ajava

Asian Journal of Animal and Veterinary Advances

Academic
Journals Inc.

www.academicjournals.com

Asian Journal of Animal and Veterinary Advances 7 (4): 288-298, 2012
ISSN 1683-9919 / DOI: 10.3923/ajava.2012.288.298

Optimal Dietary Phosphorus for Broiler Performance, Bone Integrity and Reduction of Phosphorus Excretion

Alaeldein M. Abudabos
Department of Animal Production, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

ABSTRACT

The purpose of the present study was to examine the effect of dietary Total Phosphorus (TP) on performance, serum P, bone morphometric measurements, phosphorus (P) and calcium (Ca) retention and P excretion of broilers from 3 to 7 weeks of age. The grower diets (3-6 weeks) contained 5.0, 5.5, 6.0 and 6.5 g kg^{-1} TP (2.4, 2.9, 3.4 and 3.9 g kg^{-1} calculated non-phytate P (npP), respectively); each diet was fed to 6 replicate pens. During finishing period (6-7 weeks), three pens received the same TP level as in the growing period, while the other 3 pens were fed a diet without any inorganic P supplementation (3.8 TP, 1.3 npP g kg^{-1}). Decreasing dietary TP from 6.5 to 5.0 g kg^{-1} during the growing period or removing dicalcium phosphate completely from the finisher diets had no significant effect on feed intake, body weight gain, breast muscle yield and Feed Conversion Ratio (FCR). Serum P was affected by the amount of P in the diet. Tibiae and femora ash percentages were differed significantly between diets and sex. Phosphorus intake and excretion were functions of the amount of the P in the diet, reducing or omitting P in the diets markedly reduced fecal P. In conclusion, TP levels needed by broilers to maintain growth and feed utilization were less than those needed for maximum tibia ash; TP could be reduced to 5.0 (2.4 npP) g kg^{-1} from during the growing period and omitted from the withdrawal diets without adverse effects on live performance or skeletal integrity.

Key words: Broiler, bone integrity, performance, retention, phosphorus excretion

INTRODUCTION

About 50-80% of the P in grain cereal and oilseed is bound to phytic acid (hexaphosphate of myo-inositol); the organically bound form of P is called Phytate Phosphorus (PP) (Eeckhout and DePaepe, 1994). Despite the amount of literature published on the role of PP in poultry nutrition, controversy still exists about the ability of poultry to utilize PP. The availability of PP usually ranges from 0 to 50% (Nelson, 1976; Edwards *et al*., 1989; Mohammed *et al*., 1991). Nutritionists routinely include a margin of safety for phosphorus when they formulate poultry diets. The portion of P that exceeds the requirement will eventually pass through the digestive tract and be excreted in feces creating concerns regarding environmental contamination. This is particularly true in areas of intensive poultry production; therefore, excess P is to be minimized (Cowieson *et al*., 2004; Musapuor *et al*., 2006; Manangi and Coon, 2008; Liem *et al*., 2009; Bingol *et al*., 2009).

It should be noted that many investigators have utilized maximum bone ash as the criteria for determining the chick's phosphorus requirements. The question remains regarding whether or not maximum calcification is necessary for a good carcass in the poultry industry. It would seem reasonable to seek a phosphorus level which yields maximum growth, maximum feed efficiency and adequate but not necessarily maximum, bone ash (Edwards, 1983; Ravindran *et al.*, 1995). Several reports have shown that 5 g kg^{-1} TP is required for maximum growth. However, a higher level was required for maximum bone ash (Dhandu and Angel, 2003; Abas *et al.*, 2011).

The evidence suggests that P excretion in manure could be decreased by formulating grower and finisher diets with reduced concentration of inorganic P. The purpose of the present study was to (1) examine the effect of different levels of dietary TP on performance, P excretion; P and Ca retention (2) examine the effects of TP and sex on femora and tibiae ash and femoral morphologic integrity of broilers.

MATERIALS AND METHODS

Animals and treatments: Day-old, mixed chicks (Ross x Arbor Acres) were placed into 24 pens (2.6 m^2 pen^{-1}) in an open-sided poultry house with partial environment control. At 3 week, birds were weighed on a pen basis and stocking density adjusted to 22 birds per pen. In the course of the experiment a metabolism trial was performed with 48 birds housed 2 per cage. The birds were exposed to 23 h light during the trial period.

Chicks were fed a standard corn-soybean meal starter mash *ad libitum* to 3 weeks of age. Ingredients were analyzed for TP and Ca content (AOAC, 1984) and the adjusted values were used to formulate the experimental diets. The grower diets contained 5.0, 5.5, 6.0 and 6.5 g kg^{-1} TP (2.4, 2.9, 3.4 and 3.9 g kg^{-1} calculated npP, respectively) as presented in Table 1. Each diet was fed to 6 replicate pens (3-6 weeks). From 6 to 7 weeks each treatment was divided into two groups, three pens received the same TP level as in the growing period, treatments 1 to 4 (5.0, 5.5, 6.0 and 6.5 g kg^{-1} TP) while the other 3 pens were fed a diet without inorganic phosphorus supplementation (treatments 5 to 8) and contained 4.0, 1.3 g kg^{-1} TP, np P, respectively (Table 1). Metabolism trial conducted in conjunction with experiment 1, the diets were fed to birds maintained in wire-floored battery pens, with 2 birds per pen. Each diet was fed to 6 replicate pens (3-6 weeks) and 3 pens (6-7 weeks).

