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Evaluation of the Nutrient Matrix Values for Phytase in Broilers

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Primary Audience: Nutritionists

SUMMARY

Microbial phytase has been shown to increase the availability of Ca, P, ME, and amino acids (AA) in diets for broilers. However, much more research has been conducted on the Ca and P effects than on the ME and AA effects. Therefore, 2 experiments were conducted to evaluate the effect of phytase on the release of ME and AA from corn-soybean meal diets for broilers. Experiment 1 was a battery study that lasted for 14 d and included diets adequate in all nutrients, diets deficient in ME and AA, and these later 2 diets with and without added phytase. Experiment 2 was a floor-pen study that lasted 42 d and included diets with reduced levels of ME and AA with added phytase. Growth performance, meat quality, and tibia ash were not affected by using the ME and AA values for phytase. Total P, soluble P, and inorganic soluble P in the litter were reduced when phytase was added to the diets. These data indicate that ME and AA values for phytase can be used in diet formulations for broilers with no loss in growth or yield performance, but a decrease in the P content of the litter will be observed.

Key words: phytate, soybean meal, phosphorus, nutrient matrix

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DESCRIPTION OF PROBLEM

Phytate has been shown to bind to cations, including Ca, Zn, Cu, Pb, Mn, Mg, Co, and Fe [1]. It also has been shown to have negative effects on digestive enzymes [2], protein [3], amino acid (AA) [4], and carbohydrate [5] availability. Phytate is found in feed ingredients, such as corn (C) and soybean meal (SBM), and it can cause a decrease in nutrient availability in diets containing these ingredients.

Microbial phytase has been shown to increase the availability of phytate P for swine and poultry [6, 7]. Phytase also has been shown to increase energy [8, 9] and AA [10, 11, 12] digestibility in diets for poultry. The amount of Ca and available P (aP) that phytase releases has been studied extensively [13, 14, 15], and the values range from approximately 0.09 to 0.10%. However, to fully realize the economic potential of phytase, the amount of ME and AA released by phytase needs to be evaluated. The nutrient matrix values for phytase indicates the amount of a nutrient (Ca, P, ME, or AA) that will be released when phytase is added to the diet. Having correct nutrient matrix values allows for more accurate formulation of diets that include phytase. These formulations allow the producer to add less Ca, P, AA, and ME in diets for poultry, thus, reducing the cost of feed. For example, adding phytase in the diets for poultry can reduce the amount of limestone,

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TABLE 1. Nutrient matrix values of Natuphos 1200 for broilers[A]

Nutrient	Value	Amount provided in the diet
Available phosphorus, %	188	0.094
Calcium, %	188	0.094
Crude protein, %	427	0.214
Lysine, %	29	0.015
Methionine, %	5	0.003
Cystine, %	10	0.005
Sulfur amino acids, %	15	0.008
Tryptophan, %	5	0.003
Threonine, %	24	0.012
Valine, %	26	0.013
Isoleucine, %	22	0.011
Leucine, %	33	0.017
Arginine, %	16	0.008
Phenylalanine, %	21	0.011
Histidine, %	11	0.006
ME, kcal/kg	61,937	30.969

[A]Natuphos 1200 was added at 0.05% of the diet, which provided 600 FTU (phytase units)/kg. Amino acids are on a true digestible basis.

monocalcium phosphate, SBM, crystalline AA, and fat added in the diets.

As a result of the aforementioned effects of phytase on nutrient availability, phytase also may have positive effects on the environment. This increased availability results in less P and N in the feces and less to be placed on soil, when poultry waste is used as a fertilizer. To fully utilize and receive the benefits of the addition of phytase to the diets, the objective of these experiments (EXP) was to evaluate the nutrient matrix values for phytase in broilers.

MATERIALS AND METHODS

General

All methods used in these EXP were approved by the Louisiana State University Agricultural Center (LSU) Animal Care and Use Committee. Two EXP were conducted with Ross × Ross commercial broilers (EXP 1) [16] or (EXP 2) [17] to evaluate the accuracy of the nutrient matrix values for Natuphos 1200 [18] (Table 1).

Experiment 1

In EXP 1, broilers were fed the same diet (C-SBM in Tables 2 and 3) adequate in all nutrients from 0 to 4 d posthatching [19]. They were held overnight without feed and water on the day before allotment to treatment. The broilers were then weighed, wingbanded, and allotted to treatments in a completely randomized design. There were 7 replications (4 male and 3 female) with 6 broilers per replication. The initial and final BW were 72 and 574 g, respectively, and the EXP lasted 14 d. They were housed in thermostatically controlled starter batteries with raised wire floors and continuous lighting. Feed and water were offered ad libitum throughout the experimental period. At the end of the experiment, all broilers were weighed individually, and pen feed intake was measured.

TABLE 2. Description of diets used in experiment 1

Treatment	Description[A]
1	C-SBM control diet
2	C-SBM deficient in AA
3	C-SBM diet deficient in AA but with added phytase at 600 FTU/kg using the matrix values for Ca, aP, and AA
4	As diet 3 with no added phytase
5	C-SBM diet low in ME
6	C-SBM diet low in ME but with added phytase at 600 FTU/kg using the matrix values for Ca, aP, and ME
7	As diet 6 with no added phytase

[A]C-SBM = corn-soybean meal; AA = amino acids; FTU = phytase units; aP = available P.

