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Utilization of High Levels of Meat and Bone Meal in Broiler Diets[1]

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Primary Audience: Nutritionists, Veterinarians, Broiler Production Managers

Summary

Recent sanctions on feeding rendered animal by-products to ruminants may favor feeding high levels of meat and bone meal to broilers. Two samples of meat and bone meal (MBM) – low-ash = 25.87% ash; high-ash = 34.85% ash – were subjected to amino acid and proximate analysis, with digestible amino acid (DAA) and metabolizable energy content calculated. Each source was used to formulate diets in which the minimum DAA was 100% of NRC total amino acid content. The nonphytate phosphorus (NPP) content was increased in increments of 0.10%. Control diets utilized dicalcium phosphate to maintain either a constant 0.45% NPP or to provide levels of NPP recommended by NRC for different age broilers. Inclusion of MBM in broiler diets at levels higher than traditionally used (up to 12.98% of high-ash and 17.76% of low-ash meat and bone meal) had no adverse effects. However, the economics of protein sources as well as supplemental phosphorus sources must be considered. Increasing the level of MBM above that needed to provide adequate levels of NPP may be an environmental concern in some areas of poultry production.

Key words: Animal protein, meat and bone meal, phosphorus, protein sources
2000 J. Appl. Poultry Res. 9:131–141

Description of Problem

The NRC sets guidelines for nonphytate phosphorus (NPP) in broiler chicken diets [1]. Poultry nutritionists have long used meat and bone meal (MBM) in diets for broilers [2, 3, 4, 5, 6, 7]. The level of usage is generally controlled by the quantity of phosphorus required in the diet with inclusion levels of MBM seldom exceeding the amount needed to provide the minimum levels of this nutrient (approximately 5 to 10%). However, due to growing concerns about the possible transmission of bovine spongioform encephalophy (BSE) by means of feeding rendered animal by-products to ruminant animals and the recent sanctions on this practice in the United Kingdom and the United States [8], the economic aspect of feeding higher levels of MBM to poultry may result in an increase of the percentage.

The objectives of the present study were to examine the feasibility of utilizing higher than traditional levels of MBM in diets for broiler chickens, and to elucidate possible problems that might be associated with such a practice. Using two widely disparate MBM products (high ash-low protein; low ash-high protein), diets were formulated that provided levels of MBM greatly in excess of the amount required to meet the minimum phosphorus requirement. These diets were then used to grow broilers to market weights. Live performance was evaluated and skeletal development was assessed through bone ash measurements.

TABLE 1. Composition of basal diet for high phosphorus studies (Experiment 1)

INGREDIENT	g/kg
Yellow corn	543.54
Soybean meal	315.45
Poultry oil	58.34
DL-Methionine	3.03
Threonine	0.68
Lysine HCl	0.44
Trace minerals[A]	1.00
Broiler vitamins[B]	2.00
Salt	4.28
Variable[C]	71.24
Total	1000.00

[A]Provides per kg of diet: Mn (from $MnSO_4.H_2O$), 100 mg; Zn (from $ZnSO_4.7H_2O$), 100 mg; Fe (from $FeSO_4.7H_2O$), 50 mg; Cu (from $CuSO_4.5H_2O$), 10 mg; I (from $Ca(IO_3)_2.H_2O$), 1 mg.

[B]Provides per kg of diet: vitamin A (from vitamin A acetate), 7714 IU; cholecalciferol, 2204 IU; vitamin E, 16.53 IU; vitamin B_{12}, 0.013 mg; riboflavin, 6.6 mg; niacin, 39 mg; pantothenic acid, 10 mg; choline, 465 mg; menadione (from menadione dimethylpyrimidinol), 1.5 mg; folic acid, 0.9 mg; thiamine (from thiamine mononitrate), 1.54 mg; pyridoxine (from pyridoxine hydrochloride), 2.76 mg; d-biotin, 0.066 mg; ethoxyquin, 125 mg; Se, 0.1 mg.

[C]Variable amounts of ground limestone, dicalcium phosphate, and sand.

