Benefit of Feeding Dietary Calcium and Nonphytate Phosphorus Levels Above National Research Council Recommendations to Tom Turkeys in the Growing-Finishing Phases

K. D. Roberson,[1] M. W. Klunzinger, and R. A. Charbeneau

Department of Animal Science, 2209 Anthony Hall, Michigan State University, East Lansing, Michigan 48824

ABSTRACT This experiment evaluated the effects of feeding various dietary Ca and nonphytate P (nPP) levels to Large White male turkeys from 3 to 17 wk of age. After consuming a common prestarter diet, poults were fed approximate NRC (1994) levels of dietary Ca and nPP from 3 to 9 wk of age or levels approximately 25% higher. From 9 to 17 wk of age, each starter group was fed approximately 75 (low P), 100 (medium P), or 145% (high P) of the NRC (1994) requirements for Ca and nPP. Diets were fed as crumbles to 6 wk of age and as pellets from 6 to 17 wk of age. There were no effects on BW or feed efficiency to 9 wk of age. Litter P was increased by 21% when high Ca and nPP were fed from 3 to 9 wk. High dietary Ca and nPP fed during the growing-finishing period generally improved bone strength and ash. Tibia strength and ash were higher in the medium P group compared with in the low P group. Wing bone strength was greater in the high P group than in both the birds fed low or medium P. Litter P was increased by 23% when High P was fed in the growing-finishing period compared to the birds fed the Medium P diet during the same period. The results show there is a benefit to bone strength and mineralization when Ca and nPP are fed at levels higher than NRC (1994) recommendations.

(*Key words*: bone, calcium, nonphytate phosphorus, tom, turkey)

2004 Poultry Science 83:689–695

INTRODUCTION

Studies to determine the Ca and P requirements of growing-finishing Large White toms have not been conducted in almost 40 yr (Day and Dilworth, 1962; Sullivan, 1962). Although the improved genetics of today imply increased nutrient requirements to support faster growth, published data is lacking to support the concentrations of dietary Ca and P that are recommended by turkey breeding companies. In addition to growth performance, high levels of Ca and P are fed due to concerns about leg weakness and other disorders associated with leg weakness such as breast blisters. A safety factor is usually included to ensure that all the birds consume adequate P because there may be variability in the P level in the feed.

The NRC (1994) requirement for nonphytate P (nPP) for starting poults is 0.60% based upon past research (Almquist, 1954; Bailey et al., 1986). Calcium is recommended at 1.20% to provide a 2:1 ratio of Ca and nPP, which is supported by the report of Neagle et al. (1968). However, more recent research with 16-d-old poults resulted in estimates of 1.25% Ca and 1.00% total P (0.72% nPP) for requirements of young turkeys (Sanders et al., 1992).

A recent report showed that male and female turkeys raised from 4 wk of age to market age grew just as well and had similar bone characteristics when fed 73% of the NRC (1994) requirements for nPP as when turkeys were fed 110% of the NRC (1994) requirements for Ca and nPP (Atia et al., 2002). However, other research has shown that feeding toms about 75% of the NRC (1994) requirements for nPP with a 2:1 Ca:nPP ratio results in lower breaking strength of the ulna in growing male turkeys compared with toms fed nPP at 105% of the NRC (1994) requirements (Roberson and Fulton, 2000). Ledoux et al. (1995) did not observe overall growth, bone strength, or P digestibility responses to phytase when an average of approximately 65% of the NRC (1984) requirement for available P was fed to turkey hens. The NRC (1984) requirements for available P are identical to the NRC (1994) requirements for nPP. Hocking et al. (2002) concluded that Large White male turkeys should be fed 1.00% Ca and 0.30% available P from 4 to 13 wk of age to optimize growth and feed efficiency without affecting walking ability. Hence, the Ca and P levels needed today for optimum growth performance and leg strength of commercial tom turkeys are dis-

Received for publication August 28, 2003.
Accepted for publication November 10, 2003.
[1]To whom correspondence should be addressed: robers22@msu.edu.

Abbreviation Key: nPP = nonphytate P.

puted. The objective of this study was to evaluate the Ca and nPP needs of Large White commercial toms with respect to growth performance and bone integrity through the entire grow-out of consumer size toms (15 to 16 kg final live BW). Comparison of a low P diet to other levels of dietary P was only made in the grower-finisher phases.

