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Effect of Phytase on the Sodium Requirement of Starting Broilers 2. Sodium Chloride as Sodium Source[1]

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Abstract: Recent studies have suggested that phytase enzymes may influence sodium (Na) metabolism in the chick. However, no studies have demonstrated that the dietary Na requirement itself is influenced by phytase supplementation. In the present study male broilers were fed diets with Na levels ranging from 0.10 to 0.28% using NaCl as the source of supplemental sodium. Diets were fed either without phytase or with 500 (1X), 1000 (2X), or 2000 (4X) FTU/kg of phytase. For 1X phytase the Ca and Nonphytate P (NPP) were reduced 0.10% each and 0.20% each for the 2X and 3X levels of phytase supplementation. The diets with 0.10% and 0.28% Na were blended to provide Na levels of 0.10, 0.13, 0.16, 0.19, 0.22, 0.25 and 0.28% Na. Aliquots of these diets were then supplemented with the 0, 1X, 2X and 4X levels of phytase in a 4 x 7 factorial arrangement of treatments, each of which was fed to six replicate pens of five male broilers in electrically heated battery brooders. Experimental diets and tap water were provided for ad libitum consumption from day of hatch to 18 d of age. At 16 d excreta samples from each pen were freeze dried to determine moisture, Ca and P content. At 18 d body weight and feed consumption were determined. Two birds per pen were killed by CO_2 inhalation and tibias removed and subjected to bone breaking determination. Chicks fed diets with the different levels of phytase with diets adjusted for anticipated release of Ca and P did not differ significantly in BW, Feed Conversion (FCR), mortality, or fecal moisture content, indicating that the adjustments made for anticipated release of Ca and P was adequate in relation to these measurements. Sodium levels of the diet had significant effects on BW, FCR and fecal moisture. Fecal moisture increased with each level of sodium, so lower dietary levels would be beneficial in this regard. No significant effects on mortality were noted for sodium levels. No significant interactions were noted between sodium level and phytase supplementation for BW, FCR, fecal moisture, or mortality. Regression analyses suggested a sodium requirement of 0.21±0.02% for BW and 0.15±0.01% for FCR. Estimates of sodium requirement at different levels of phytase supplementation did not show any consistent effect of phytase supplementation on the sodium requirement for BW or FCR. Therefore there is no evidence that phytase supplementation will modifiy the dietary sodium requirement of the broiler chick.

Key words: Broiler, sodium, phytase

INTRODUCTION

Exogenous phytase enzymes are known to release not only phosphorus bound by the phytase molecule but also other nutrients including calcium and amino acids (Cosgrove, 1966; Ravindran *et al*., 2006). Recent work has indicated that phytase enzymes may also affect sodium metabolism (Cowieson *et al*., 2004; Ravindran *et al*., 2006; Selle *et al*., 2009). While sodium is not an expensive nutrient in itself, space in the diet is a premium. In addition, producers are concerned about litter moisture and excessive levels of sodium in the diet are not desirable from the standpoint of litter moisture. As the cost of phytase enzymes has been reduced in recent years coupled with a great increase in cost of phosphorus-rich supplements, there is great interest in using higher levels of phytase in broiler diets, as studies have demonstrated further improvements in P release as phytase levels increase (Shirley and Edwards, 2003). Therefore this study was conducted to evaluate the use of a phytase enzyme fed at "normal" and "super" levels on the need for supplemental sodium in broiler diets.