MATERIALS AND METHODS

EXPERIMENT 1

A preliminary experiment was conducted to evaluate the effects of high levels of phosphorus independent of the potential problems that might be associated with amino acid content and digestibility of meat and bone meal. A corn-soybean meal diet was formulated to provide 3080 ME kcal/kg with minimum requirements for total amino acids at 110% of NRC [1] recommendations, adjusted for the reduction in dietary energy (Table 1). The lower energy level was chosen so as not to have excessive amounts of supplemental fat in the diet. The non-mineral portion of the basal diet was mixed in a large lot, and aliquots were used to blend with limestone, dicalcium phosphate, and washed builder's sand to provide the desired levels of calcium and NPP.

For the experimental diets, graded levels of NPP ranged from 0.40 to 1.00% in increments of 0.10%. Two different series of diets were fed. In the first series, calcium was maintained at a minimum of 1.0%, while in the second series the calcium level was maintained at a Ca:NPP ratio of 2:1 (for NPP levels greater than 0.50%). This strategy resulted in a total of 12 test diets.

Male chicks of a commercial broiler strain were obtained from a local hatchery and randomly assigned to pens in electrically heated battery brooders with wire floors. Six chicks were assigned to each compartment; six replicate groups of chicks were fed each of the experimental diets. Replicate pens were assigned such that each tier of the battery was included among each treatment group.

The test diets and tap water were provided for *ad libitum* consumption from day of hatch to 21 days. Any bird that died during the study was weighed and the weight used to adjust the feed conversion ratio [FCR, figured as total feed consumed (weight of live birds + weight of dead birds)]. At 21 days, pen body weights and feed consumption were determined and two representative birds per pen were killed for bone ash determination [9]. Samples of the basal diet were subjected to calcium and phosphorus assay.

EXPERIMENT 2

Two lots of MBM were obtained from a major renderer and analyzed for proximate components and total amino acid content (Table 2). The amino acid values are a composite of results from three major laboratories that specialize in amino acid analysis of feedstuffs. Mean amino acid digestibility coefficients for MBM reported by Parsons *et al.* [10]

TABLE 2. Composition and estimated amino acid digestibility of low-ash and high-ash meat and bone meals

INGREDIENT	LOW-ASH	HIGH-ASH	DIGESTIBILITY[A]
	%		
Moisture	3.73	5.37	
Crude protein	57.93	47.08	
Crude fat	10.16	10.34	
Calcium	8.79	12.67	
Total phosphorus	4.34	5.91	
Ash	25.87	34.85	
Sodium	0.54	0.46	
Chloride	0.18	0.14	
Methionine	0.83	0.61	85.14
Cystine	0.50	0.41	57.71
Lysine	2.95	2.20	80.93
Tryptophan	0.31	0.24	ND
Threonine	1.75	1.34	80.14
Isoleucine	1.55	1.16	84.29
Histidine	1.02	0.70	75.64
Valine	2.31	1.85	84.50
Leucine	3.20	2.52	85.71
Arginine	4.23	3.47	87.14
Phenylalanine	1.80	1.42	86.57
Glycine	8.81	7.74	ND
Serine	2.02	1.66	ND

[A]Mean of values reported by Parsons et al. [10]; ND = not determined.

were applied to the total amino acid values to derive the estimated digestible amino acid content of the MBM samples. The metabolizable energy value of the MBM samples was estimated from their proximate composition using equations reported by Dale [11]. The NPP contents of the meat and bone meals were considered as equivalent to the total phosphorus content [12]. Nutrient values for corn and soybean meal were based on NRC recommendations. Diets were formulated with digestible amino acid requirements set at 100% of NRC [1] total amino acid requirements because most NRC total amino acid requirements were established using corn-soybean meal based diets which are approximately 90% digestible. This policy gives a reasonable margin of safety such as would be done in commercial practice.

