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July, 1996 #280

AVAILABILITY FOR POULTS OF PHOSPHORUS FROM MEAT AND BONE MEALS OF DIFFERENT PARTICLE SIZES[1]

Jerry L. Sell[2] and Martha J. Jeffrey
Department of Animal Science, Iowa State University, Ames, Iowa 50011-3150

ABSTRACT Two experiments were conducted to compare the dietary availability of P from meat and bone meal (MBM) with that of P from dicalcium phosphate (DP) for poults. Two batches of the same MBM were tested. The batches differed in fineness of grind; one was passed through a 10-mesh screen (openings of 2.03 mm) (MBM10) and the other through a 12-mesh screen (openings of 1.91 mm) (MBM12). In Experiments 1 and 2, the low-P basal diets contained, by analysis, 0.54% P (0.2% nonphytate P) and 0.64% P (0.3% nonphytate P), respectively. Each batch of MBM and DP were included in isocaloric, equinitrogenous diets to obtain increments of 0.1, 0.2, 0.3, and 0.4% P added to the basal diet. Three pens, each containing seven poults, were assigned to each of the 13 dietary treatments. Poults were fed the diets from 5 to 11 and 6 to 13 d of age in Experiments 1 and 2, respectively. Regression analyses of the data showed that increases in BW and tibia ash were linearly related ($P \leq 0.01$) to percentage dietary P and to quantity of P consumed. Common-intercept multiple linear regression was used to derive relative availabilities (RA) with DP assigned a value of 100. On the basis of BW gains, RA of MBM10 and MBM12 ranged from 99.1 to 105.5, depending on the independent variable and the experiment. Similarly, on the basis of tibia ash, RA ranged from 97.3 to 104.8. None of the RA differed ($P > 0.05$) from 100. Thus, the RA of P from MBM tested were equal to that of P from DP, and particle size of the MBM did not affect RA of P.

(*Key words*: turkey, phosphorus availability, dicalcium phosphate, meat and bone meal, tibia ash)

1996 Poultry Science 75:232–239

Received for publication June 16, 1995.
Accepted for publication October 10, 1995.
[1]Journal Paper Number J-16394 of the Iowa Agriculture and Home Economics Experiment Station, Ames, IA 50011. Project Number 3224.
[2]To whom correspondence should be addressed.

INTRODUCTION

Meat and bone meal has generally been considered to be a dietary source of readily available phosphorus for poultry (Waldroup *et al.*, 1965; Peeler, 1972). Results of earlier research on P utilization from bone meals obtained as by-products of the rendering industry supported this assumption. Miller and Joukovsky (1953) reported that, on the basis of weight gain and tibia ash of chickens, the bioavailability of P from bone meal was equal to that of P from dicalcium phosphate and defluorinated rock phosphate. These observations with chicks were supported by the findings of Motzok *et al.* (1956, 1957) that P utilization from several sources of bone meal was equivalent to that from dicalcium phosphate and monosodium phosphate. Wilcox *et al.* (1955) reported that, in comparison with dicalcium phosphate (USP), the availability of P from steamed bone meal was 95% for bone development and weight gains of turkeys fed practical diets: Wilcox *et al.* (1954) also reported that, when purified diets were used, P availability from steamed bone meal was 75% of that from dicalcium phosphate. Although the latter report indicated that ingredient composition of diet influenced utilization of P from bone meal, the preponderance of data obtained from research on P availability from bone meals, and presumably, from meat and bone meals, indicates that under normal circumstances meat and bone meals should be sources of available P for poultry. Recently, Waldroup and Adams (1994) provided information confirming these indications. They evaluated 11 meat and bone meals and found them to be equivalent to mono-dicalcium phosphate as dietary P sources for broiler chicks.

Concern about the availability of P from meat and bone meal was generated by reports of Burnell *et al.* (1989) and Cromwell (1989), indicating that as compared with the P from monosodium phosphate, P of meat and bone meal was less available for pigs. Orban and Roland (1992) also reported that utilization by chicks of P from laboratory-prepared bone meals was less than that from dicalcium phosphate. Orban and Roland (1992) and Cromwell (1989) suggested that large-particle bone fragments in the meals may have impaired P utilization by chicks and pigs, respectively.