MATERIALS AND METHODS

Dietary treatments: A corn-soybean meal diet adequate in all known nutrients (NRC, 1994) was used as the basal diet. By modification of the amounts of ground limestone, dicalcium phosphate, sodium chloride and washed builders sand the levels of sodium, calcium and nonphytate P (NPP) were modified. The changes in NPP were based on the assumption that P was released when phytase was used. Modifications were based on 0.10% for 1X usage, 0.15% for 2X usage and 0.20% for 4X usage of Quantum phytase, based on previous studies from our laboratory (Karimi *et al*., unpublished data). The recommended usage rate of the phytase (Quantum Phytase 5000 XT; ABVista, Marlborough UK)

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Table 1: Composition (g/kg) of basal diets with different levels of phytase

	No phytase		1X phytase[1]		2X phytase		4X phytase	
Ingredient	A	B	C	D	E	F	G	H
Yellow corn	552.51	SAME FOR ALL DIETS						
Soybean meal	373.45							
Poultry oil	33.38							
MHA-84[2]	1.98							
L-Lysine HCl	1.05							
Vitamin premix[3]	5.00							
Mintrex P_Se[4]	1.00							
Limestone	7.62	7.62	8.11	8.11	7.05	7.05	8.61	8.61
Dicalcium phosphate	17.10	17.10	11.70	11.70	8.99	8.99	6.29	6.29
Sodium chloride	6.91	0.00	6.93	0.00	6.93	0.00	6.94	0.00
Sand	0.00	6.91	4.89	11.82	8.66	15.59	9.79	16.73
Calcium %	0.90	0.90	0.80	0.80	0.70	0.70	0.70	0.70
Total P %	0.76	0.76	0.66	0.66	0.61	0.61	0.56	0.56
Nonphytate P %	0.45	0.45	0.35	0.35	0.30	0.30	0.25	0.25
Sodium %	0.30	0.03	0.30	0.03	0.30	0.03	0.30	0.03
Chloride %	0.47	0.05	0.47	0.05	0.47	0.05	0.47	0.05
Crude protein %	22.00	SAME FOR ALL DIETS						
Methionine %	0.55							
Lysine %	1.30							
TSAA %	0.90							
ME kcal/lb	1400.00							

[1]X = 500 FTU/kg of phytase (Quantum Phytase 5000 XT; ABVista, Marlborough, UK).

[2]Methionine hydroxy analogue calcium salt. Novus International, St. Louis MO 63141.

[3]Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.

[4]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg. Novus International, Inc., St. Louis MO 63141

is 500 FTU/kg. Calcium levels were reduced by 0.10% with 1X phytase usage and 0.20% with 2X and 4X phytase usage levels. Diets were then formulated to contain 0.03 and 0.30% Na. By blending the highest and lowest Na levels within each phytase level, intermediate levels of Na were obtained. The composition of the formulated diets is shown in Table 1.

The high and low sodium diets were blended within each series to provide the following estimated levels of sodium: 0.10, 0.13, 0.16, 0.19, 0.22, 0.25 and 0.28%. This resulted in a total of 28 dietary treatments. Each of these was fed to 6 replicate pens of five male chicks each, stratified across tiers in the battery brooder. The test diets and tap water were provided for ad libitum consumption.

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated in ovo for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Five chicks were assigned to each of 168 compartments in electrically heated battery brooders with wire floors. Fluorescent lights provided 24 hr of light daily. Care and management of the birds followed recommended guidelines (FASS, 2010). All procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee.

Measurements were made of pen body weight at one and 18 d of age. Feed consumption during the period was determined. At 16 d of age excreta samples were taken from each pen for determination of moisture content. Excreta samples were collected on aluminum foil in an area relatively free from spilled feed or feathers. The samples were immediately frozen and freeze dried to determine moisture content. The high and low diets within each series were analyzed for crude protein, calcium, total P and sodium. At the conclusion of the study two birds per pen were killed by CO_2 inhalation and the tibia used for bone breaking studies. The tibias were cleaned of adherent tissues and the biomechanical strength of each bone was measured using an Instron 4502 material testing machine with a 100 kg load cell (Instron Inc. 825 University Avenue, Norwood MA 02062-2643). The bones were held in identical positions and the mid-diaphyseal diameter of the bone at the site of impact was measured using a dial caliper. The maximum load at failure was determined using a three-point flexural bend fixture with a total distance of 30 mm between the two lower supporting ends. The load, defined as force in kilograms

per square millimeter of cross-sectional area (kilograms per square millimeter), represents bone strength. The rate of loading was kept constant at 20 mm/min collecting 10 data points per second. The data were automatically calculated using Instron Series IX Software.