Measurements: Body weight and feed consumption were recorded weekly by pen and FCR computed at 6 and 7 weeks of age. At both ages one female and one male was sampled from each pen. Blood samples were collected by cardiac puncture for serum phosphorus (Baginski *et al.*, 1967) and after euthanasia, the breast muscle was dissected and weighed (Uittenboogaart and Gerrits, 1982). The left limb was identified and the middle toe (between second and third tarsal) was removed from each sample. Toes were cleaned, dried overnight at 100°C and ash determined (AOAC, 2000). The left limbs were cleaned, tibiae and femora were obtained, dried at 100°C and fat was extracted with hexane. Tibiae were ashed and femora were used to determine the morphometric measurements then were ashed (Crespo *et al.*, 2000). The metabolism trial determined TP excretion (3-6 weeks) and Ca and P retention at 6 weeks. Birds (6 replications per each diet) were housed (2 birds/cage) in 24 cages with wire bottoms. Birds had free access to feed and water throughout the trial period. All diets were supplemented with 3 g kg^{-1} chromic oxide as an analytical marker and birds were fed chromium oxide mashed feed for 5 days and excreta was collected to determine Ca and P retention (Edwards and Gillis, 1959). Feed and excreta samples were dried at 60°C until constant weight and were ground, Ca and P concentrations in feed and excreta were determined by inductive coupled plasma (ACP) analysis (Smith, 1965) and Cr concentration was determined (Bolin *et al.*, 1952). Percent Ca and P retention was calculated (Scott *et al.*, 1976).

Table 1: Dietary ingredients (g kg^{-1}) and chemical composition of the broiler grower (3-6 weeks) and finisher (6-7 weeks) diets

	Grower diets (g kg^{-1})				Finisher diets (g kg^{-1})				
Item	1	2	3	4	1	2	3	4	5 to 8
Ingredients									
Corn	611.2	610.1	607.0	606.0	682.7	680.8	678.0	676.0	688.5
Soybean meal	312.5	312.5	312.4	312.4	258.0	258.5	259.0	259.0	257
Poultry fat	46.0	46.0	48.0	48.0	33.5	34.0	35.0	36.0	31.5
Dicalcium phosphate	5.5	8.0	11.0	13.5	6.3	9.0	11.8	14.5	0
Ground limestone	16.2	14.8	13.0	11.5	13.5	11.7	10.2	8.5	17
Choline chloride	1.5	1.5	1.5	1.5					
DL-methionine	0.6	0.6	0.6	0.6					
Salt	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3
Vitamin premix[1]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Trace mineral mix[2]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Coccidiostat	0.5	0.5	0.5	0.5					
Calculated analysis									
ME (kcal kg^{-1})	3200	3200	3200	3200	3200	3200	3200	3200	3200
Total Phosphorns (g kg^{-1})	5.0	5.5	6.0	6.5	5.0	5.5	6.0	6.5	3.8
Non phytate P (g kg^{-1})	2.4	2.9	3.4	3.9	2.5	3.0	3.5	4.0	1.3
Determined analysis									
Total Phosphorns (g kg^{-1})	5.1	5.7	6.1	6.7	4.9	5.5	6.12	6.4	4.0
Crude protein (%)	22.2	21.6	21.6	22.4	18	18	19	18	18
Calcium (g kg^{-1})	9.2	9.2	1.01	1.09	8.5	8.5	8.5	8.4	9.0
Fe (ppm)	208	264	276	332	175	215	252	282	132

[1]Vitamin mix provided per kg diet using roche broiler premix: Retinyl acetate, 3.41 mg; cholecalciferol, 0.07 mg; DL-α-tocopheryl acetate, 27.5 mg; menadione sodium bisulphate, 6 mg; riboflavin, 7.7 mg; niacin, 44 mg; pantothenic acid, cyanocobalamin, 0.02; choline 496 mg; folic acid, 1.32 mg; pyridoxine HCl, 4.82 mg; thiamine mononitrate, 2.16 mg; D-biotin, 0.11 mg, [2]Mineral mix provided per kg diet using Mar-Jac Poultry Trace Mineral Mix: manganese, 67 mg; zinc, 54 mg; copper, 2 mg; iodine, 0.5 mg; iron, 75 mg; and selenium, 0.2 mg

Statistical analysis: All statistical analyses were performed using the Statistical Analysis System (SAS Institute, 1996). A pen of birds on litter or in metabolism cage constituted the experimental unit. From (3- 6 weeks), 4 dietary treatments were arranged in 6 replications and from (6-7 weeks), 8 treatments were arranged in 3 replications in a randomized complete block design. Means for measurements showing significant differences in the analysis of variance were tested using the PDIFF option. Means±Standard error of the mean (SEM) are presented in the tables and differences were considered statistically significant at $p<0.05$.