MATERIALS AND METHODS

One thousand British United Turkeys of America Big 6 male poults obtained from a commercial hatchery[2] were group brooded at 62 to 63 poults per pen in 16 pens. The birds were fed a commercially prepared prestarter diet[3] in crumbled form that was formulated to contain 1.41% Ca and 0.80% available P (1.44% Ca, 0.99% total P, and 0.20% phytate P by analysis). At 3 wk of age, the poults were separated into 30 treatment pens at 31 poults/pen. The birds were fed crumbles to 6 wk of age and 3/16-inch pellets from 6 to 17 wk of age. The feed was mixed and pelleted at a commercial feed mill.[4] Feed was provided in plastic hanging tube feeders[5] with a 91.4-cm circumference in the feeding pan area the first 6 wk and then in metal hanging tube feeders[6] with a 121.9-cm circumference at the feeding area after 6 wk of age. Water was provided via bell drinkers that were cleaned every other day.

During the starter I period (3 to 6 wk of age) and starter II period (6 to 9 wk of age), birds were fed a diet formulated to contain Ca and nPP at approximate NRC (1994) requirements or at higher levels suggested by breeder guidelines[7] to 15 pens/treatment. The starter I diet (Table 1) was fed at a Ca:nPP ratio of 1.8:1 in which nPP was fed slightly higher than NRC (1994) recommendations to narrow the ratio, which is consistent with turkey industry feeding practices in the United States. Hence, calculated Ca and nPP levels were 1.20 and 0.64% for the NRC (1994) diet and 1.40 and 0.75% for the high P diet. The Ca:nPP ratio was fed at 2:1 during the remainder of the experiment. Dietary Ca and nPP were formulated at 1.00 and 0.50% for the NRC (1984) diet from 6 to 9 wk of age and 1.30 and 0.65% for the high P treatment.

At 9 wk of age, the 2 starter treatment groups were divided into 3 subgroups. Within each starter group, birds were fed diets for 3-wk phases that were formulated to provide Ca and nPP at approximately 75, 100, or 145% of the NRC (1994) requirements (Table 2) to result in a 2 × 3 factorial design during the growing-finishing phases. Hence, there were 5 pens per individual dietary treatment during this period. The high level of nPP is based upon breeder company recommendations. The finisher phase was only 2 wk from 15 to 17 wk of age, and the birds were marketed as consumer toms (about 15.5 kg of live weight). Actual BW measurements and feed changes occurred after 22, 19, or 15 d for the 9- to 12-, 12- to 15-, and 15- to 17-wk periods, respectively.

Feed Ca and total P were measured at a commercial laboratory,[8] and feed phytate P was measured by the method described by Latta and Eskin (1980). The actual Ca and nPP levels were lower than expected in the finisher phase. Porcine meat and bone meal, a common feed ingredient in turkey diets, was fed in the later stages of growth to decrease the amount of fat that was needed to meet the high energy levels that were fed to be consistent with industry practices. Feed intake was measured at the end of each feeding phase, and feed efficiency was calculated after correcting BW gain with BW of dead birds, which were recorded daily.

Bone samples (ulna, femur, humerus, and tibia) were taken from 3 toms/pen at 15 and 17 wk of age and were selected based upon the average BW of the birds in the pen. The turkeys were slaughtered at the Michigan State University Meat Laboratory, and the bones were excised from the left side of the carcasses after they were chilled for 4 h. The bones were cleaned and frozen until analyzed for bone strength testing using an Instron Universal Testing Machine.[9] Bones were thawed overnight in a cooler before breaking strength was tested. Breaking strength of the bones was defined as the maximum amount of fracture force required to break the bone at the midshaft of the bone. The femur, humerus, tibia, and ulna were broken by the double shear block method at 15 wk of age (ASAE, 1999). At 17 wk of age, the femur, humerus, and ulna were broken by the same method, but the tibia was broken by the 3-point bend method, which is appropriate for bones that have a length:width ratio of at least 10:1 (ASAE, 1999). The width of the bone is measured at the mid-shaft across the area in which the force will be exerted. The broken pieces were fat extracted and ashed according to AOAC (2000) procedures.