Pen means served as the experimental unit for statistical analysis. Data were subjected to ANOVA using the General Linear Models procedure of the SAS Institute (1991). The data were analyzed as a factorial arrangement of treatments with four phytase levels and seven sodium levels as main effects along with their interaction. When significant differences among treatments were found, means were separated using repeated t-tests using the LSMEANS option of the GLM procedure. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers.

Within each level of supplemental phytase analyses were conducted to estimate the sodium needs for BW, FCR, tibia diameter and tibia breaking force. Nonlinear regression analysis was conducted using the PROC LIN procedure of SAS (SAS Institute, 1991) and incorporating the SAS macro of Robbins (1986). The requirement was established as the inflection point of the one-slope regression model (Robbins *et al*., 1979; Yu and Morris, 1999; Waldroup *et al*., 2000).

RESULTS AND DISCUSSION

The effects of different levels of phytase and sodium on live performance and fecal moisture content of broilers are shown in Table 2. Chicks fed diets with the different levels of phytase with diets adjusted for anticipated release of Ca and P did not differ significantly in BW, Feed Conversion (FCR), mortality, or fecal moisture content. This indicates that the adjustments made for anticipated release of Ca and P was adequate in relation to these measurements. Sodium levels of the diet had significant effects on BW, FCR and fecal moisture. Fecal moisture increased with each level of sodium, so lower dietary levels would be beneficial in this regard. No significant effects on mortality were noted for sodium levels. No significant interactions were noted between sodium level and phytase supplementation for BW, FCR, fecal moisture, or mortality. Regression analyses suggested a sodium requirement of 0.21±0.02% for BW and 0.15±0.01% for FCR (Table 3). Estimates of sodium requirement at different levels of phytase supplementation did not show any consistent effect of phytase supplementation on the sodium requirement for BW or FCR.

The effects of different levels of phytase and sodium on bone strength and mineral excretion are shown in Table 4. Chicks fed diets with the different levels of phytase with diets adjusted for anticipated release of Ca and P had no significant effect on tibia diameter. Although significant differences were observed in tibia break force among chicks fed the various levels of phytase, none of the treatments differed significantly from that of chicks fed the positive control diet with NRC (1994) recommended levels of Ca and NPP. This indicates that the adjustments made for anticipated release of Ca and P was adequate in relation to these measurements.

Table 2: Effects of different levels of phytase and sodium from sodium chloride on live performance and fecal moisture content of broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