RESULTS

Decreasing dietary TP 6.5 to 5.0 g kg^{-1} from 3 to 6 weeks had no significant effect on feed intake, body weight gain, breast muscle yield and FCR (Table 2). A dietary TP x sex interaction was not detected at 6 weeks (Table 2). Serum P were lower ($p<0.01$) for birds fed 5.0 g kg^{-1} TP compared to the other 3 diets from 3 to 6 weeks. Serum P increased abruptly when TP was increased to 5.5 g kg^{-1} and as dietary TP increased from 5.5 to 6.5 g kg^{-1} serum P was not responsive.

Increasing the TP content of the diets from 5.0 to 6.5 g kg^{-1} (diets 1 to 4) or removing dicalcium phosphate completely from the diets (diets 5 to 8) at 7 weeks of age had no significant effects on feed consumption, body weight gain, breast muscle yield and FCR (Table 3). A gender effect was evident at 7 weeks, breast yield was 8.5% higher in males but a diet x gender interaction was not

Table 2: Effect of dietary phosphorus on feed consumption, body weight gain, FCR, breast muscle yield and serum phosphorus content of broiler chicks from 3 to 6 weeks

Analysis	Total phosphorus ($g\ kg^{-1}$)	Feed consumption[2] (g)	Body weight gain[2] (g)	FCR (g feed: g gain)	Breast muscle yield[3] (g)	Serum phosphorus[3] ($mg\ dL^{-1}$)
Diet						
1	5.0	3135	1484	2.11	338	5.0[b]
2	5.5	3026	1520	1.99	339	6.5[a]
3	6.0	3082	1574	1.96	345	7.0[a]
4	6.5	3062	1577	1.94	369	7.2[a]
SEM[1]		±77	±32	±0.05	±18	±0.3
Sex						
F					332	6.8[a]
M					364	6.1[b]
SEM[1]					±12	±0.2
Statistical probabilities						
Treatment		NS	NS	NS	NS	0.01
Sex					NS	0.01
Treatment×sex					NS	NS

[a,b]Treatments means within columns followed by different superscripts are significantly different ($p<0.05$), [1]Standard error of the mean, [2]Feed consumption and body weight gain per bird during 21 days, [3]Each mean based on 12 samples (6 females and 6 males) per treatment taken at 6 weeks of age. The following regression equations were found from calculation of the relationship between serum P and dietary P for females and males, Serum P (F) = -69.37+25.06 *P -2.04 P* P Serum P (M) = -0.881+1.206 * P

Table 3: Effect of dietary phosphorus on feed consumption, body weight change, FCR, breast mnscle yield and serum phosphorus content in broiler chicks from 6 to 7 weeks

Analysis	Total phosphorus ($g\ kg^{-1}$)	Feed consumption (g)	Body weight gain (g)	FCR (g feed: g gain)	Breast muscle yield[3] (g)	Serum phosphorus[3] ($mg\ dL^{-1}$)
Diet						
1	5.0	1021	387	2.65	441	7.2[a]
2	5.5	1060	411	2.57	435	7.8[a]
3	6.0	1095	278	4.21	437	7.3[a]
4	6.5	1172	387	3.06	455	7.8[a]
5	3.8	1076	306	3.64	408	5.0[bc]
6	3.8	1094	301	3.71	410	4.5[c]
7	3.8	1195	302	4.03	430	5.5[b]
8	3.8	1038	313	3.44	406	5.2[bc]
SEM[1]		±76	±41	±0.48	±21	±0.3
Sex						
F					410[b]	6.6[a]
M					445[a]	6.0[b]
SEM[1]					±10	±0.2
Statistical probabilities						
Treatment		NS	NS	NS	NS	0.01
Sex					0.05	0.01
Treatment×sex					NS	NS

[a,b,c,d]Treatments means within columns followed by different superscripts are significantly different ($p<0.05$), [1]Standard error of the Mean. [2]Feed consumption and body weight gain per bird during 7 d period, [3]Each mean based on 6 samples (3 females and 3 males) per treatment taken at 7 weeks of age

detected. At 7 weeks, serum P content was affected by treatment ($p<0.01$) and sex ($p<0.01$). Birds that received supplemented diets (diets 1 to 4) had higher serum P compared to the other group (diets 5 to 8), (7.52 vs. 5.07 $mg\ dL^{-1}$, respectively). Diets (1 to 4) showed no significant differences

Table 4: Effect of dietary phosphorus on broiler chicks Femora and Tibiae measurements at 6 weeks of age