The research reported here was conducted to determine the availability of P from a commercial meat and bone meal for young turkeys. Concurrently, a comparison was made of P availability from meat and bone meals passed through 10-mesh or 12-mesh screens during grinding.

MATERIALS AND METHODS

Two experiments of nearly identical design were conducted with male Nicholas poults obtained at 1 d of age from a commercial hatchery. The poults were placed in Petersime[3] brooder batteries and were fed a corn-soybean meal-based starter diet containing 0.5% nonphytate P (0.76% P) from 1 to 5 and from 1 to 6 d of age in Experiments 1 and 2, respectively. This diet was formulated to meet or slightly exceed nutrient concentrations recommended by NRC (1994). At the end of these pre-experimental periods, the poults were weighed individually, and seven poults were allotted to each of 39 pens in the brooder batteries so that average poult weights per pen and representation of poults from different body weight categories in each pen were similar.

Three sources of dietary P were compared in the two experiments: dicalcium phosphate (19.9% Ca, 19.0% P) and two meat and bone meals (MBM10 and MBM12). The MBM10 and MBM12 came from one processing batch and were obtained from a commercial supplier.[4] Laboratory analyses[5] showed that MBM10 and MBM12 contained 5.1% P, 10.4% Ca, and 54.4% CP. According to the supplier, they consisted of approximately 50% beef by-products and 50% poultry by-products. The beef by-product consisted of 30% bone and 70% offal and tissue. The meat and bone meal was processed through a batch cooker; 3.1 h for the poultry by-product, endpoint temperature = 121 C; 2.85 h for the beef by-product, endpoint temperature = 132 C. The mixture of by-products was passed through a grinder equipped with a 10-mesh screen (MBM10; openings of 2.03 mm) or a 12-mesh screen (MBM12; openings of 1.91 mm).

The three sources of P were used to establish three series of diets (13 total dietary treatments) in each experiment. In Experiment 1, dicalcium phosphate was used as a P source to obtain diets calculated to contain 0.2, 0.3, 0.4, 0.5, and 0.6 nonphytate P. The MBM10 and MBM12 were each used to establish another two-diet series by including increments of each meal in diets to achieve nonphytate P concentrations of 0.3, 0.4, 0.5, and 0.6%. Phosphorus contributed to diets by dicalcium phosphate, MBM10, or MBM12 was categorized as nonphytate P. Nonphytate P values listed by the NRC (1994) for corn and soybean meal also were used in formulating the diets. The dietary treatments were fed to poults from 5 to 11 d of age in Experiment 1. In Experiment 2, three series of dietary treatments also

[3]Petersime Incubator Co., Gettysburg, OH 45328-0308.
[4]Van Hoven Co., Inc., So. St. Paul, MN 55075.
[5]AGP Limited, Courtland, MN 56021.

were evaluated. However, because nearly 50% of the poults fed the diet containing the least concentration of P (0.2% nonphytate P) in Experiment 1 developed overt signs of rickets within the 6-d experimental period, the P concentrations used in Experiment 2 were increased by 0.1%. Thus, the diets of the dicalcium phosphate series contained nonphytate P concentrations of 0.3, 0.4, 0.5, 0.6, and 0.7%. The MBM10 and MBM12 series diets were formulated to provide 0.4, 0.5, 0.6, and 0.7% nonphytate P. In Experiment 2, the dietary treatments were fed from 6 to 13 d of age.

The composition of diets of Experiments 1 and 2 is shown in Tables 1 and 2. All diets were formulated to be isocaloric and equinitrogenous, to contain 1.2% calcium, and to meet or slightly exceed concentrations of other nutrients, except for P, recommended by the NRC (1994). All diets were analyzed for total P, and the results of these analyses together with the calculated total P values are shown in Table 3. In all instances, the analyzed total P concentrations were slightly greater than the calculated values.