Phytase[1]		0-18 d BW gain (kg)	0-18 d FCR	Fecal moisture (%)	0-18 d Mortality (%)
0		0.572	1.380	63.78	3.43
1X		0.587	1.318	64.60	3.33
2X		0.570	1.369	66.02	5.24
4X		0.564	1.349	63.24	8.10
Sodium					
0.10		0.427^{e}	1.550^{a}	60.68^{c}	3.50
0.13		0.516^{d}	1.374^{b}	62.29^{c}	2.50
0.16		0.569^{c}	1.353^{bc}	62.66^{bc}	5.00
0.19		0.614^{b}	1.310^{cd}	62.79^{bc}	5.83
0.22		0.609^{b}	1.302^{cd}	66.67^{ab}	2.50
0.25		0.624^{ab}	1.308^{cd}	66.97^{ab}	8.33
0.28		0.651^{a}	1.280^{d}	68.48^{a}	7.50
Phy	**Na**				
0	0.10	0.444	1.648	54.60	4.00
0	0.13	0.489	1.431	64.19	0.00
0	0.16	0.579	1.359	59.83	6.67
0	0.19	0.599	1.340	60.70	3.33
0	0.22	0.638	1.273	67.44	0.00
0	0.25	0.610	1.348	69.56	10.00
0	0.28	0.646	1.264	70.15	0.00
1X	0.10	0.452	1.439	63.08	3.33
1X	0.13	0.567	1.318	63.07	3.33
1X	0.16	0.594	1.304	63.74	6.67
1X	0.19	0.620	1.276	66.93	3.33
1X	0.22	0.603	1.316	64.76	0.00
1X	0.25	0.616	1.302	65.37	0.00
1X	0.28	0.654	1.269	65.25	6.67
2X	0.10	0.419	1.566	63.85	6.67
2X	0.13	0.530	1.319	60.11	0.00
2X	0.16	0.523	1.396	61.73	3.33
2X	0.19	0.599	1.351	67.58	3.33
2X	0.22	0.603	1.304	70.28	3.33
2X	0.25	0.655	1.270	66.30	6.67
2X	0.28	0.659	1.378	72.27	13.33
4X	0.10	0.394	1.547	61.29	0.00
4X	0.13	0.478	1.428	61.78	6.67
4X	0.16	0.579	1.354	65.06	3.33
4X	0.19	0.639	1.273	56.64	13.33
4X	0.22	0.594	1.317	64.04	6.67
4X	0.25	0.618	1.311	66.53	16.67
4X	0.28	0.643	1.211	67.34	10.00
Prob > F					
Phytase		0.26	0.07	0.30	0.14
Sodium		0.01	0.01	0.03	0.31
Phy x Na		0.21	0.13	0.16	0.52
CV		9.51	7.67	10.37	7.74

[1]X = 500 FTU/kg of phytase (Quantum Phytase 5000 XT; ABVista, Marlborough, UK).

[abc]Means in column with common superscripts do not differ significantly ($p \leq 0.05$)

Table 3: Estimate of sodium requirement of broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

Treatment	Value at inflection	Inflection point	Asymptotic standard error	Asymptotic 95% confidence interval
Body weight				
No Phytase	No Convergence			
1X Phytase	0.591	0.15	0.02	0.09-0.21
2X Phytase	0.639	0.21	0.02	0.15-0.28
4X Phytase	0.624	0.18	0.008	0.15-0.20
All levels	0.611	0.21	0.02	0.15-0.27
FCR				
No Phytase	1.353	0.16	0.02	0.09-0.22
1X Phytase	1.305	0.14	0.02	0.07-0.22
2X Phytase	1.317	0.19	0.04	0.07-0.32
4X Phytase	No Convergence			
All levels	1.346	0.15	0.01	0.11-0.18
Tibia diameter				
No Phytase	No convergence			
1X Phytase	5.12	0.19	0.07	-0.04-0.42
2X Phytase	No convergence			
4X Phytase	5.19	0.22	0.02	0.17-0.27
All levels	No convergence			
Tibia break force				
No Phytase	14.71	0.21	0.05	0.05-0.36
1X Phytase	16.05	0.14	0.04	0.01-0.27
2X Phytase	No convergence			
4X Phytase	16.66	0.22	0.02	0.16-0.29
All levels	14.60	0.15	0.01	

Table 4: Effects of different levels of phytase and sodium from sodium chloride on bone strength and mineral excretion by broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