Diets were formulated for starter (0 to 21 days), grower (21 to 42 days), and finisher (42 to 49 days) periods. Test diets began with 0.45% NPP with incremental increases of 0.10% up to 0.85% from either dicalcium phosphate, high-ash meal, or low-ash meal. In addition, a positive control diet was fed that utilized dicalcium phosphate as the primary P source and was formulated to provide the minimum NRC recommended level of NPP for the appropriate age. Diets were pelleted with steam; starter diets were crumbled. Composition of the diets appears in Tables 3, 4, and 5.

Day-old male chicks of a commercial strain were obtained from a local hatchery and randomly assigned to floor pens in a house of commercial design. Fifty chicks were placed in each of 48 pens (50 ft^2) with four pens assigned to each of the dietary treatments.

Body weight by pen and feed consumption were determined at 21, 42, and 49 days. Birds were checked twice daily for mortality with the weight used to adjust feed utilization. At these same ages, two randomly chosen birds from each pen were killed by CO_2 inhalation; the right tibia were removed and ash content of

TABLE 3. Composition (g/kg) and nutrient content of starter (0 to 21 days) diets with low-ash and high-ash meat and bone meal (MBM) (Experiment 2)

INGREDIENT	DIET #											
	1	2	3	4	5	6	7	8	9	10	11	12
Low-ash MBM	0.00	0.00	0.00	0.00	0.00	0.00	79.32	103.07	126.95	150.84	174.73	0.00
High-ash MBM	0.00	57.50	74.74	92.07	109.39	126.71	0.00	0.00	0.00	0.00	0.00	0.00
Yellow corn	565.19	601.05	599.15	587.80	576.47	565.11	611.55	614.36	607.34	599.65	591.75	565.19
Soybean meal	330.75	283.64	275.64	268.89	262.14	255.39	259.61	244.48	230.42	216.44	202.48	330.75
Poultry oil	59.35	39.96	37.64	38.78	39.92	41.07	31.55	26.06	24.22	22.62	21.02	59.35
Dicalcium phosphate	17.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.97
Ground limestone	13.45	4.66	0.00	0.00	0.00	0.00	5.64	0.33	0.00	0.00	0.00	13.45
DL-Methionine	3.35	3.39	3.36	3.34	3.32	3.31	3.29	3.23	3.18	3.13	3.09	3.35
Threonine	0.89	1.02	0.98	0.94	0.89	0.85	0.93	0.86	0.79	0.72	0.65	0.89
Lysine HCl	0.49	0.82	0.72	0.61	0.49	0.37	0.56	0.38	0.18	0.00	0.00	0.49
Salt	4.56	3.96	3.77	3.57	3.38	3.19	3.55	3.23	2.92	2.60	2.28	4.56
Constant[A]	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NUTRIENT CONTENT[B]												
CP, % (C)	21.61	22.27	22.64	23.01	23.38	23.74	22.98	23.59	24.17	24.76	25.36	21.61
CP, % (A)	21.56	21.72	22.06	23.34	23.68	24.12	22.56	23.00	23.63	24.65	25.78	21.56
Total P, % (C)	0.70	0.68	0.78	0.88	0.97	1.07	0.68	0.77	0.86	0.96	1.05	0.70
Total P, % (A)	0.68	0.66	0.76	0.85	0.98	1.06	0.62	0.78	0.82	0.93	1.01	0.68
Available P, % (C)	0.45	0.45	0.55	0.65	0.75	0.85	0.45	0.55	0.65	0.75	0.85	0.45
Ca, % (C)	1.00	1.00	1.04	1.25	1.47	1.69	1.00	1.00	1.19	1.40	1.60	1.00
Ca, % (A)	0.80	0.87	0.92	1.23	1.56	1.58	0.86	0.90	1.18	1.47	1.60	0.80