Each of the 13 dietary treatments tested in Experiments 1 and 2 was assigned to three pens located in brooder batteries. Each pen contained seven poults. When the poults were 11 and 13 d old in Experiments 1 and 2, respectively, body weight and feed consumption data were recorded. Two poults were selected randomly from each pen. The two poults per pen were euthanatized by inhalation of Halothane[6] (1, 1, 1-trifluoro-2, 2-chlorobromoethane), and the left tibia of each poult was excised and cleaned of adhering tissue. Two tibias per pen were pooled and dried at 85 C for 24 h in an air convection oven. Dried tibias were extracted with ethyl ether in a Goldfisch extractor for 4 h, dried, and weighed. The extracted tibias were ashed in a muffle furnace at 600 C for 18 h, cooled in a desiccator, and weighed. Percentage tibia ash was calculated as a proportion of fat-extracted dry tibia weight.

Feed consumption data and analyzed P concentrations of diets were used to calculate the average P consumed per poult during the experimental periods. Regression analyses were conducted by using the General Linear Models procedure of SAS® (SAS Institute, 1985). The availabilities of P from MBM10 and MBM12 were determined relative to dicalcium phosphate by using common-intercept multiple linear regression analyses (Finney, 1978). Common-intercept multiple linear regression (slope-ratio) was performed on weight gain and percentage tibia ash as functions of percentage dietary total P (analyzed) or as functions of P consumed per poult. Multiple linear regression was justified for each experiment by performing simple linear regression followed by significance of differences tests between intercepts. In all instances, intercepts were not different ($P > 0.05$), and thus the use of common-intercept multiple linear regression was justified.

Procedures used in these experiments were approved by the Laboratory Animal Care Committee, Iowa State University.

[6]Halocarbon Laboratories, River Edge, NJ 07661.

TABLE 1. Composition of diets containing phosphorus from dicalcium phosphate or meat and bone meal, Experiment 1

	Total phosphorus concentration of dicalcium phosphate diets					Total phosphorus concentration of meat and bone meal diets			
Ingredients and analysis	0.48%	0.58%	0.68%	0.78%	0.88%	0.57%	0.66%	0.76%	0.85%
	(%)								
Corn (7.07% CP)	37.38	36.95	36.51	36.07	35.64	38.85	40.35	41.84	43.38
Soybean meal (46.6% CP)	55.46	55.53	55.60	55.66	55.73	52.85	50.23	47.61	44.93
Animal-vegetable fat	3.41	3.56	3.71	3.87	4.02	3.06	2.71	2.36	1.99
Limestone	2.76	2.43	2.11	1.78	1.45	2.20	1.63	1.07	0.51
Dicalcium phosphate (19.9% Ca, 19% P)	0.16	0.70	1.24	1.79	2.33	0.16	0.16	0.16	0.16
Mineral premix[1]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix[2]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine (98%)	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19
L-lysine-HCl	...	...	...	...	...	...	...	...	0.03
StaFac®[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Meat and bone meal[4]	...	...	...	...	...	2.04	4.08	6.12	8.16
Analysis									
ME, kcal/kg	2,850	2,850	2,850	2,850	2,850	2,850	2,850	2,850	2,850
CP, analyzed	28.8	28.7	29.2	29.1	29.1	29.4	29.0	28.8	28.9
Lys	1.76	1.77	1.77	1.77	1.77	1.74	1.72	1.70	1.70
Met	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63
SAA	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Ca, analyzed	1.24	1.22	1.24	1.24	1.23	1.20	1.23	1.21	1.21
Nonphytate P	0.20	0.30	0.40	0.50	0.60	0.30	0.40	0.50	0.60

[1]Supplied per kilogram of diet: manganese, 70 mg; zinc, 40 mg; copper, 6 mg; selenium, 0.15 mg; sodium chloride, 2.60 g.

[2]Supplied per kilogram of diet: vitamin A (retinyl acetate), 5,000 IU; cholecalciferol, 1,500 IU; dl-α-tocopheryl acetate, 12 IU; vitamin B_{12}, 11 μg; vitamin K (menadione sodium bisulfite), 1.8 mg; riboflavin, 2.7 mg; pantothenic acid, 7 mg; niacin, 75 mg; choline, 509 mg; folic acid, 0.55 mg; biotin, 75 μg.

