is not necessarily limited to cholecalciferol, because other vitamins are known to affect bone mineralization (Scott *et al.*, 1982). The increase in tibia ash in chicks fed the –CP diet was probably due to consumption of excess Ca and P relative to overall growth rate of the chicks. The –CP diet did not affect feed intake but dramatically decreased growth, which would result in an increase in Ca and P intake relative to body size. The increase in P and decrease in Ca in tibia ash of chicks fed the –MM diet also has been reported in chicks fed diets more deficient in Ca than in P (Watkins and Southern, 1992).

Tibia Zn and Mn were decreased ($P < .01$) in chicks fed the –TMV diet, but these minerals were dramatically increased ($P < .01$) in chicks fed the –MM diet (Table 4).

TABLE 4. Tibia zinc and manganese of chicks fed nutrient-deficient diets containing sodium bentonite (NaB) or hydrated sodium calcium aluminosilicate (HSCA)[1]

	Tibia zinc			Tibia manganese		
Diet[2]	None	NaB	HSCA	None	NaB	HSCA
	(μg/g ash)					
Complete	432	438	434	13.1	13.0	12.9
-MM	651	637	627	29.8	27.9	28.2
-TMV	297	361	315	11.7	11.3	11.7
–CP	419	430	408	15.6	15.5	15.3
Pooled SEM		18			.6	
Source of variation	Probability					
-MM[3]		.01			.01	
-TMV		.01			.01	
–CP		NS			.01	

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

[2]Complete = nutritionally adequate diet; -MM = deficient in sodium, chloride, calcium, and phosphorus; -TMV = deficient in trace minerals and vitamins; –CP = deficient in CP.

[3]The -MM, -TMV, or –CP effects are the contrasts of the Complete diets (with and without feed additives) vs the -MM, -TMV, or –CP diets (with and without feed additives), respectively.

The decrease in tibia Zn and Mn in chicks fed the –TMV diet was expected and previously has been reported in chicks fed diets deficient in these minerals (Southern and Baker, 1983a,b). The increase in tibia Zn and Mn that resulted from feeding the –MM diet also was expected, but the magnitude of the increase was somewhat unexpected. This increase was likely due to dietary deficiencies of Ca and P. Variable dietary Ca and P concentrations have been shown to affect tissue concentrations of Zn and Mn, respectively (Lewis *et al.*, 1957; O'Dell *et al.*, 1958; Bafundo *et al.*, 1984; Wedekind *et al.*, 1991; Watkins and Southern, 1992).

The –CP diet increased ($P < .01$) tibia Mn concentration. This increase could have resulted from a slightly higher level of Mn in these diets, which must have been provided by the cornstarch, relative to the Complete diet (Table 1). Also, the availability of Mn was probably higher in the diet containing 40% cornstarch. Tissue uptake of Mn has been shown to be decreased by corn and soybean meal (Halpin and Baker, 1986). In addition, the intake of Mn relative to body size was greater in chicks fed the –CP diet than in chicks fed the Complete diet. However, tibia Zn was not affected by the –CP diet.

The nutrient-deficient diets used in this experiment caused a myriad of adverse affects on growth and tibia mineral concentrations, most of which were expected and have been reported previously. However, the objective of the experiment was to assess the effect of NaB or HSCA in chicks fed nutrient-deficient diets. The feed additives did not adversely affect growth or tibia mineral concentrations, regardless of the nutrient adequacy of the diet. In fact, NaB increased feed intake and tibia Zn concentrations. We have no explanation for the increase in feed intake. Our diets contained no detectable aflatoxin, and thus the increased feed intake cannot be attributed to the potential of NaB to diminish aflatoxicosis. The increase in tibia Zn concentration was probably due to Zn being provided by NaB.

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