[A]Contains: 0.50 g/kg Sacox 60 (Hoechst-Roussel Agri-Vet Co., Somerville, NJ. Provides 60 g/lb salinomycin activity); 0.50 g/kg BMD-50 (Alpharma, Inc., Fort Lee, NJ. Provides 50 g/lb bacitracin methylene disalicylate activity); 2.0 g/kg vitamin premix [provides per kg of diet: vitamin A (from vitamin A acetate), 7714 IU; cholecalciferol, 2204 IU; vitamin E, 16.53 IU; vitamin B_{12}, 0.013 mg; riboflavin, 6.6 mg; niacin, 39 mg; pantothenic acid, 10 mg; choline, 465 mg; menadione (from menadione dimethylpyrimidinol), 1.5 mg; folic acid, 0.9 mg; thiamine (from thiamine mononitrate), 1.54 mg; pyridoxine (from pyridoxine hydrochloride), 2.76 mg; d-biotin, 0.066 mg; ethoxyquin, 125 mg; Se, 0.1 mg]; 1.0 g/kg trace mineral premix [provides per kg of diet: Mn (from $MnSO_4.H_2O$), 100 mg; Zn (from $ZnSO_4.7H_2O$), 100 mg; Fe (from $FeSO_4.7H_2O$), 50 mg; Cu (from $CuSO_4.5H_2O$), 10 mg; I (from $Ca(IO_3)_2.H_2O$), 1 mg].

[B]A = Analyzed value; C = Calculated value.

TABLE 4. Composition (g/kg) and nutrient content of grower (21 to 42 days) diets with low-ash and high-ash meat and bone meal (MBM) (Experiment 2)

INGREDIENT	DIET #											
	1	2	3	4	5	6	7	8	9	10	11	12
Low-ash MBM	0.00	0.00	0.00	0.00	0.00	0.00	80.37	104.19	128.07	151.96	175.85	0.00
High-ash MBM	0.00	58.27	75.56	92.88	110.20	127.53	0.00	0.00	0.00	0.00	0.00	0.00
Yellow corn	619.56	653.54	646.26	634.90	623.56	612.20	663.93	662.28	654.61	646.92	639.06	629.97
Soybean meal	285.31	243.67	236.47	229.72	222.97	216.22	219.54	204.90	190.91	176.93	162.96	283.71
Poultry oil	51.09	30.77	30.40	31.54	32.68	33.83	22.29	18.45	16.85	15.26	13.65	47.30
Dicalcium phosphate	18.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.84
Ground limestone	13.58	2.06	0.00	0.00	0.00	0.00	3.06	0.00	0.00	0.00	0.00	13.95
DL-Methionine	1.93	1.90	1.87	1.86	1.84	1.83	1.80	1.74	1.70	1.65	1.60	1.92
Threonine	0.97	1.00	0.95	0.91	0.87	0.83	0.90	0.83	0.76	0.69	0.62	0.98
Lysine HCl	0.74	0.85	0.74	0.63	0.51	0.39	0.58	0.40	0.20	0.01	0.00	0.77
Salt	4.55	3.94	3.75	3.56	3.37	3.17	3.53	3.21	2.90	2.58	2.26	4.56
Constant[A]	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NUTRIENT CONTENT[B]												
CP, % (C)	19.69	20.61	20.99	21.35	21.72	22.09	21.34	21.94	22.53	23.12	23.72	19.70
CP, % (A)	19.83	20.13	21.20	21.43	21.66	21.93	21.55	21.82	22.04	23.43	23.27	19.38
Total P, % (C)	0.69	0.68	0.77	0.87	0.96	1.06	0.67	0.76	0.86	0.95	1.04	0.59
Total P, % (A)	0.68	0.68	0.73	0.89	0.92	1.07	0.63	0.73	0.84	0.97	1.09	0.61
Available P, % (C)	0.45	0.45	0.55	0.65	0.75	0.85	0.45	0.55	0.65	0.75	0.85	0.35
Ca, % (C)	0.90	0.90	1.04	1.25	1.47	1.68	0.90	0.99	1.19	1.40	1.61	0.90
Ca, % (A)	0.84	0.84	0.85	1.34	1.34	1.73	1.04	0.77	1.25	1.31	1.79	0.97

[A]See Table 3.

[B]A = Analyzed value; C = Calculated value.