		Femur					Tibia				
Analysis	Total phosphorus (g kg^{-1})	Weight[2] (g)	Length[2] (mm)	Width[2] (¼) (mm)	Width[2] (½) (mm)	Width[2] (¾) (mm)	Weight[2] (g)	Length[2] (mm)	Width[2](¼) (mm)	Width[2](½) (mm)	Width[2](¾) (mm)
Diet											
1	5.0	5.4	69.1	10.5	9.3	9.3	7.6	100.0	11.1	8.5	10.7
2	5.5	5.5	69.9	10.3	9.2	9.3	7.8	101.4	11.0	8.5	10.6
3	6.0	5.8	68.8	10.2	9.6	9.6	8.5	101.7	11.3	9.1	11.1
4	6.5	5.9	68.9	10.5	9.6	9.7	8.4	101.0	11.3	8.6	10.6
SEM[1]		±0.2	±0.7	±0.2	±0.2	±0.2	±0.3	±0.9	±0.2	±0.2	±0.2
Sex											
F		±5.1^{b}	±68.2^{b}	±9.9^{b}	±9.1^{b}	±9.1^{b}	±7.2^{b}	±99^{b}	±10.4^{b}	±8.0^{b}	±9.8^{b}
M		±6.2^{a}	±70.2^{a}	10.8^{a}	±9.7^{a}	±9.8^{a}	±9.0^{a}	±102^{a}	±12^{a}	±9.4^{a}	±11.5^{a}
SEM[1]		0.16	0.5	0.2	0.1	0.2	0.2	0.7	0.2	0.1	0.1
Statistical probabilities											
Treatment		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sex		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Treatment×sex		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a,b]Treatments means within columns followed by different superscripts are significantly different ($p<0.05$), [1]Standard error of the Mean. [2]Each mean based on 12 samples (6 females and 6 males) per treatment taken at 6 weeks of age

among them ($p>0.05$). On the other hand, serum from females contained 10.4% higher P than males ($p<0.05$).

Results of bone measurement at 6 weeks are shown in Table 4. Dietary P did not affect femora weights, lengths and diameters (Table 4). Sex had a significant effect on femora weights, lengths and widths ($p<0.01$), males had heavier, longer and wider femora bones compared to females. Ash content of the femora was significantly influenced by TP and sex ($p<0.01$). Femora ash content was not consistently responsive to TP level, ash contents were lower for birds receiving 5.0 g kg^{-1} TP compared to the three other treatments (Table 5). Femora of females contained 3.6% higher ash than males ($p<0.05$).

Increasing TP content of the diets had no significant effect on tibiae weights, lengths and widths ($p>0.05$), while sex had a significant effect. Males had heavier, longer and wider tibiae compared to the females ($p<0.01$). Results of bone ash content are presented in Table 5. Tibiae ash differed between diets and sex ($p<0.01$); there was an increase in tibia ash content as the level of TP increased in the diets ($p<0.01$). Birds that received the highest TP had 12% higher tibia ash compared to those that received the lowest TP level. Tibia ash was 6.4% higher in females compared to the results for males.

Dietary P affected toe ash ($p<0.01$) as documented in Table 5. Birds that received 5.0 and 5.5 g kg^{-1} TP diets had lower toe ash content compared to the other two groups. Cross-sectional cortical area (A), area moment of inertia (I), polar moment of inertia (J) and diaphysial curvature (θ) were not significantly affected by diet (Table 5). However, I, J and θ were affected by sex ($p<0.01$, 0.01, 0.05, respectively). Males had 47.8 and 37% higher I and J values, respectively compared to females; also femora from females showed more curvature than femora of males (165 vs. 163), respectively (Table 5).

The bone measurements at 7 weeks showed that femora were affected by sex, males had heavier, longer and wider ($p<0.01$) femora compared to the females, while diet had no significant effect (Data not shown). Significant effects of sex on tibiae weights, lengths and widths were

Table 5: Effect of dietary phosphorus on femur ash content, femur geometric values, tibia ash content and toe ash of broiler chicks at 6 weeks

Analysis	Total phosphorus (g kg^{-1})	Femur Ash[2] (%)	I[3] mm	A[4] mm^2	J[5] mm^4	Curvature[6] θ	Tibia ash[2] (%)	Toe ash[2] (%)
Diet								
1	5.0	37.4[b]	416.2	47.6	714.9	163.0	39.6[d]	10.18[b]
2	5.5	40.3[a]	430.4	50.5	789.3	163.8	41.9[c]	10.31[b]
3	6.0	41.1[a]	524.0	48.9	852.5	164.2	43.1[b]	11.32[a]
4	6.5	41.7[a]	510.7	53.4	927.8	164.9	44.4[a]	11.55[a]
SEM[7]		±0.44	±37.10	±3.00	±59.70	±0.75	±0.37	±0.20
Sex								
F		±40.8[a]	±379.5[b]	±47.2	±639.5[b]	±164.9[a]	±43.5[a]	±10.98
M		±39.4[b]	±561.2[a]	±52.9	±948.8[a]	±163[b]	±40.9[b]	±10.7
SEM[7]		0.32	26	2.1	42	0.5	0.26	0.14
Statistical probabilities								
Treatment		0.01	NS	NS	NS	NS	0.01	0.01
Sex		0.01	0.01	NS	0.01	0.05	0.01	NS
Treatment×sex		0.02	NS	NS	NS	NS	NS	NS