Litter samples were taken from each pen at 9 and 17 wk of age. Subsamples were taken from 5 points in each pen. One subsample was taken from the middle of the pen, and 4 subsamples were taken about 30 cm from each corner of the pen. The subsamples were mixed together and dried at 50°C and ground through a 2-mm screen before analysis. Phosphorus was analyzed by plasma emission spectroscopy at a commercial laboratory.[7]

The data were subjected to analysis of variance by the GLM procedure of SAS software (SAS Institute, 2000) using pen as the experimental unit. Main effect means from the 2 × 3 factorial arrangement from 9 to 17 wk were separated by Duncan's new multiple range test.

RESULTS AND DISCUSSION

There were no treatment effects on BW gain or feed efficiency from 3 to 9 wk of age (data not shown). The

[2]Cooper Hatchery, Inc. Oakwood, OH.
[3]Akey, Inc., Lewisburg, OH.
[4]Hamilton Farm Bureau, Hamilton, MI.
[5]Plasson, Ltd., Menashe, Israel.
[6]Shenandoah Manufacturing, Inc., Harrisonburg, VA.
[7]Commercial Stock Management Guide-2000, British United Turkeys of America, Lewisburg, WV.
[8]Experiment Station Chemical Laboratories, Columbia, MO.
[9]Instron Model 4202, Canton, MA.

TABLE 1. Percentage composition of the experimental diets from 3 to 9 wk of age[1]

	Starter I (3 to 6 wk)		Starter II (6 to 9 wk)	
Ingredient	NRC	High P	NRC	High P
Ground corn	45.25	44.22	47.40	45.72
Dehulled soybean meal	40.00	40.38	37.45	37.98
Wheat middlings	4.85	4.22	6.50	5.75
Menhaden meal	3.00	3.00	0.00	0.00
Animal–vegetable fat	2.55	3.00	4.30	5.00
Dicalcium phosphate	1.94	2.48	1.70	2.43
Limestone	1.45	1.75	1.43	1.91
Salt	0.30	0.30	0.36	0.36
Vitamin mix[2]	0.15	0.15	0.15	0.15
Trace mineral mix[3]	0.10	0.10	0.10	0.10
L-Lysine-HCl	0.19	0.18	0.33	0.32
DL-Methionine	0.22	0.22	0.28	0.28
Calculated nutrient level				
Crude protein, %	26.00	26.00	23.50	23.50
ME, kcal/kg	2,940	2,940	3,050	3,050
Calcium, %	1.20	1.40	1.00	1.30
Nonphytate P, %	0.64	0.75	0.50	0.65
Analyzed nutrient level				
Calcium, %	1.22	1.56	0.89	1.31
Total P, %	0.84	0.92	0.73	0.88
Phytate P, %	0.26	0.24	0.27	0.26

[1]Treatment diets fed 21 d during each starter phase; NRC = levels of dietary P and Ca were approximately at NRC (1994) recommendations.

[2]Vitamin premix provided per kilogram of diet: vitamin A (all-*trans*-retinyl acetate), 11,000 IU; cholecalciferol, 5,000 ICU; vitamin E (all-*rac*-α-tocopheryl acetate), 35 IU; menadione (as menadione sodium bisulfite), 2.75 mg; riboflavin, 10 mg; Ca pantothenate, 20 mg; nicotinic acid, 80 mg; vitamin B_{12}, 0.025 mg; vitamin B_6, 4.3 mg; thiamin (as thiamin mononitrate), 2.9 mg; folic acid, 2.2 mg; biotin, 0.2 mg; vitamin C, 0.10 g; selenium, 0.275 mg; and ethoxyquin, 125 mg.

[3]Mineral premix supplied per kilogram of diet: M, 100 mg; Zn, 100 mg; Fe, 50 mg; Cu, 10 mg; and I, 1 mg.

birds weighed an average of 2.57 kg at 6 wk of age and 5.49 kg at 9 wk of age. However, litter P was increased ($P < 0.001$) by 21% at 9 wk when the higher Ca and nPP diets were fed (1.16 vs. 1.40%). Consumption of the low Ca and nPP diets in the growing-finishing phases resulted in decreased 17-wk BW ($P = 0.071$) and 9- to 12-wk feed efficiency ($P = 0.059$) (Table 3). Average daily gain was affected ($P < 0.100$) in the grower I (9 to 12 wk) and finisher (15 to 17 wk) phases. Average daily gain for the entire 9- to 17-wk grow-finish period was 171, 176, or 179 g/d for the low P, medium P, or high P dietary treatment, respectively. Litter P was increased ($P = 0.001$) at 17 wk by each level of Ca and nPP diets in the growing-finishing period. The group fed high P had litter P levels averaging 23% higher than the medium P group.