[3]Contributed 44 mg virginiamycin/kg of diet: SmithKline Beecham, Exton, PA 19341.

[4]Van Hoven Co., Inc., So. St. Paul, MN 55075.

TABLE 2. Composition of diets containing phosphorus from dicalcium phosphate or meat and bone meal, Experiment 2

Ingredients and analysis	Total phosphorus concentration of dicalcium phosphate diets					Total phosphorus concentration of meat and bone meal diets			
	0.58%	0.67%	0.77%	0.86%	0.96%	0.67%	0.76%	0.85%	0.95%
	(%)								
Corn (6.7% CP)	37.98	37.50	37.00	36.51	36.02	39.55	41.06	42.61	44.15
Soybean meal (46.9% CP)	55.29	55.35	55.44	55.51	55.58	52.62	49.97	47.31	44.65
Animal-vegetable fat	2.70	2.88	3.06	3.24	3.42	2.30	1.92	1.53	1.14
Limestone	2.49	2.20	1.91	1.62	1.33	1.92	1.36	0.80	0.23
Dicalcium phosphate (19.9% Ca, 19% P)	0.68	1.21	1.74	2.26	2.79	0.68	0.68	0.68	0.68
Mineral premix[1]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix[2]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine (98%)	0.19	0.19	0.19	0.20	0.20	0.20	0.21	0.21	0.22
L-lysine·HCl	0.02	0.02	0.01	0.01	0.01	0.04	0.07	0.09	0.12
StaFac®[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Meat and bone meal[4]	...	...	...	...	...	2.04	4.08	6.12	8.16
Analysis									
ME_n, kcal/kg	2,850	2,850	2,850	2,850	2,850	2,850	2,850	2,850	2,850
CP, analyzed	29.2	29.6	30.0	29.4	29.5	29.3	29.5	29.7	29.4
Lys	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Met	0.61	0.61	0.61	0.61	0.61	0.62	0.62	0.63	0.64
SAA	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Ca, analyzed	1.20	1.25	1.22	1.21	1.22	1.12	1.22	1.24	1.21
Nonphytate P	0.30	0.40	0.50	0.60	0.70	0.40	0.50	0.60	0.70

[1]Supplied per kilogram of diet: manganese, 70 mg; zinc, 40 mg; copper, 6 mg; selenium, 0.15 mg; sodium chloride, 2.60 g.

[2]Supplied per kilogram of diet: vitamin A (retinyl acetate), 5,000 IU; cholecalciferol, 1,500 IU; dl-α-tocopheryl acetate, 12 IU; vitamin B_{12}, 11 μg; vitamin K (menadione sodium bisulfite), 1.8 mg; riboflavin, 2.7 mg; pantothenic acid, 7 mg; niacin, 75 mg; choline, 509 mg; folic acid, 0.55 mg; biotin, 75 μg.

[3]Contributed 44 mg virginiamycin/kg of diet; SmithKline Beecham, Exton, PA 19341.

[4]Van Hoven Co., Inc., So. St. Paul, MN 55075.

TABLE 3. Calculated and determined phosphorus concentrations of diets, Experiments 1 and 2

Diet code	Phosphorus source	Total dietary phosphorus			
		Experiment 1		Experiment 2	
		Calculated	Determined	Calculated	Determined
		(%)			
A	Dicalcium phosphate	0.48	0.54	0.58	0.68
B		0.58	0.64	0.67	0.76
C		0.68	0.75	0.77	0.84
D		0.78	0.84	0.86	0.90
E		0.88	0.95	0.96	1.00
F	Meat and bone meal 10[1]	0.57	0.63	0.67	0.75
G		0.66	0.74	0.76	0.86
H		0.76	0.81	0.85	0.96
I		0.85	0.91	0.95	1.02
J	Meat and bone meal 12[2]	0.57	0.62	0.67	0.76
K		0.66	0.72	0.76	0.85
L		0.76	0.81	0.85	0.92
M		0.85	0.89	0.94	0.99

[1]Meat and bone meal passed through a 10-mesh screen (openings of 2.03 mm) during grinding. Analyzed to contain 5.14% P.