[a,b,c]Treatments means within columns followed by different superscripts are significantly different ($p<0.05$), [2]Each mean based on 12 samples (6 females and 6 males) per treatment taken at 6 weeks of age, I, A and J were measured at three points, (1/4, ½ and 3/4 of femoral length), the mean based on the average values of the three measurements, [3]Area moment of inertia, [4]Cross sectional cortical area, [5]Polar moment of inertia, [6]Diaphyseal curvature, [7]Standard error of the mean. The following regression equations were found from calculation of the relationship between tibia ash and dietary P for females and males: Tibia ash (F) = 23.78+3.44 * P Tibia ash (M) = 24.22+2.91

detected ($p<0.01$). Males showed higher values for the three responses. In contrast, diet had no effect on these responses ($p>0.05$). Differences in I, A and J were affected by the sex of the bird rather than treatment; males had higher values. Diaphyseal curvature was not affected by treatments or sex of the bird.

Ash content of femora were higher in the inorganic P supplemented compared to unsupplemented group (40.4 vs. 37.3%), respectively. Males had 6.6% lower femora ash compared to the females ($p<0.01$). Dietary P or gender had no effect on toe ash ($p>0.05$).Tibiae ash showed an effect due to different dietary treatments ($p<0.01$). Tibiae from birds fed the inorganic P supplemented diets had 5.9% higher ash content compared to the unsupplemented group. Males had 7.2% lower tibia ash compared to the females ($p<0.01$).

The effects of dietary treatments on P and Ca retention and P intake and excretion at 6 weeks are shown in Table 6. Birds given 5.5 g kg^{-1} TP diets retained more P than those given 5.0, 6.0 and 6.5 g kg^{-1}, respectively ((11.5, 46.8 and 43.6%), $p<0.01$). This group also retained more Ca than those that received 5.0, 6.0 and 6.5 g kg^{-1} TP, respectively (31.8, 22.0 and 58.9%, $p<0.01$). Dietary phosphorus level linearly increased P intake and excretion ($p<0.01$). Birds fed 6.5 g kg^{-1} TP consumed 13, 22 and 31% and excreted 8.0, 20.5 and 26.5% more P than those fed 6.0, 5.5 and 5.0 g kg^{-1} TP.

Phosphorus intake and excretion data at 7 weeks are shown in Table 7. Birds that received diets 3 and 4 consumed 56.8 and 49.8% and excreted 25.4 and 31.1% more P than those that received diets 7 and 8, respectively ($p<0.01$). Birds fed 5.0 g kg^{-1} TP during growing period and 3.8 g kg^{-1} TP during finishing period showed a great reduction in P intake and excretion (69.9 and 62.5%, respectively) compared to those fed 6.5 g kg^{-1} TP during growing and finishing periods ($p<0.01$).

Table 6: Effect of dietary phosphorus on calcium and phosphorus retention and phosphorus excretion at 6 weeks

Analysis	Total phosphorus ($g\ kg^{-1}$)	Ca Retention[2] (%)	Phosphorus retention[2] (%)	Phosphorus intake[3] (mg/bird/day)	Phosphorus excretion[3] (mg/bird/day)
Diet					
1	5.0	38.7^{b}	58.5^{b}	791^{c}	312^{c}
2	5.5	51.0^{a}	65.2^{a}	850^{bc}	327^{bc}
3	6.0	41.8^{b}	44.4^{c}	913^{b}	365^{ab}
4	6.5	32.1^{c}	45.4^{c}	1035^{a}	395^{a}
SEM[1]		±1.4	±1.0	±28	±13
Statistical probabilities					
Treatment		0.01	0.01	0.01	0.01

[a,b,c] Treatments means within columns followed by different superscripts are significantly different ($p<0.05$), [1]Standard error of the mean, [2]Based on fecal collection from 6 pens per treatment (2 birds per pen) for 24 h period during week five, [3]Based on pooled samples from 4 fecal collections from 6 pens per treatment (2 birds per pen). The following regression equation was found from calculation of the relationship between P intake and dietary P: P intake = -15.83+158.8 * P. The following regression equation was found from calculation of the relationship between P excretion and dietary P: P excretion = 21.9+57.1* P

Table 7: Effect of dietary phosphorus on P intake and excretion of broiler chicks from 6 to 7 weeks

Analysis	Total phosphorus ($g\ kg^{-1}$)	Phosphorus intake[2] (mg/bird/day)	Phosphorus excretion[2] (mg/bird/day)
Diet			
1	5.0	774^{bc}	360^{cd}
2	5.5	742^{bc}	378^{cd}
3	6.0	1083^{a}	453^{b}
4	6.5	1006^{ab}	525^{a}
5	3.8	592^{c}	323^{d}
6	3.8	737^{c}	398^{bc}
7	3.8	640^{c}	361^{cd}
8	3.8	671^{c}	401^{bc}
SEM[1]		±88	±21
Statistical probabilities			
Treatment		0.05	0.01

[a,b,c,d]Means within columns followed by different superscripts are significantly different ($p<0.05$), [1]Standard error of the mean, [2]Each mean based on the pooled collection from 3 pens per treatment taken at 7 weeks of age. The following regression equation was found from calculation of the relationship between P intake and dietary P for treatments 1 to 4: P intake = -8391.8+3113.1 * P - 256.3 P *P. The following regression equation was found from calculation of the relationship between P excretion and dietary P for treatments 1 to 4: P excretion = -226.8+114.1* P

DISCUSSION

The results obtained from this study indicated that it is possible to reduce dietary P and as a result reduce P excretion with no adverse effect on the performance from 3 to 7 weeks.