There were no significant carryover effects of starter feed treatments on bone breaking strength (Table 4). Breaking strength of the humerus ($P = 0.025$) and ulna ($P = 0.001$) was increased at 15 wk of age by feeding the high level of Ca and nPP in the grower phases. Tibia breaking strength was increased ($P = 0.002$) when the medium level of Ca and nPP were fed during the same period. The high level of dietary Ca and nPP also resulted in a stronger humerus ($P = 0.001$) and ulna ($P = 0.003$) in birds at 17 wk of age. The strength of the tibia was measured by the 3-point bend method at 17 wk of age because the length to width ratio of tibiae was greater than 10:1 (width was measured at the midshaft on the bone). Tibiae were affected ($P = 0.090$) in which the treatment responses were similar to other effects reported. The results of this experiment indicate that the shear block method was more sensitive for detecting dietary treatment effects on tibia breaking strength. The ulna was found to be an ideal bone for the shear block method because the curved side of the bone sets into the fulcra that have a similar shape to hold the bone. There were no treatment effects on femur breaking strength. Breakage of the femur resulted in a shattering response, which resulted in many separated small pieces compared with the other bones in which a clean break was forced through the bone during the shearing process. The relatively lower bone breaking force of the femur provided evidence of a more fragile and less developed bone in the turkey skeleton. Lilburn (1993) suggested that the femur may be the weak link with respect to long bone developmental abnormalities. A small proportion (4 to 5%) of turkeys in the experiment had some difficulty walking. These birds were primarily associated with the treatments in which Ca and nPP were fed at low levels in the grow-finish phases or were fed the NRC (1994) diet throughout the experiment. A few birds became lame and had to be culled. In a couple of cases, spontaneous femur fractures occurred when low Ca and nPP levels were fed.

Bone ash was generally higher in relation to higher levels of dietary Ca and nPP in the grower and finisher phases (Table 5). There was an unexpected decrease ($P = 0.024$) in 15-wk humerus ash of birds fed the high Ca and nPP diets in the starter phases. A starter phase ×

TABLE 2. Percentage composition of the experimental diets from 9 to 17 wk of age[1]

	Grower I (9 to 12 wk)			Grower II (12 to 15 wk)			Finisher (15 to 17 wk)		
Ingredient	Low P	Med P	High P	Low P	Med P	High P	Low P	Med P	High P
Ground corn	54.73	53.55	51.39	57.85	56.18	53.26	59.76	58.36	55.38
Dehulled soybean meal	31.08	31.50	32.12	25.06	25.30	25.81	20.22	20.47	20.99
Wheat middlings	6.28	5.67	4.90	7.00	7.00	7.00	7.50	7.50	7.50
Animal–vegetable fat	5.00	5.50	6.37	6.77	7.31	8.33	8.60	9.09	10.13
Porcine meat and bone meal	0.00	0.00	0.00	1.35	1.35	1.35	2.70	2.70	2.70
Dicalcium phosphate	0.84	1.38	2.24	0.63	0.93	1.74	0.00	0.39	1.25
Limestone	0.83	1.19	1.77	0.59	0.85	1.43	0.23	0.51	1.07
Salt	0.36	0.36	0.37	0.34	0.34	0.34	0.32	0.32	0.32
Vitamin mix[2]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral mix[3]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-Lysine-HCl	0.37	0.36	0.35	0.29	0.28	0.27	0.16	0.15	0.14
DL-Methionine	0.24	0.24	0.24	0.21	0.21	0.21	0.25	0.25	0.26
Calculated nutrient level									
Crude protein, %	21.00	21.00	21.00	19.00	19.00	19.00	17.50	17.50	17.50
ME, kcal/kg	3,200	3,200	3,200	3,350	3,350	3,350	3,500	3,500	3,500
Calcium, %	0.62	0.84	1.20	0.56	0.75	1.10	0.48	0.65	1.00
Nonphytate P, %	0.31	0.42	0.60	0.28	0.38	0.55	0.24	0.32	0.50
Analyzed nutrient level									
Calcium, %	0.66	0.81	1.22	0.58	0.78	1.01	0.43	0.59	0.89
Total P, %	0.53	0.64	0.79	0.50	0.64	0.76	0.49	0.55	0.73
Phytate P, %	0.27	0.26	0.24	0.28	0.29	0.26	0.31	0.29	0.30