TABLE 5. Composition (g/kg) and nutrient content of finisher (42 to 49 days) diets with low-ash and high-ash meat and bone meal (MBM) (Experiment 2)

INGREDIENT	DIET #											
	1	2	3	4	5	6	7	8	9	10	11	12
Low-ash MBM	0.00	0.00	0.00	0.00	0.00	0.00	82.23	105.99	129.87	153.75	177.64	0.00
High-ash MBM	0.00	59.62	76.86	94.18	111.50	128.83	0.00	0.00	0.00	0.00	0.00	0.00
Yellow corn	687.07	720.22	717.96	706.60	695.26	683.91	730.85	733.64	726.57	718.90	711.15	704.02
Soybean meal	228.17	182.94	175.17	168.42	161.67	154.93	158.25	143.13	129.08	115.09	101.11	226.57
Poultry oil	40.65	21.21	18.97	20.12	21.26	22.40	12.54	7.05	5.22	3.63	2.03	34.21
Dicalcium phosphate	18.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.49
Ground limestone	13.73	4.60	0.00	0.00	0.00	0.00	5.62	0.31	0.00	0.00	0.00	12.99
DL-Methionine	1.22	1.22	1.19	1.18	1.16	1.14	1.12	1.06	1.01	0.97	0.92	1.19
Threonine	1.22	1.30	1.26	1.21	1.17	1.13	1.20	1.13	1.06	0.99	0.92	1.21
Lysine HCl	0.75	0.97	0.86	0.75	0.63	0.51	0.69	0.51	0.32	0.12	0.00	0.76
Salt	4.54	3.92	3.73	3.54	3.35	3.15	3.50	3.18	2.87	2.55	2.23	4.56
Constant[A]	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NUTRIENT CONTENT[B]												
CP, % (C)	17.31	18.12	18.51	18.88	19.24	19.61	18.87	19.48	20.07	20.66	21.25	17.37
CP, % (A)	16.78	18.62	18.81	18.93	19.44	19.67	19.44	19.71	19.92	21.01	21.64	17.42
Total P, % (C)	0.68	0.67	0.76	0.86	0.95	1.05	0.66	0.75	0.85	0.94	1.03	0.53
Total P, % (A)	0.64	0.71	0.79	0.89	0.99	1.16	0.68	0.76	0.85	1.03	0.97	0.83
Available P, % (C)	0.45	0.45	0.55	0.65	0.75	0.85	0.45	0.55	0.65	0.75	0.85	0.30
Ca, % (C)	0.90	0.90	1.00	1.26	1.47	1.69	1.00	1.00	1.19	1.40	1.61	0.80
Ca, % (A)	0.94	0.86	0.90	1.40	1.38	1.93	0.96	1.10	1.29	1.68	1.57	0.83

[A]See Table 3.

[B]A = Analyzed value; C = Calculated value.

dried, fat-free bone determined as described by AOAC [9]. At 21 and 42 days, cohort birds that had previously been fed the experimental diets were placed in battery cages with wire floors with continued feeding of the test diets. Fecal samples were collected for a 3-day period, freeze-dried, allowed to equilibrate to room temperature, and analyzed for phosphorus content. Samples of the mixed feeds were analyzed for crude protein, calcium, and total phosphorus.

Data were subjected to analysis of variance using the General Linear Models option of SAS [13] with pen means as the experimental unit. Where significant differences ($P \leq .05$) among treatments were observed, means were separated by repeated t-tests using the lsmeans option of SAS [13].

RESULTS AND DISCUSSION

EXPERIMENT 1

The effects of the various levels of NPP on body weight, feed conversion, mortality, and tibia ash appear in Table 6. Performance of broilers was not impaired by feeding diets containing up to 0.70% NPP when calcium levels were maintained at a minimum of 1%. At higher levels of NPP, body weight was gradually diminished although not always significantly so. Keeping a 2:1 calcium to available phosphorus ratio did not appear to be consistently beneficial.

Feed conversion also appeared to be impaired at the higher levels of phosphorus and especially in diets where the calcium:NPP ratio was maintained at 2:1. High levels of calcium are known to tie up fat in the intestine through the production of calcium soaps, reducing its availability to the chick and consequently reducing the available energy in the diet [14, 15].