During the growing period, birds which had received diet with 5.0 $g\ kg^{-1}$ TP gained weight similarly to those fed the highest level 6.5 $g\ kg^{-1}$. This result agreed with the result obtained when breast muscle yield was measured, no significant effects were detected for the dietary treatments. Moreover, TP did not affect feed consumption or FCR. In this experiment, 6.3% reduction in body weight gain from 3 to 6 weeks period was found when the birds were fed 30% less TP but this was not a significant difference. These results are in agreement with those of Skinner *et al.* (1992), Chen and Moran Jr. (1995), Waldroup *et al.* (2000) and Dhandu and Angel (2003), who reported that 5.0 $g\ kg^{-1}$ P level was required for maximum growth. In agreement with the results obtained by Chen and Moran Jr. (1995) FCR was not affected by the level of P in the diet. Yan *et al.* (2000) concluded that body weight gain and FCR of broilers from 3 to 6 weeks were similar when birds were fed diet containing 2.6 g kg^{-1} npP compared to those fed the NRC-recommended level of 3.5 g kg^{-1}. Later, Yan *et al.* (2001) did not find any significant difference in body weight gain of broilers which had fed levels of npP from 1.5 to 4.5 g kg^{-1} from 3 to 6 weeks. Recently, Shaw *et al.* (2010) found that body weight increased significantly with an increase in npP from 3.5 to 5.0 g kg^{-1} at 4 weeks.

Omitting inorganic P source from the diet during the finishing period decreased TP content of excreta to 71% compared to a 6.5 g kg^{-1} TP diet. Live performance was not affected when the inorganic P source was omitted from the finishing diets. No significant differences could be detected for any dietary treatment on feed intake, body weight gain and FCR; birds received diets supplemented with inorganic P gained weight similar to those fed diets without inorganic P supplementation. Previous investigators had removed inorganic P source from the withdrawal feed of broiler males without adverse effects on body weight gain, feed intake, feed utilization and carcass yield (Skinner *et al.*, 1992; Chen and Moran Jr., 1994, 1995). Yan *et al.* (2000) reported that males fed diets with 0.075% less npP did not differ significantly in body weight (at 6 and 8 weeks old) from those fed NRC the level but they detected significant differences when the birds fed diets with 0.15% less than the NRC level. Dhandu and Angel (2003) reported that body weight gain, feed intake and FCR of birds fed 1.0 g kg^{-1} npP was not different from that of those fed the NRC (1994) level of 3.1 g kg^{-1} from 6 to 7 weeks.

Serum P showed treatment and sex effects during growing and finishing periods. Gardiner (1962) concluded that the level of plasma inorganic P responded very quickly to suboptimal dietary P levels and to feed withdrawal. During the growing period, birds that received 5.5 g kg^{-1} TP showed no significant differences than those that received the highest level of TP. During the finishing period, serum P was inconsistently responsive to dietary P levels. Birds that received any level of inorganic P supplementation showed no significant differences among them. Females in both periods had a higher serum P compared to males; this could be explained by the fact that males have more phosphate deposited in their bones since they have longer and heavier bones.

The weight, length and width of femora or tibiae showed no significant differences during growing or finishing periods and were inconsistently responsive to TP levels. Similar results were reported by Skinner *et al.* (1992). As expected, there was a significant sex effect for the criteria measured and same results were reported by Bond *et al.* (1991) who reported an increase in bone weight and length for male chicks. Similarly, Applegate and Lilburn (2002) reported a significant sex effect in tibia and femur weight from 28 through 43 days of age.

The skeletal status of chicken is assessed by estimation of tibia ash and occasionally supplemented by estimation of ash composition. The results obtained in this experiment suggested that incremental additions of P during growing and finishing periods improved tibia and femur ash but did not improve the mechanical properties of femur. Previous studies have produced results that are consistent with observations in the current study. Bond *et al.* (1991) reported similar results for tibia ash weight in females and males at 6 and 7 weeks. In agreement with the results of Applegate and Lilburn (2002), ash percentage was greater in tibia than femur. However, bone ash values in this study were lower than have been observed for chicks of this age receiving the same level of P (Ravindran *et al.*, 1995; Yan *et al.*, 2000). This finding supports the idea that even with the lower level of P the strength and mobility of bones were not affected. Dhandu and Angel (2003) reported that tibia ash weight and percentage of broilers fed 1.5 g kg^{-1} npP were significantly lower than that of broilers fed 1.9, 2.3 and 3.1 g kg^{-1} npP. Generally optimum P level for maximum growth is less than that required for maximum bone ash; many investigators have utilized maximum bone ash as the criteria for determining P requirements by chickens. Thorp and Waddington (1997) reported that the inadequacies in cortical bone of chicken would contribute to increased incidence in bone fracture. In this experiment differences in the cortical area between different treatments were not found. There were no problems in mortality or bone fractures during the entire study even when the inorganic P was removed completely from the diets during finishing period. Females were found to have higher percentage of ash. Bond *et al.* (1991) reported that weight of tibiae ash in males was greater than in females but females had higher percent of ash.