[1]Treatment diets fed 22, 19, and 15 d during the grower I, grower II, and finisher phases, respectively; Med P = medium level of dietary P.

[2]Vitamin premix provided per kilogram of diet: vitamin A (all-*trans*-retinyl acetate), 9,000 IU; cholecalciferol, 3,500 ICU; vitamin E (all-*rac*-α-tocopheryl acetate), 25 IU; menadione (as menadione sodium bisulfite), 1.5 mg; riboflavin, 6 mg; Ca pantothenate, 15 mg; nicotinic acid, 70 mg; vitamin B_{12}, 0.014 mg; vitamin B_6, 3.0 mg; thiamin (as thiamin mononitrate), 1.4 mg; folic acid, 2.0 mg; biotin, 0.1 mg; selenium, 0.25 mg; and ethoxyquin, 125 mg.

[3]Mineral premix supplied per kilogram of diet: Mn, 100 mg; Zn, 100 mg; Fe, 50 mg; Cu, 10 mg; and I, 1 mg.

grow-finish phase interaction for 15-wk ulna ash was observed ($P = 0.023$) due to low ash when the medium levels of Ca and nPP were fed throughout the experiment. The most sensitive bone for bone ash determination was the tibia. Each level of dietary Ca and nPP in the grower phases resulted in an increase ($P = 0.001$) in tibia ash as bone mineralization was maximized at the high levels of Ca and nPP and minimized by the low level of Ca and nPP. Tibia ash at 17 wk was increased ($P = 0.001$) when the medium level of Ca and P was fed. Ulna ash content was higher ($P = 0.001$) for birds fed the high level of Ca and nPP at 15 wk but was not different at 17 wk. However, humerus ash was increased ($P = 0.005$) by the high level of Ca and nPP over the low level at 17 wk, but there was no difference at 15 wk. Interestingly, there was no treatment effect on femur ash, which was consistent with the lack of a bone strength effect. The lack of an effect was due to the birds fed high Ca and nPP throughout the experiment not having the same bone strength and mineralization as the birds fed NRC (1994) levels of Ca and P in the starter period and high Ca and P later. It is not known why this occurred. The relatively lower femur ash values at both ages compared with other bones are consistent with the statement by Lilburn (1993) that mineralization rates of the femur develop more slowly than the tibia.

The data in this experiment support feeding Ca and nPP at levels higher than the NRC (1994) requirements on a 3-wk basis during the grower and finisher phases to improve bone strength. The lack of an effect in the starter phase may be related to the high levels of Ca and nPP fed in the prestarter period and the slightly higher than NRC (1994) recommendation in the starter I (3 to 6 wk) phase for birds fed the lower levels of Ca and nPP. The increase in feed intake of turkeys through genetic improvements for growth would result in higher P intake on a daily basis even if the same percentage of nPP is considered adequate as recommended by NRC (1994). The general lack of growth performance response to varying dietary Ca and nPP levels in the growing-finishing phases compared with the numerous significant bone ash differences agrees with previous reports that birds will meet their requirements for BW gain and feed utilization before optimizing bone ash (Dhandu and Angel, 2003; Yan et al., 2003).