Mortality was almost nonexistent in this study and was not influenced by dietary treatment. No significant differences in tibia ash content were observed, as all but one phosphorus level was in excess of the NRC [1] recommended level of NPP, based primarily upon maximizing tibia ash.

EXPERIMENT 2

Analysis of the experimental diets indicated that anticipated levels of calcium, total phosphorus, and crude protein were in close agreement with anticipated values (Tables 3, 4, and 5). The effects of feeding diets containing various levels of phosphorus from low-ash or high-ash MBM on body weight of broilers appear in Table 7. At 21 days, the

TABLE 6. Effects of high levels of phosphorus from dicalcium phosphate and calcium to nonphytate phosphorus (NPP) ratio of diets on performance of male broilers (Experiment 1)

NPP	TOTAL PHOSPHORUS	CALCIUM	21-DAY BODY WEIGHT	FEED:GAIN RATIO	MORTALITY	TIBIA ASH
%			g	g:g	%	
0.40	0.63	1.00	681[a]	1.365[cd]	0.03	46.33
0.50	0.73	1.00	696[a]	1.345[d]	0.00	46.86
0.60	0.83	1.00	688[a]	1.362[cd]	0.03	47.22
0.70	0.93	1.00	691[a]	1.360[cd]	0.03	47.17
0.80	1.03	1.00	646[ab]	1.346[d]	0.00	47.33
0.90	1.13	1.00	623[b]	1.439[a]	0.03	46.48
1.00	1.23	1.11	655[ab]	1.382[abcd]	0.03	47.28
0.60	0.83	1.20	662[ab]	1.370[bcd]	0.00	47.38
0.70	0.93	1.40	646[ab]	1.425[abc]	0.10	46.89
0.80	1.03	1.60	645[ab]	1.372[bcd]	0.00	46.84
0.90	1.13	1.80	651[ab]	1.436[ab]	0.00	47.11
1.00	1.24	2.00	653[ab]	1.444[a]	0.03	47.82
Probability>F			0.0005	0.039	0.32	0.17
SEM			20.8	0.024	0.04	0.55

[a–d]Means within columns with common superscripts do not differ significantly ($P \leq .05$).

TABLE 7. Effect of high levels of phosphorus from low-ash and high-ash meat and bone meal on body weight of male broilers

SOURCE AND NPP CONTENT OF DIET	21 DAYS	42 DAYS	49 DAYS
		g	
Corn-soy NRC[A]	704[cd]	2350	2990
Corn-soy constant 0.45%	710[cd]	2320	2930
High-ash constant 0.45%	762[ab]	2280	2900
High-ash constant 0.55%	757[b]	2370	2980
High-ash constant 0.65%	760[ab]	2330	2990
High-ash constant 0.75%	773[ab]	2420	3060
High-ash constant 0.85%	796[a]	2340	3000
Low-ash constant 0.45%	715[cd]	2530	2970
Low-ash constant 0.55%	681[d]	2280	2870
Low-ash constant 0.65%	737[bc]	2390	2950
Low-ash constant 0.75%	721[bc]	2330	2920
Low-ash constant 0.85%	706[cd]	2210	2840
Probability > F	0.0001	0.15	0.28
SEM	14	64	55

[A]NRC recommendation = 0.45% NPP for 0 to 21 days, 0.35% for 21 to 42 days, and 0.30% for 42 to 49 days.

[a–d]Means within columns with common superscripts do not differ significantly ($P \leq .05$).

body weight of chicks fed the diets containing the various levels of low-ash or high-ash MBM was equal or superior to that of broilers fed the control diets containing 0.45% NPP from dicalcium phosphate. At 42 and 49 days, no significant differences in body weight were noted among the various dietary treatments. There were no trends to suggest any depression in body weight as dietary phosphorus level increased from either type of MBM.