Phytase[1]		Tibia Diameter (mm)	Tibia Break force (kg)	Fecal P Mg/kg	Fecal Ca Mg/kg	Fecal Na Mg/kg
0		4.88	14.81^{ab}	$15,066^{a}$	$16,574^{a}$	$2,915^{a}$
1X		5.02	15.74^{a}	$10,516^{b}$	$12,980^{b}$	$2,751^{b}$
2X		4.88	14.57^{b}	$9,262^{c}$	$9,588^{c}$	$2,664^{c}$
4X		4.90	14.34^{b}	$7,082^{d}$	$9,428^{c}$	$2,452^{d}$
Sodium						
0.10		4.53^{c}	11.19^{d}	$11,447^{a}$	$13,134^{a}$	362^{g}
0.13		4.87^{b}	13.91^{c}	$10,637^{b}$	$12,791^{a}$	802^{f}
0.16		4.87^{b}	14.52^{bc}	$10,700^{b}$	$13,032^{a}$	$2,048^{e}$
0.19		4.96^{ab}	15.46^{ab}	$9,898^{c}$	$11,686^{b}$	$2,765^{d}$
0.22		5.06^{ab}	15.84^{ab}	$10,231^{bc}$	$11,569^{b}$	$3,587^{c}$
0.25		5.04^{ab}	16.29^{a}	$10,247^{bc}$	$11,296^{b}$	$4,352^{b}$
0.28		5.09^{a}	16.81^{a}	$10,212^{bc}$	$11,488^{b}$	$4,952^{a}$
Phy	**Na**					
0	0.10	4.64^{ghi}	12.61^{fgh}	15,977	$17,876^{ab}$	470^{no}
0	0.13	4.67^{fghi}	13.03^{efgh}	14,709	$15,877^{cd}$	668^{n}
0	0.16	4.81^{cdefgh}	14.87^{bcdef}	15,657	$18,086^{a}$	$2,333^{k}$
0	0.19	4.71^{fghi}	13.77^{defg}	14,602	$14,547^{ef}$	$2,315^{k}$
0	0.22	5.10^{abcde}	15.13^{abcdef}	14,856	$15,452^{de}$	$3,675^{g}$
0	0.25	5.07^{abcde}	16.41^{abcd}	14,725	$16,753^{bc}$	$5,004^{b}$
0	0.28	5.10^{abcde}	17.56^{ab}	14,935	$17,673^{ab}$	$5,939^{a}$
1X	0.10	4.70^{fghi}	13.12^{efg}	11,017	$13,657^{f}$	308^{o}
1X	0.13	5.15^{abc}	15.76^{abcde}	10,749	$14,966^{de}$	$1,139^{m}$
1X	0.16	$4.90^{abcdefgh}$	16.22^{abcd}	10,821	$14,885^{de}$	$2,171^{k}$
1X	0.19	5.11^{abcd}	16.53^{abcd}	9,743	$12,323^{g}$	$3,009^{j}$
1X	0.22	5.12^{abcd}	16.00^{abcde}	10,203	$12,560^{g}$	$3,751^{fg}$
1X	0.25	5.02^{abcdef}	15.27^{abcdef}	10,724	$12,323^{g}$	$4,104^{e}$
1X	0.28	5.08^{abcde}	17.26^{ab}	10,358	$10,636^{ij}$	$4,777^{c}$
2X	0.10	4.40^{i}	10.04^{hi}	10,390	$10,833^{hi}$	409^{o}
2X	0.13	5.02^{abcdef}	14.90^{abcdef}	9,556	$10,589^{ijk}$	$1,136^{m}$
2X	0.16	4.72^{efghi}	12.47^{fgh}	9,515	$9,886^{ijkl}$	$2,340^{k}$
2X	0.19	$4.83^{bcdefgh}$	14.73^{bcdef}	9,108	$10,817^{hi}$	$3,004^{i}$
2X	0.22	4.78^{defgh}	15.45^{abcdef}	8,952	$8,660^{mnop}$	$3,442^{h}$
2X	0.25	5.16^{abc}	17.77^{a}	8,689	$8,020^{p}$	$3,884^{f}$
2X	0.28	5.21^{a}	16.25^{abcd}	8,627	$8,311^{op}$	$4,436^{d}$

Table 4 Cont.:

Phytase[1]		Tibia Diameter (mm)	Tibia Break force (kg)	Fecal P Mg/kg	Fecal Ca Mg/kg	Fecal Na Mg/kg
4X	0.10	4.38^{i}	8.98^{i}	8,405	10,415^{ijk}	263^{o}
4X	0.13	4.61^{hi}	11.81^{ghi}	7,533	9,734^{jkl}	267^{o}
4X	0.16	5.01^{abcdef}	14.17^{cdefg}	6,807	9,272^{lmno}	1,349^{l}
4X	0.19	5.17^{ab}	16.81^{abc}	6,141	9,059^{lmno}	2,732^{j}
4X	0.22	5.23^{a}	16.76^{abc}	6,915	9,604^{klm}	3,481^{h}
4X	0.25	4.92^{abcdefgh}	15.69^{abcde}	6,849	8,580^{nop}	4,417^{d}
4X	0.28	4.98^{abcdefg}	16.15^{abcd}	6,929	9,332^{lmn}	4,659^{c}
Prob > F						
Phytase		0.14	0.05	0.01	0.01	0.01
Sodium		0.01	0.01	0.01	0.01	0.01
Phy x Na		0.02	0.04	0.38	0.01	0.01
CV		9.15	24.2	4.27	4.04	3.36

[1]X = 500 FTU/kg of phytase (Quantum Phytase 5000 XT; ABVista, Marlborough, UK).
[abc]Means in column with common superscripts do not differ significantly ($p \leq 0.05$)

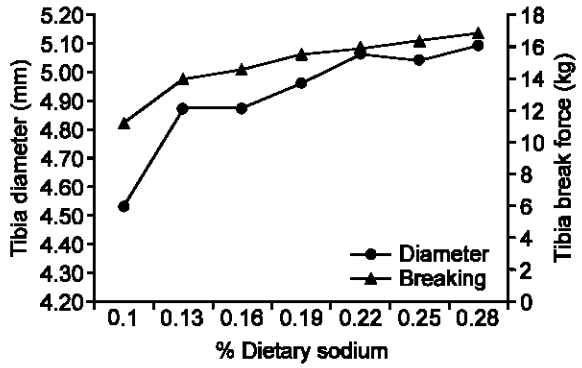

Fig. 1: Relationship of dietary sodium level to tibia diameter and bone breaking force

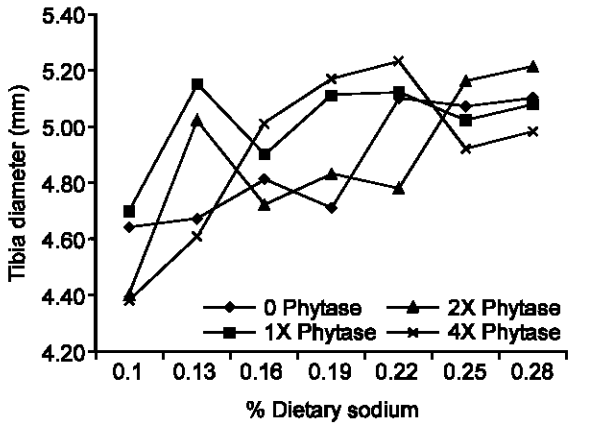

Fig. 2: Interaction of dietary sodium and phytase levels on tibia diameter of broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

As would be expected, the levels of both fecal Ca and P decreased significantly as the level of phytase supplementation increased, since diets were reduced in both NPP and Ca with the addition of phytase. The level of fecal sodium decreased significantly as the level of phytase supplementation increased. This suggests some interaction between sodium and phytase during metabolism of sodium.

Dietary sodium levels significantly increased tibia diameter and tibia break force (Table 4). Regression analysis did not find a sharp breakpoint for tibia diameter, but it appeared that diameter increased continually over the range of sodium levels. Regression analysis indicated an estimate of 0.15±0.01% sodium for tibia break force, but visual evaluation of the response suggested continual improvements over the range of sodium levels (Fig. 1).

As would be expected, the fecal Na content increased as the dietary sodium levels increased (Table 4). There were significant differences among chicks fed the different sodium levels for fecal Ca and P levels. It appeared that the primary differences in fecal P were between chicks fed the lowest level of sodium and those fed higher levels, with little indication of difference between chicks fed diets with 0.13% or greater. Fecal Ca levels were highest in chicks fed sodium levels ranging from 0.10-0.16% and dropped significantly at higher sodium levels.