[2]Meat and bone meal passed through a 12-mesh screen (openings of 1.91 mm) during grinding. Analyzed to contain 5.14% P.

RESULTS

Body weight, body weight gain, feed consumption, and tibia ash data for Experiments 1 and 2 are presented in Tables 4 and 5, respectively. In Experiment 1, overt signs of rickets (crippling and very pliable bones) were observed among poults fed the diet containing the lowest P concentration (0.54%). These signs were not evident in treatment groups receiving 0.64% or more P in Experiment 1 or 0.68% or more P in Experiment 2.

Regression analyses showed that, within each dietary P source, body weight gain and percentage tibia ash were linearly related to increments of dietary P concentration and to increments of P consumed per poult during each experiment. The results of common-intercept multiple linear regression analyses performed

TABLE 4. Influence of dietary phosphorus from dicalcium phosphate or meat and bone meal on weight gain and tibia ash of poults, Experiment 1

Source of P	Dietary total P[1]	Feed consumed	P consumed	11-d BW[2]	BW gain 5 to 11 d[3]	Tibia ash[4]
	(%)	(g/poult)				(%)
Dicalcium phosphate	0.54	146[5]	0.76	220	107	27.7[6]
	0.64	163	1.02	245	133	32.3
	0.75	172	1.29	260	147	36.2
	0.84	176	1.53	270	156	42.3
	0.95	186	1.80	275	162	45.0
Meat and bone meal 10[7]	0.63	158	1.04	242	129	31.0
	0.74	166	1.27	253	139	34.4
	0.81	177	1.49	267	154	39.6
	0.91	175	1.57	268	155	43.0
Meat and bone meal 12[8]	0.62	166	1.08	248	134	30.1
	0.72	164	1.20	248	135	34.0
	0.81	169	1.40	258	146	38.9
	0.89	181	1.61	271	157	42.6
SEM	. . .	3.2	0.024	3.4	3.3	0.96

[1]Total phosphorus as determined by analysis.

[2]Average BW per poult at the start of the experiment (5 d of age) ranged from 112 to 114 g among pens.

[3]Multiple linear regression equations of BW gain as a function of percentage dietary phosphorus or P consumed per poult are presented in Table 6.

[4]Multiple linear regression equations of tibia as a function of percentage dietary P or P consumed per poult are presented in Table 6.

[5]Means of three pens of seven poults per pen.

[6]Means of three pens, with representation by two poults per pen.

[7]Meat and bone meal passed through a 10-mesh screen (openings of 2.03 mm) during grinding. Analyzed to contain 5.14% P.

[8]Meat and bone meal passed through a 12-mesh screen (openings of 1.91 mm) during grinding. Analyzed to contain 5.14% P.

TABLE 5. Influence of dietary phosphorus from dicalcium phosphate or meat and bone meal on weight gain and tibia ash of poults, Experiment 2

Source of P	Dietary total P[1]	Feed consumed	P consumed	13-d BW[2]	BW gain 6 to 13 d[3]	Tibia ash[4]
	(%)	(g/poult)				(%)
Dicalcium phosphate	0.68	190[5]	1.24	261	138	31.3[6]
	0.76	202	1.50	272	148	36.0
	0.84	207	1.72	293	170	40.9
	0.90	217	2.00	302	178	43.1
	1.00	229	2.29	319	195	45.9
Meat and bone meal 10[7]	0.75	200	1.44	281	158	35.9
	0.86	211	1.78	297	173	40.5
	0.96	211	1.94	307	184	44.2
	1.02	226	2.24	318	194	46.2
Meat and bone meal 12[8]	0.76	198	1.46	275	152	37.1
	0.85	213	1.77	297	173	41.8
	0.92	221	2.01	308	185	44.2
	0..99	226	2.26	320	197	45.8
SEM	. . .	3.6	0.033	4.4	4.2	0.52

[1]Total P as determined by analysis.

[2]Average BW per poult at the start of the experiment (6 d of age) ranged from 123 to 124 g among pens.

[3]Multiple linear regression equations of BW gain as a function of percentage dietary P or P consumed per poult are presented in Table 6.