Table 8 lists the effects of feeding diets containing various levels of phosphorus from low-ash or high-ash MBM on feed utilization by broilers. In contrast to Experiment 1, inclusion of high levels of phosphorus did not impair feed utilization. This may have resulted from the fact that the increased levels of calcium that accompanied the higher phosphorus levels was provided primarily by the meat and bone meal and not by ground limestone that might be more reactive with the dietary fat supplement. At 21 days, the feed utilization of chicks fed the diets containing the various levels of low-ash or high-ash MBM was equal to or superior to that of broilers fed the control diets containing 0.45% NPP from dicalcium phosphate. At 42 and 49 days, no significant differences in feed utilization were noted among the various dietary treatments.

Mortality of broilers fed diets containing various levels of phosphorus from low-ash or high-ash MBM appears in Table 9. No significant differences in mortality among the various dietary treatments were noted at 21 days. Although significant differences in mortality were observed among the dietary treatments at 42 and 49 days, they followed no consistent trend in relation to either source or level of supplemental phosphorus. In comparison to the mortality of chicks fed the standard NRC levels, mortality among chicks fed the diets with low-ash or high-ash MBM was significantly higher only in the chicks fed the low-ash meat and bone meal to provide 0.65% NPP.

The tibia ash content of broilers fed diets containing various levels of phosphorus provided from low-ash or high-ash MBM appears in Table 10. No significant differences in tibia ash content among dietary treatments were noted at 21 or 49 days. At 42 days, the tibia ash of broilers fed diets containing higher levels

TABLE 8. Effect of high levels of phosphorus from low-ash and high-ash meat and bone meal on feed utilization of male broilers

SOURCE AND NPP CONTENT OF DIET	21 DAYS	42 DAYS	49 DAYS
	g feed:g gain)		
Corn-soy NRC[A]	1.539[a]	1.700	1.789
Corn-soy constant 0.45%	1.466[b]	1.683	1.744
High-ash constant 0.45%	1.362[cd]	1.672	1.695
High-ash constant 0.55%	1.351[d]	1.639	1.709
High-ash constant 0.65%	1.366[cd]	1.651	1.673
High-ash constant 0.75%	1.373[cd]	1.638	1.683
High-ash constant 0.85%	1.359[cd]	1.671	1.740
Low-ash constant 0.45%	1.424[bc]	1.692	1.721
Low-ash constant 0.55%	1.447[b]	1.619	1.631
Low-ash constant 0.65%	1.400[bcd]	1.635	1.696
Low-ash constant 0.75%	1.398[bcd]	1.631	1.720
Low-ash constant 0.85%	1.418[bcd]	1.643	1.643
Probability > F	0.0001	0.98	0.24
SEM	0.024	0.049	0.038

[A]NRC recommendation = 0.45% NPP for 0 to 21 days, 0.35% for 21 to 42 days, 0.30% for 42 to 49 days.

[a–d]Means within columns with common superscripts do not differ significantly ($P \leq .05$).

TABLE 9. Effect of high levels of phosphorus from low-ash and high-ash meat and bone meal on mortality of male broilers

SOURCE AND NPP CONTENT OF DIET	21 DAYS	42 DAYS	49 DAYS
	g		
Corn-soy NRC[A]	2.01	5.53[bcd]	7.03[bcd]
Corn-soy constant 0.45%	1.00	2.50[d]	3.48[d]
High-ash constant 0.45%	0.99	9.96[ab]	9.96[abc]
High-ash constant 0.55%	0.00	6.50[bcd]	7.00[bcd]
High-ash constant 0.65%	2.00	8.00[abc]	10.50[abc]
High-ash constant 0.75%	1.50	6.03[bcd]	11.05[abc]
High-ash constant 0.85%	0.00	7.03[bcd]	8.53[abcd]
Low-ash constant 0.45%	2.00	7.00[bcd]	11.00[abc]
Low-ash constant 0.55%	1.44	9.81[ab]	11.26[ab]
Low-ash constant 0.65%	1.00	12.09[a]	13.09[a]
Low-ash constant 0.75%	1.50	5.00[cd]	6.00[cd]
Low-ash constant 0.85%	1.00	6.00[bcd]	10.00[abc]
Probability > F	0.41	0.03	0.03
SEM	0.67	1.74	1.90

[A]NRC recommendation = 0.45% NPP for 0 to 21 days, 0.35% for 21 to 42 days, 0.30% for 42 to 49 days.