Significant interactions were noted between dietary sodium levels and phytase supplementation levels for tibia diameter and break force and for fecal Ca and Na levels (Table 4). None of these interactions are clear-cut, however. For tibia diameter (Fig. 2), chicks fed diets with 2X and 4X levels of phytase tended to have reduced tibia diameter at the very lowest level of sodium, but equal or greater tibia diameter at other levels of sodium. Similar results were observed for tibia break force (Fig. 3). At the lowest level of sodium, chicks fed the diets with 2X and 4X phytase tended to have reduced bone strength that was not apparent at higher levels of sodium. These two interactions suggest a possible influence of phytase on sodium metabolism in the bird that was not observable at sodium levels at or near the requirement for body weight or FCR.

The interactions between dietary sodium levels and phytase supplementation levels on fecal Ca content and

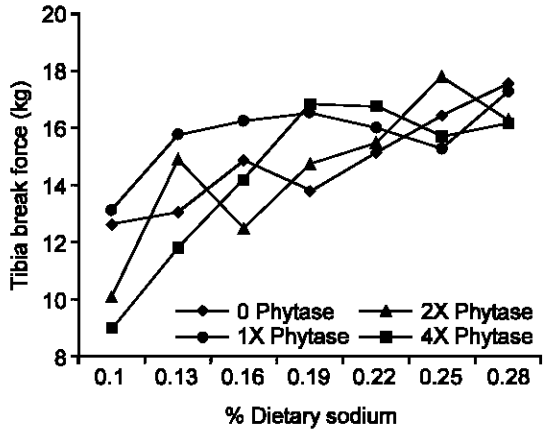

Fig. 3: Interaction of sodium and phytase on tibia break force of broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

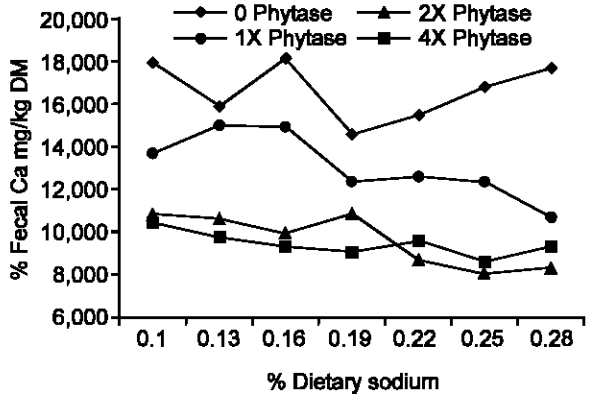

Fig. 4: Interaction of dietary sodium and phytase on fecal calcium output of broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

fecal sodium content is more difficult to ascertain. For fecal Ca (Fig. 4), it would appear that there was a greater reduction in fecal Ca output related to phytase supplementation, compared to the control diet, when the diets contained higher levels of sodium. For fecal Na (Fig. 5), there was no clear pattern of variation associated with levels of sodium and phytase supplementation.

The relationship between dietary sodium and bone development has been noted by several authors with highly variable results. Slinger *et al.* (1950) reported that there was a sparing relationship between phosphorus and salt in broiler diets; there was an antagonism between Ca at high levels and salt. Saad and Jalaludin (1972) saw no significant interaction between Ca:P ratios and levels of NaCl. Sharma and Malik (1986) found depressed calcium and phosphorus deposition in