Ledoux et al. (1995) fed turkey hens on a 4-wk basis and only observed BW gain and feed conversion effects during the feeding period from 8 to 12 wk of age. In that study, the low P diet was formulated by feeding 0.15 percentage units less inorganic P than the NRC (1984) requirement for available P without decreasing dietary Ca. Over the entire experiment, the average reduction in dietary available P was about 35% compared with the control diet. Ledoux et al. (1995) observed a reduction in toe ash but reported no effect on tibia breaking strength when dietary P was decreased. The type of breaking strength test was not indicated, but the bones were placed on supports 20 mm apart indicating that the test was likely the 3-point bend method. Although there was a bone ash effect, the authors concluded that the birds had adequate mineralization even when the low P diet was fed and concluded that the P require-

TABLE 3. Effect of dietary calcium and nonphytate phosphorus (nPP) levels on growth performance of tom turkeys and 17-wk litter phosphorus concentration[1]

Treatment diet: Starter	Grower/finisher	12-wk BW (kg)	9- to 12-wk ADG (g)	9- to 12-wk gain:feed (kg:kg)	15-wk BW (kg)	12- to 15-wk ADG (g)	12- to 15-wk gain:feed (g:g)	17-wk BW (kg)	15- to 17-wk ADG (g)	15- to 17-wk gain:feed (kg:kg)	Litter P (%)
NRC	Low P	9.32	175	0.422	12.69	178	0.318	15.15	164	0.288	1.00
NRC	Medium P	9.50	183	0.443	12.77	172	0.317	15.36	172	0.298	1.08
NRC	High P	9.52	183	0.444	13.09	188	0.345	15.92	189	0.325	1.49
High P	Low P	9.50	181	0.431	12.75	171	0.316	15.36	174	0.300	1.01
High P	Medium P	9.63	187	0.442	13.11	184	0.335	15.71	173	0.355	1.17
High P	High P	9.56	185	0.445	12.78	170	0.312	15.43	177	0.305	1.43
Mean		9.50	182	0.438	12.87	177	0.324	15.49	175	0.312	1.19
Pooled SEM		0.08	3	0.008	0.18	5	0.008	0.18	6	0.023	0.04
Main effect means											
Starter diets											
NRC		9.45	180	0.436	12.85	179	0.326	15.48	175	0.304	1.18
High P		9.56	185	0.440	12.88	175	0.321	15.50	175	0.320	1.20
Grower/finisher diets											
Low P		9.41	178	0.426	12.72	175	0.317	15.26	169	0.294	1.01[c]
Medium P		9.56	185	0.443	12.94	178	0.326	15.54	173	0.327	1.14[b]
High P		9.54	184	0.445	12.94	179	0.328	15.68	183	0.315	1.40[a]
ANOVA		Probability									
Source											
Starter		0.109	0.157	0.602	0.800	0.269	0.441	0.851	0.947	0.396	0.841
Grower/finisher		0.161	0.091	0.059	0.258	0.642	0.364	0.071	0.093	0.378	0.001
Starter × grower/finisher		0.696	0.761	0.774	0.115	0.013	0.020	0.055	0.215	0.278	0.218

[a–c]Means with no common superscript are different at $P < 0.05$.

[1]Treatment diets fed 22, 19, and 15 d during the grower I, grower II, and finisher phases, respectively; ADG = average daily gain; average starting body weight at 9 wk of age was 5.49 kg.

TABLE 4. Effect of dietary calcium and nonphytate phosphorus (nPP) levels on fracture force of bones from tom turkeys[1]

Treatment diet		Shear (N)[2]—15 wk				Shear (N)[2]—17 wk			3-Point bend (N)[2]
Starter	Grower/finisher	Femur	Humerus	Ulna	Tibia	Femur	Humerus	Ulna	Tibia
NRC	Low P	1,516	2,364	1,812	2,151	1,754	2,619	2,068	523
NRC	Medium P	1,423	2,303	1,778	2,614	1,603	2,784	2,032	553
NRC	High P	1,715	2,763	2,151	2,859	1,971	3,256	2,354	614
High P	Low P	1,537	2,497	1,663	2,307	1,759	2,633	2,079	553
High P	Medium P	1,658	2,450	1,873	2,614	1,785	2,579	2,186	570
High P	High P	1,520	2,679	2,036	2,776	1,766	3,580	2,518	582
Mean		1,563	2,509	1,886	2,553	1,773	2,909	2,206	566
Pooled SEM		80	126	88	144	127	143	104	26
Main effect means									
Starter diets									
NRC		1,551	2,477	1,914	2,541	1,776	2,886	2,152	563
High P		1,576	2,542	1,856	2,566	1,770	2,931	2,261	568
Grower diets									
Low P		1,526	2,430[b]	1,738[b]	2,229[b]	1,756	2,626[b]	2,074[b]	538[b]
Medium P		1,540	2,377[b]	1,825[b]	2,614[a]	1,694	2,682[b]	2,109[b]	561[ab]
High P		1,629	2,721[a]	2,094[a]	2,817[a]	1,868	3,418[a]	2,436[a]	598[a]
ANOVA		Probability							
Source									
Starter		0.761	0.529	0.441	0.836	0.954	0.704	0.211	0.821
Grower/finisher		0.509	0.025	0.001	0.002	0.396	0.001	0.003	0.090
Starter × grower/finisher		0.051	0.595	0.337	0.705	0.332	0.198	0.719	0.475