The amount of P in the diet and the efficiency with which the chick utilizes this dietary P are the major factors in determining the amount of P in the excreta. Reducing TP content of the diets markedly reduced fecal P. In this study there were significant reductions in TP intake and excretion from 3 to 7 weeks as a result of P in the diet. Birds that received the lower TP diet consumed and excreted less than those that received higher levels. This agrees with the results obtained by Powell *et al.* (2008) who reported that TP was decreased in the litter of broilers by 21.5% in the low P diet (a 0.05% reduction in npP compared to the control).

Increased dietary TP resulted in reduced P and Ca retention is in agreement with the results of Yi *et al.* (1996) who found that retention of P and Ca linearly decreased as the level of the npP increased in the diets. This may be due to the lower intestinal phytase activity and as a result lower PP utilization (Abudabos *et al.*, 2000). Fox *et al.* (1981) reported that feeding diets low in P increased the duodenal absorption of P.

The results of this study indicate that the TP levels needed by broilers to maintain growth and feed utilization from 3 to 7 weeks are less than those needed for maximum tibia ash. On the other hand, retention of P will decrease as the P consumed surpasses the requirement. Birds utilized PP, especially those that received a low level of inorganic source during the growing period and no supplementation during finishing period. In conclusion, the results of this study clearly show that dietary P could be reduced to 5.0 g kg^{-1} from 3 to 6 weeks and omitted from the withdrawal diets without adverse effects on live performance or skeletal integrity and this could decrease P intake and as a result P excretion.

ACKNOWLEDGMENT

This project was supported by King Saud University, Deanship of Scientific Research, College of Food and Agriculture Sciences, Research Center.

REFERENCES

AOAC, 1984. Official Methods of Analysis of the Association of Official Analytical Chemists. 14th Edn., Association of Official Analytical Chemists, Virginia, USA.

AOAC, 2000. Official Methods of Analysis of the Association of Official Analytical Chemists. 17th Edn., AOAC International, Washington, DC USA.

Abas, I., T. Bilal, E. Ercag and O. Keser, 2011. The effect of organic acid and zeolite addition alone and in combination on the bone Mineral value in broiler fed different dietary phosphorus levels. Asian J. Anim. Vet. Adv., 6: 678-687.

Abudabos, A., S.F. Lightsey, J.E. Toler and D.V. Maurice, 2000. Intestinal phytase activity in meat type chickens. Poult. Sci., 79: 12-12.

Applegate, T.J. and M.S. Lilburn, 2002. Growth of the femur and tibia of a commercial broiler line. Poult. Sci., 81: 1289-1294.

Baginski, E.S., P.P. Foa and B. Zak, 1967. Determination of phosphate: Study of labile organic phosphate interference. Clin. Chem. Acta, 15: 155-158.

Bingol, N.T., M.A. Karsli, D. Bolat, I. Akca and T. Levendoglu, 2009. Effects of microbial phytase on animal performance, amount of phosphorus excreted and blood parameters in broiler fed low non-phytate phosphorus diets. Asian J. Anim. Vet. Adv., 4: 160-166.

Bolin, D.W., R.P. King and E.W. Klosterman, 1952. A simplified method for the determination of Chromic Oxide (Cr2O3) when used as an inert substance. Science, 116: 634-635.

Bond, P.L., T.W. Sullivan, J.H. Douglas and L.G. Robeson, 1991. Influence of age, sex and method of rearing on tibia length and mineral deposition in broilers. Poult. Sci., 70: 1936-1942.

Chen, X. and E.T. Moran Jr., 1994. Response of broilers to omitting dicalcium phosphate from the withdrawal feed: Live performance, carcass downgrading and further-processing yields. J. Appl. Poult. Res., 3: 74-79.

Chen, X. and E.T. Moran Jr., 1995. The withdrawal feed of broilers: Carcass responses to dietary phosphorus. J. Applied Poult. Res., 4: 69-82.

Cowieson, A.J., T. Acamovic and M.R. Bedford, 2004. The effect of phytic acid and phytase on the digestibility of maize starch for growing broiler chickens. Poult. Sci., 83: 1791-1791.

Crespo, R., S.M. Stover, K.T. Taylor, R.P. Chin and H.L. Shivaprasad, 2000. Morphometric and mechanical properties of femora in young adult male turkeys with and without femoral fractures. Poult. Sci., 79: 602-608.

Dhandu, A.S. and R. Angel, 2003. Broiler nonphytin phosphorus requirement in the finisher and withdrawal phases of a commercial four-phase feeding system. Poult. Sci., 82: 1257-1265.