[4]Multiple linear regression equations of tibia as a function of percentage dietary P or P consumed per poult are presented in Table 6.

[5]Means of three pens of seven poults per pen per dietary treatment.

[6]Means of three pens, with representation by two poults per pen, per dietary treatment.

[7]Meat and bone meal passed through a 10-mesh screen (openings of 2.03 mm) during grinding. Analyzed to contain 5.14% P.

[8]Meat and bone meal passed through a 12-mesh screen (openings of 1.91 mm) during grinding. Analyzed to contain 5.14% P.

on body weight gain and percentage tibia ash as functions of percentage dietary total P or P consumed per poult are shown in Table 6. The regression coefficients obtained for each dependent variable within each experiment were used to estimate the relative availabilities (RA) of P from MBM10 and MBM12, compared with that of P from dicalcium phosphate, with the latter set at 100. In Experiment 1, the RA of P from MBM10 and MBM12 ranged from 97.3 to 101, depending on whether weight gain or tibia ash was the criterion and whether dietary P concentration or P consumed per poult was the independent variable (Table 7). None of these values differed significantly ($P \leq 0.05$) from 100. The RA of P from the meat and bone meals obtained in Experiment 2 ranged from 102.1 to 105.5, compared with 100 for the P from dicalcium phosphate, and no significant ($P \leq 0.05$) differences among these RA were detected. The composite averages of all RA values, irrespective of criteria, independent variable, and experiment, were 101.4 and 101.2 for MBM10 and MBM12, respectively.

DISCUSSION

The data obtained from the two experiments reported here show clearly that young turkeys utilized the P from meat and bone meal for weight gain and deposition of tibia ash as efficiently as from dicalcium phosphate. Also, the particle size of the different meat and bone meal samples did not affect this efficiency of phosphorus utilization. These observations disagree with those of Burnell *et al.* (1989), who reported that P availability from meat and bone meal for young pigs was only 64%

TABLE 6. Multiple linear regressions of weight gain and tibia ash as functions of dietary phosphorus concentration (DPHOS) or phosphorus consumed (PCON)

Experiment	Dependent variable (Y)	Independent variable (X)[1]	Regression equation
1	Weight gain, g	DPHOS, %	$Y = 55.4 + 115.6\ (\pm 9.9)\ X_1 + 114.6\ (\pm 9.9)\ X_{10} + 114.7\ (\pm 10.0)\ X_{12}$, $R^2 = 0.80$ ($P < 0.001$)
2			$Y = 38.6 + 153.6\ (\pm 10.6)\ X_1 + 159\ (\pm 10.2)\ X_{10} + 158.7\ (\pm 10.2)\ X_{12}$, $R^2 = 0.88$ ($P < 0.001$)
1		PCON, g/poult	$Y = 75.4 + 51.8\ (\pm 3.7)\ X_1 + 52.3\ (\pm 3.8)\ X_{10} + 51.9\ (\pm 3.8)\ X_{12}$, $R^2 = 0.86$ ($P < 0.001$)
2			$Y = 74.0 + 52.7\ (\pm 2.7)\ X_1 + 55.6\ (\pm 2.6)\ X_{10} + 55\ (\pm 2.6)\ X_{12}$, $R^2 = 0.93$ ($P < 0.001$)
1	Tibia ash, %	DPHOS, %	$Y = 3.1 + 45\ (\pm 2.2)\ X_1 + 43.8\ (\pm 2.1)\ X_{10} + 43.8\ (\pm 2.2)\ X_{12}$, $R^2 = 0.93$ ($P < 0.001$)
2			$Y = 7.8 + 38.3\ (\pm 1.8)\ X_1 + 39.1\ (\pm 1.7)\ X_{10} + 39.5\ (\pm 1.7)\ X_{12}$, $R^2 = 0.94$ ($P < 0.001$)
1		PCON, g/poult	$Y = 12.3 + 19.1\ (\pm 1.2)\ X_1 + 18.9\ (\pm 1.2)\ X_{10} + 18.6\ (\pm 1.3)\ X_{12}$, $R^2 = 0.88$ ($P < 0.001$)
2			$Y = 17.6 + 12.5\ (\pm 0.7)\ X_1 + 13.0\ (\pm 0.7)\ X_{10} + 13.1\ (\pm 0.7)\ X_{12}$, $R^2 = 0.91$ ($P < 0.001$)

[1]X_1 = dicalcium phosphate, X_{10} = meat and bone meal passed through a 10-mesh screen, and X_{12} = meat and bone meal passed through a 12-mesh screen.