[a,b]Means with no common superscript are different at $P < 0.05$.

[1]Each bone measurement was taken from 3 toms per pen and five pens per treatment.

[2]N = Newtons; N = 0.102 kilograms of force = 9.8 kilograms of mass.

ments recommended for turkey hens by NRC may be too high.

Atia et al. (2000) observed no significant decreases in bone (tibia) parameters or leg conditions of toms or hens fed 100 or 73% of the NRC (1994) Ca or nPP requirements compared with feeding 110% of the NRC (1994) Ca and nPP requirements after 4 wk of age. The concentrations of Ca and nPP in relation to NRC (1994) recommendations were based upon 4-wk phase feeding periods. Our results are in disagreement with the data reported by Atia et al. (2000) that bone strength and mineralization of the tibia are not significantly reduced when dietary P is fed at about 25% lower than NRC (1994) recommendations. However, the low dietary Ca and nPP treatment

TABLE 5. Effect of dietary calcium and nonphytate phosphorus (nPP) levels on percentage ash from bones of tom turkeys[1]

Treatment diet		15 wk				17 wk			
Starter	Grower/finisher	Femur	Humerus	Ulna	Tibia	Femur	Humerus	Ulna	Tibia
		(%)							
NRC	Low P	39.2	49.1	46.6	45.6	42.5	50.6	50.6	46.9
NRC	Medium P	38.6	49.0	43.4	46.6	42.4	52.8	49.4	48.1
NRC	High P	42.8	48.8	50.4	48.4	45.0	53.7	51.6	50.2
High P	Low P	38.9	45.6	44.6	44.8	42.9	51.2	49.2	45.3
High P	Medium P	41.8	47.0	48.8	47.8	43.4	52.0	51.7	50.2
High P	High P	41.0	48.3	50.7	50.3	43.3	54.8	52.4	50.7
Mean		40.4	48.0	47.4	47.3	43.3	52.5	50.8	48.5
Pooled SEM		1.4	1.0	1.3	0.8	0.9	0.9	1.7	0.9
Main effect means									
Starter diets									
NRC		40.2	49.0[a]	46.8	46.9	43.3	52.4	50.5	48.4
High P		40.6	46.9[b]	48.1	47.6	43.2	52.7	51.1	48.7
Grower diets									
Low P		39.0	47.3	45.6[b]	45.2[c]	42.7	50.9[b]	49.9	46.1[b]
Medium P		40.2	48.0	46.1[b]	47.2[b]	42.9	52.4[ab]	50.6	49.1[a]
High P		41.9	48.6	50.5[a]	49.4[a]	44.2	54.3[a]	52.0	50.4[a]
ANOVA		Probability							
Source									
Starter		0.746	0.024	0.234	0.246	0.901	0.666	0.679	0.713
Grower/finisher		0.145	0.508	0.001	0.001	0.261	0.005	0.440	0.001
Starter × grower/finisher		0.209	0.357	0.023	0.204	0.333	0.601	0.550	0.163

[a,b]Means with no common superscript are different at $P < 0.05$.

[1]Each bone measurement was taken from 3 toms per pen and five pens per treatment.

in the current experiment was formulated to provide about 75% of the NRC (1994) recommendations on a 3-wk basis. Also, dietary Ca was not decreased in the studies of Atia et al. (2000) or Ledoux et al. (1995).