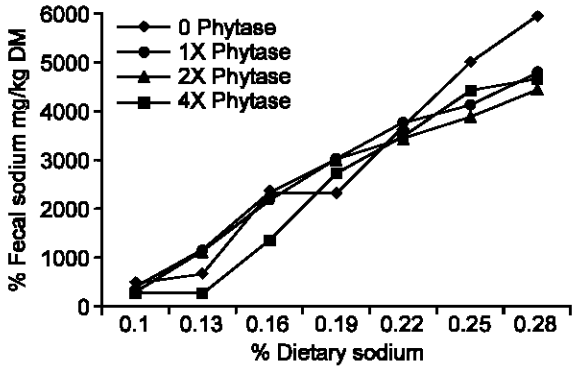

Fig. 5: Interaction of dietary sodium and phytase on fecal sodium output of broilers fed diets with calcium and phosphorus levels adjusted for anticipated release by phytase

bone when sodium chloride levels were high (0.75 and 1.0% NaCl). Jemison and Dilworth (1981) found that increasing sodium appeared to decrease the requirement for calcium and available P for weight gain; however bone breaking strength were significantly reduced. Egwuatu *et al.* (1983) reported that increasing the sodium in the diet of turkey poults from deficient to adequate levels resulted in significant improvements in bone ash, bone breaking strength, tibia weight and reduced abnormal tibia scores in young turkey poults. In a study with growing-finishing swine, Kornegay *et al.* (1991) found that when metacarpals and metatarsals taken from barrows at slaughter were examined on a weight-corrected basis, Na intake and P source did not consistently influence bone dimensional and strength characteristics.

The reports cited above, with the exception of Egwuatu *et al.* (1983), typically involved a factorial arrangement including levels of Ca, P and Na with limited number of dietary treatments and usually were more concerned with adverse effects of high levels of Na on Ca and P metabolism. The levels used in the present study were more similar to those used by Egwuatu *et al.* (1983) in that they explored the effects of Na levels that were near the minimum requirements for BW and FCR. The data from the present study suggest that the dietary Na level influences bone mineralization and growth, in agreement with the report of Egwuatu *et al.* (1983); however, levels of Na that optimize BW and FCR appear to be adequate for bone development as well.

In a previous study from our laboratory, Goodgame *et al.* (2011) reported that Na levels had a significant effect on excretion of Ca and P by broilers, but did not appear to follow a consistent pattern. There was no effect of phytase level of the diet on the overall sodium requirements for BW and FCR, in agreement with the present study.

The estimate of sodium requirement for optimum body weight found in the present study (0.21±0.02%) is in agreement with the NRC (1994) recommendation of 0.20%. Watkins *et al.* (2005) suggested a Na requirement of 0.17±0.006%. Studies by Murakami *et al.* (1997a, 1997b, 2000) suggest a slightly greater need for Na during this period of 0.20-0.25%. Goodgame *et al.* (2011) reported a Na requirement of 0.18% for BW and 0.19% for FCR. The present study utilized sodium chloride as the primary source of Na while Goodgame *et al.* (2011) utilized sodium bicarbonate; these have been shown to be equivalent sources of Na (Murakami *et al.*, 1997a).

Cowieson *et al.* (2004) reported that ingestion of *myo*-inositol hexaphosphate (IP_6) by broilers increased the excretion of endogenous Na compared to birds fed only glucose, while the addition of supplemental phytase reduced the excretion of Na in birds fed IP_6. Ravindran *et al.* (2006) reported that phytase addition significantly improved the apparent ileal digestibility of Na in birds fed a corn-soybean meal diet with apparent improvement as the level of phytase increased from 500 to 1000 FTU/kg of diet. Selle *et al.* (2009) reported that phytase significantly increased the apparent ileal digestibility coefficient of Na in a wheat-based diet to -0.038 from -0.516 in the negative control diet and the combination of phytase and xylanase increase the same coefficient to 0.043. While it is apparent that phytate and phytase influence the metabolism of Na within the body, the data from the present study suggests that this has little impact on the dietary need for Na, in agreement with previous work from our laboratory (Goodgame *et al.*, 2011). Some evidence that an interaction exists between dietary Na and phytase supplementation was demonstrated by interactions between dietary sodium and phytase for tibia diameter and breaking force and excretion of Ca and Na, but not for fecal excretion of P. Further studies are suggested to explore the possible interaction of dietary Na and phytase supplementation as influenced by levels of Ca and NPP.

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