[a–d]Means within columns with common superscripts do not differ significantly ($P \leq .05$).

TABLE 10. Effect of high levels of phosphorus from low-ash and high-ash meat and bone meal on tibia ash of male broilers

SOURCE AND NPP CONTENT OF DIET	21 DAYS	42 DAYS	49 DAYS
	%		
Corn-soy NRC[A]	45.69	46.25[e]	48.93
Corn-soy constant 0.45%	46.60	46.77[cde]	48.77
High-ash constant 0.45%	47.09	47.56[abcde]	49.74
High-ash constant 0.55%	46.56	47.15[abcde]	49.24
High-ash constant 0.65%	46.92	48.05[abc]	49.46
High-ash constant 0.75%	47.00	48.26[ab]	50.11
High-ash constant 0.85%	46.73	48.17[abc]	50.03
Low-ash constant 0.45%	46.64	46.60[de]	48.70
Low-ash constant 0.55%	46.01	47.29[abcde]	49.57
Low-ash constant 0.65%	46.88	48.42[a]	49.84
Low-ash constant 0.75%	46.93	47.67[abcd]	49.12
Low-ash constant 0.85%	47.03	46.91[bcde]	48.82
Probability > F	0.88	0.045	0.44
SEM	0.59	0.49	0.27

[A]NRC recommendation = 0.45% NPP for 0 to 21 days, 0.35% for 21 to 42 days, 0.30% for 42 to 49 days.

[a–e]Means within columns with common superscripts do not differ significantly ($P \leq .05$).

of NPP from the two MBM sources tended to be significantly greater than that of chicks fed the NRC recommended levels of NPP, but this effect was not consistent.

The results of this study suggest that inclusion of MBM in broiler diets at levels higher than traditionally used (up to 12.98% of high-ash and 17.76% of low-ash MBM to provide up to 0.85% NPP) had no adverse effects on body weight, feed utilization, mortality, or tibia ash content at 21, 42, or 49 days of age, when diets were formulated on the basis of estimated digestible amino acid content. Economics of protein sources as well as supplemental phosphorus sources must be considered. Increasing the level of MBM above that needed to provide required levels of NPP will increase levels of phosphorus in the excreta (Table 11); this situation may be an environmental concern in some areas of poultry production.

TABLE 11. Effect of high levels of phosphorus from low-ash and high-ash meat and bone meal on tibia

SOURCE AND NPP CONTENT OF DIET	21 DAYS	42 DAYS
	%	
Corn-soy NRC[A]	1.21	1.58
Corn-soy constant 0.45%	1.29	1.58
High-ash constant 0.45%	1.47	2.11
High-ash constant 0.55%	2.03	2.31
High-ash constant 0.65%	2.31	2.46
High-ash constant 0.75%	2.72	2.70
High-ash constant 0.85%	2.72	2.94
Low-ash constant 0.45%	1.56	1.86
Low-ash constant 0.55%	1.76	2.15
Low-ash constant 0.65%	2.14	2.49
Low-ash constant 0.75%	2.43	2.82
Low-ash constant 0.85%	2.37	2.73

[A]NRC recommendation = 0.45% NPP for 0 to 21 days, 0.35% for 21 to 42 days, 0.30% for 42 to 49 days.

CONCLUSIONS AND APPLICATIONS

1. The incorporation of a low-ash (25.87%) or high-ash (34.85%) meat and bone meal into nutritionally balanced broiler diets to provide levels up to 0.85% nonphytate phosphorus had no detrimental effects on body weight, feed utilization, mortality, or tibia ash content of male broilers grown to 49 days of age.
2. Fecal phosphorus output increased with each incremental increase in dietary phosphorus and could be an environmental concern in some areas of intensive poultry production.
3. The economics of competing protein sources as well as supplemental phosphorus sources must be considered in application of these results.

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ACKNOWLEDGEMENTS

This study was supported by a grant from the Fats and Proteins Research Foundation.

Contribution of the meat and bone meal samples by Griffin Industries is greatly appreciated.