There was no benefit observed in this study to fed Ca and P levels at high levels from 3 to 9 wk of age. However, there was a clear benefit from feeding Ca and nPP at levels above NRC (1994) requirements after 9 wk of age for bone strength and mineralization. Analysis of the feeds indicated that Ca and P levels were lower than calculated in the finisher phase. The Ca and P levels provided by meat and bone meal could have been different than the values reported by the feed manufacturer. Average daily intake of nPP was approximately 2.5 g/d for birds fed the high levels of Ca and nPP from 9 to 17 wk of age (2.3, 2.7, or 2.5 for 9 to 12 wk, 12 to 15 wk, or 15 to 17 wk, respectively). Based upon estimated feed intake levels given by NRC (1994), male turkeys would require 1.5 or 1.95 g/d from 8 to 12 wk or 12 to 16 wk of age, respectively. If diets were switched on a 3-wk basis to match improved growth potential as referenced in footnote a of Table 3-1 in NRC (1994), nPP requirements would be 1.45, 1.58, or 1.65 g/d in the 9- to 12-, 12- to 15-, or 15- to 18-wk phases, respectively. Due to the importance of P in nutrient management planning to address environmental concerns about water quality, more research is needed to confirm the dietary P needs of turkeys.

REFERENCES

Almquist, H. J. 1954. The phosphorus requirement of young chicks and poults—A review. Poult. Sci. 33:936–943.

ASAE. 1999. Shear and three-point bending test of animal bone. Pages 584–686 in ASAE Standards: Standards, Engineering Practices and Data. 46th ed. Society of Agricultural Engineers, St. Joseph, MI.

AOAC. 2000. Official Methods of Analysis. 17th ed. Association of Official Analytical Chemists. Arlington, VA.

Atia, F. A., P. E. Waibel, I. Hermes, C. W. Carlson, and M. M. Walser. 2002. Effect of dietary phosphorus, calcium, and phytase on performance of growing turkeys. Poult. Sci. 79:231– 239.

Bailey, C. A., S. Linton, R. Brister, and C. R. Creger. 1986. Effects of graded levels of dietary phosphorus on bone mineralization in the very young poult. Poult. Sci. 65:1018–1020.

Day, E. J., and B. C. Dilworth. 1962. Dietary phosphorus levels and calcium:phosphorus ratios needed by growing turkeys. Poult. Sci. 41:1324–1328.

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.

Hocking, P. M., G. W. Robertson, and C. Nixey. 2002. Effects of dietary calcium and phosphorus on mineral retention, growth, feed efficiency and walking ability in growing turkeys. Br. Poult. Sci. 43:607–614.

Latta, M., and M. Eskin. 1980. Phytate phosphorus determination. J. Agric. Food Chem. 28:1313–1315.

Ledoux, D. R., K. Zyla, and T. L. Veum. 1995. Substitution of phytase for inorganic phosphorus for turkey hens. J. Appl. Poult. Res. 4:157–163.

Lilburn, M. S. 1993. Skeletal growth of commercial poultry species. Poult. Sci. 73:897–903.

National Research Council. 1984. Nutrient Requirements of Poultry. 8th rev. ed. National Academy Press, Washington, DC.

National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.

Neagle, L. H., L. G. Blaylock, and J. H. Goihl. 1968. Calcium, phosphorus and vitamin D_3 levels and interactions in turkeys to 4 weeks of age. Poult. Sci. 47:174–180.

Roberson, K. D., and R. M. Fulton. 2000. Estimation of the calcium and phosphorus requirements of 4.5 to 12 kg commercial tom turkeys. Poult. Sci. 79(Suppl. 1):98. (Abstr.)

Sanders, A. M., H. M. Edwards, Jr., and G. N. Rowland III. 1992. Calcium and phosphorus requirements of the very young turkey as determined by response surface analysis. Br. J. Nutr. 67:421–435.

SAS Institute. 2000. SAS Online Doc. Version 8. SAS Institute Inc., Cary, NC.

Sullivan, T. W. 1962. Studies on the calcium and phosphorus requirements of turkeys, 8 to 20 weeks of age. Poult. Sci. 41:253–259.

Yan, F., J. H. Kersey, C. A. Fritts, and P. W. Waldroup. 2003. Phosphorus requirements of broiler chicks six to nine weeks of age as influenced by phytase supplementation. Poult. Sci. 82:294–300.