TABLE 7. Relative availabilities (RA) of phosphorus from meat and bone meals, compared with dicalcium phosphate (DP)

Experiment	Phosphorus source	RA[1] on basis of dietary phosphorus concentration		RA[1] on basis of phosphorus consumed	
		Weight gain	Tibia ash	Weight gain	Tibia ash
		(%)		(g/poult)	
1	DP	100	100	100	100
	MBM10[2]	99.1	97.3	101	99
	MBM12[3]	99.2	97.3	100.2	97.4
2	DP	100	100	100	100
	MBM10	103.5	102.1	105.5	104
	MBM12	103.3	103.1	104.4	104.8

[1]Relative availabilities (RA) within each criteria and experiment were determined using common-intercept multiple linear regression and slope ratio method. No differences in RA ($P < 0.05$) among dietary phosphorus were observed.

[2]Meat and bone meal passed through a 10-mesh screen (openings of 2.03 mm) during grinding. Analyzed to contain 5.14% P.

[3]Meat and bone meal passed through a 12-mesh screen (openings of 1.91 mm) during grinding. Analyzed to contain 5.14% P.

of that from monosodium phosphate. These researchers also reported that 30% of the P of the meat and bone meal evaluated was found in particles ≥ 4 mm. Burnell *et al.* (1989) and Cromwell (1989) suggested that bone particles of relatively large size caused the relatively low availability of P from this source, although Gillis *et al.* (1951), working with chicks, observed that particle size of defluorinated rock phosphate did not influence P utilization unless the phosphate source was relatively insoluble in weak acid. The meat and bone meal evaluated in the current study had been ground to pass through screens with openings of 1.91 or 2.03 mm. Thus, few bone fragments in this meal would have been 4 mm or more in size. However, particle sizes of bone fragments were not measured in the current study.

The results of the current study agree with those of Waldroup *et al.* (1965) that P availability from meat and bone meal for chicks was 102% of that of P from monosodium phosphate or dicalcium phosphate. The results also agree with a more recent report by Waldroup and Adams (1994) showing that P from 11 different meat and bone meals was as available for chicks as was P from mono-dicalcium phosphate. The meat and bone meals evaluated by Waldroup and Adams (1994) differed in species sources of by-product materials and were processed by a variety of processing systems.

Data reported here show that the phosphorus of meat and bone meal obtained after passing through either 10-mesh or 12-mesh screens was as available to young turkeys as P from dicalcium phosphate. Most processors of meat and bone use 10-mesh screens in preparing meat and bone meals as a feed ingredient (G. G. Pearl, 1994, Fats and Proteins Research Foundation, Inc., RR 2, Box 298, Bloomington, IL 61704, personal communication). Consequently, satisfactory availability of P for poults from most commercial sources of meat and bone meals would be expected.

ACKNOWLEDGMENTS

The research reported was supported, in part, by the Fats and Proteins Research Foundation, Inc., Bloomington, IL 61704. The L-lysine and DL-methionine were kindly provided by Nutri-Quest Inc., Chesterfield, MO 63017, and DeGussa Corp., Allendale, NJ 07401, respectively. Feed Energy, Inc., Des Moines, IA 50318, contributed the animal-vegetable fat, and vitamins were supplied by Roche Vitamins and Fine Chemicals, Ames, IA 50010. The assistance of D. Baker, University of Illinois, Urbana, IL 61801, with the statistical procedures is acknowledged. The technical assistance of Adrizal, T. Applegate, W. Larson, P. Palo, M. Soto-Salanova, J. Tjelta, and K. Turner and the assistance of M. Cochran in preparation of the manuscript are gratefully acknowledged.

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