Edwards, H.M.Jr., P. Palo, S. Soonchaerenying and M.A. Elliot, 1989. Factors Influencing the Bioavailability of Phytate Phosphorus to Chickens. In: Nutrient availability: Chemical and Biological Aspects, Southgate, D., I. Jonhson and G.R. Fenwick (Eds.). The Royal Society of Chemistry, Cambridge, pp: 271-276.

Edwards, Jr. H.M. and M.B. Gillis, 1959. A chromic oxide balance method for determining phosphorus availability. Poult. Sci., 38: 569-574.

Edwards, Jr. H.M., 1983. Effect of breed and strain on utilization of suboptimal levels of phosphorus in the ration. Poult. Sci., 62: 77-84.

Eeckhout, W. and M. DePaepe, 1994. Total phosphorus, phytate phosphorus and phytase activity in plant feedstuffs. Anim. Feed Sci. Technol., 47: 19-29.

Fox, J., N.W. Bunnett, A.R. Farrar and A.D. Care, 1981. Stimulation by low phosphorus and low calcium diets of duodenal absorption of phosphate in betamethasone-treated chicks. J. Endoc., 88: 147-153.

Gardiner, E.E., 1962. The relationship between dietary phosphorus level and the level of plasma inorganic phosphorus of chicks. Poult. Sci., 41: 1156-1163.

Manangi, M.K. and C.N. Coon, 2008. Phytate phosphorus hydrolysis in broilers in response to dietary phytase, calcium and phosphorus concentrations. Poult. Sci., 87: 1577-1586.

Mohammed, A., M.J. Gibney and T.G. Taylor, 1991. The effects of dietary levels of inorganic phosphorus, calcium and cholecalciferol on the digestibility of phytate-P by the chick. Br. J. Nutr., 66: 251-259.

Musapuor, A., M. Afsharmanesh and H. Moradi, 2006. Use of microbial phytase for decrease of pollutant environmental poultry excreta phosphorus. Int. J. Agric. Biol., 8: 35-37.

Nelson, T.S., 1976. The hydrolysis of phytate phosphorus by chicks and laying hens. Poult. Sci., 55: 2262-2264.

NRC, 1994. Nutrient Requirements of Poultry. 9th Edn., National Academy Press, Washington, DC., USA., ISBN-13: 9780309048927, Pages: 155.

Powell, S., S. Johnston, L. Gaston and L.L. Southern, 2008. The effect of dietary phosphorus level and phytase supplementation on growth performance, bone-breaking strength and litter phosphorus concentration in broilers. Poult. Sci., 87: 949-957.

Ravindran, V., W.L. Bryden and E.T. Kornegay, 1995. Phytates: Occurrence, bioavailability and implications in poultry nutrition. Poult. Avian Biol. Rev., 6: 125-143.

SAS Institute, 1996. SAS Users Guide: Statistics. Version 7.0. SAS Institute, Cary NC.

Scott, M.L., M.C. Nesheim and R.J. Young, 1976. Nutrition of the Chicken. In: Energy, Scott, M.L. and Associates (Eds.). Ithaca, New York, USA., pp: 7-54.

Shaw, A.L., J.P. Blake and E.T. Moran, 2010. Effects of flesh attachment on bone breaking and of phosphorus concentration on performance of broilers hatched from young and old flocks. Poult. Sci., 89: 295-302.

Skinner, J.T., A.L. Izat and P.W. Waldroup, 1992. Effects of removal of supplemental calcium and phosphorus from broiler finisher diets. J. Applied Poult. Res., 1: 42-47.

Smith, G.E., 1965. The wet chemical oxidation of organic compositions employing perchloric acid. G. Frederick Smith Chemical Co., Inc., Columbus, OH.

Thorp, B.H. and D. Waddington, 1997. Relationships between the bone pathologies, ash and mineral content of long bones in 35-day-old broiler chickens. Res. Vet. Sci., 62: 67-73.

Uittenboogaart, G. and A.R. Gerrits, 1982. Methods of dissection of broiler carcass and description of parts. IPS Report No. 370, Institute for Poultry Research, Spelderholt, Netherlands.

Waldroup, P.W., J.H. Kersey, E.A. Saleh, C.A. Fritts and F. Yan *et al*., 2000. Nonphytate phosphorus requirement and phosphorus excretion of broiler chicks fed diets composed of normal or high available phosphate corn with and without microbial phytase. Poult. Sci., 79: 1451-1459.

Yan, F., J.H. Kersey, C.A. Fritts, P.W. Waldroup and H.L. Stilborn *et al*., 2000. Evaluation of normal yellow dent corn and high available phosphorus corn in combination with reduced dietary phosphorus and phytase supplementation for broilers grown to market weights in litter pens. Poult. Sci., 79: 1282-1289.

Yan, F., J.H. Kersey and P.W. Waldroup, 2001. Phosphorus requirements of broiler chicks 3-6 weeks of age as influenced by phytase supplementation. Poult. Sci., 80: 455-459.

Yi, Z., E.T. Konegay and D.M. Denbow, 1996. Supplemental microbial phytase improves zink utilization in broilers. Poult. Sci., 75: 540-546.