Diets 1 to 4 (Table 3) evaluated the AA matrix values of Natuphos 1200. Diet 1 (basal) was adequate in all nutrients. Diet 2 (LAA) was deficient in AA, providing 0.82% true digestible Lys, and all other AA met or exceeded the ratio to Lys [20]. Diet 3 (LAA+Phy) was similar to diet 2 but formulated with phytase nutrient matrix values for AA, Ca, and aP. Diet 4 (LAA-Phy) was similar to diet 3 but with supplemental Ca and P to reach adequate levels and no added phytase. Diet 1 and diets 5 to 7 evaluated the energy matrix value of Natuphos 1200 (Table 3). Diet 5 (LME) was low in energy, providing 2,937 kcal ME/kg. Diet 6 (LME+Phy) was similar to diet 5 but formulated with phytase nutrient matrix values for energy, Ca, and aP. Diet 7 (LME-Phy) was similar to diet 6 but with supplemental Ca and

TABLE 3. Composition of diets for experiment 1[A]

Diet Ingredient	1 Basal	2 LAA	3 LAA+Phy	4 LAA-Phy	5 LME	6 LME+Phy	7 LME-Phy
Corn	52.47	66.53	67.23	67.23	56.72	56.72	56.72
Soybean meal (47.5% CP)	36.85	24.83	24.24	24.24	36.53	36.53	36.53
Soy oil	6.46	4.34	4.24	4.24	1.00	1.00	1.00
Monocalcium phosphate	1.52	1.61	1.16	1.61	1.51	1.06	1.51
Limestone	1.66	1.72	1.65	1.72	1.66	1.59	1.66
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral premix[B]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[C]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Choline chloride[D]	—	0.04	0.04	0.04	—	—	—
DL-Methionine	0.19	0.08	0.08	0.07	0.18	0.18	0.18
Rice hulls	0.05	0.05	—	0.05	0.05	—	0.05
Phytase[E]	—	—	0.05	—	—	0.05	—
Cornstarch	—	—	—	—	1.55	0.78	0.78
Sand	—	—	0.51	—	—	1.29	0.78
Calculated composition[F]							
ME, kcal/kg	3,200	3,200	3,200	3,200	2,937	2,937/(2,906)	2,906
Crude protein, %	22.44	17.74	17.73/(17.51)	17.51	22.65	22.65	22.65
Lysine, %	1.12	0.82	0.82/(0.81)	0.81	1.12	1.12	1.12
Sulfur amino acids, %	0.81	0.59	0.59/(0.58)	0.58	0.81	0.81	0.81
Threonine, %	0.76	0.60	0.60/(0.59)	0.59	0.76	0.76	0.76
Valine, %	0.96	0.77	0.77/(0.76)	0.76	0.97	0.97	0.97
Tryptophan, %	0.24	0.18	0.18/(0.18)	0.18	0.24	0.24	0.24
Isoleucine, %	0.86	0.66	0.66/(0.65)	0.65	0.86	0.86	0.86
Calcium, %	1.00	1.00	1.00/(0.91)	1.00	1.00	1.00/(0.91)	1.00
Available phosphorus, %	0.45	0.45	0.45/(0.45)	0.45	0.45	0.45	0.45
Total phosphorus, %	0.72	0.70	0.70/(0.61)	0.70	0.73	0.73/(0.64)	0.73

[A]Amino acids (AA) formulated on a true digestible basis. LAA = corn-soybean meal (C-SBM) diet low in AA; LAA+Phy = C-SBM diet low in AA but with 600 FTU (phytase units)/kg; LAA-Phy = the LAA+Phy diet without phytase but with adequate Ca and aP; LME = C-SBM diet low in ME; LME+Phy = C-SBM diet low in ME but with 600 FTU/kg; LME-Phy = the LME+Phy diet without phytase but with adequate Ca and aP.

[B]Provided the following per kilogram of diet: Fe, 50 mg; Mn, 100 mg; Cu, 7 mg; Se, 0.15 mg; Zn, 75 mg; I, 1 mg, as ferrous sulfate monohydrate, manganese sulfate, copper sulfate, sodium selenite, zinc sulfate, ethylenediamine dihydriodide, respectively, with calcium carbonate as the carrier.

[C]Provided the following per kilogram of diet: vitamin A (retinyl palmitate), 8,000 IU; vitamin D_3, 3,000 IU; vitamin E (DL-α-tocopherol acetate), 25 IU; vitamin K, 1.5 IU; riboflavin, 10 mg; pantothenic acid, 15 mg; niacin, 50 mg; vitamin B_{12}, 0.02 μg; biotin, 0.1 μg; folic acid, 1 mg; pyridoxine, 4 mg; thiamin, 3 mg.

[D]Contains 600,000 mg/kg choline.

[E]Phytase (as Natuphos 1200) provided 600 FTU/kg. Actual analysis was 670 FTU/kg for diet 3 and 855 FTU/kg for diet 6.

[F]Numbers not in parentheses are the calculated composition using the analyzed values for the ingredients and the nutrient matrix values for phytase. Numbers in parentheses are the calculated composition using the analyzed values for ingredients but as if phytase was not added.

P to reach adequate levels and no added phytase. In all diets, vitamins and minerals met or exceeded the requirement for broilers from 0 to 21 d posthatching [19]. The control and the low-energy diets were formulated to provide 1.12% true digestible Lys and all other AA met or exceeded the ratio to Lys [20]. Natuphos 1200 was included in the diet at 0.05%, which provided 600 FTU/kg. Actual analysis of diets indicated that phytase provided 670 FTU/kg for diet 3 and 855 FTU/kg for diet 6. All diets were C-SBM and produced in mash form.

Data were analyzed by ANOVA procedures appropriate for completely randomized designs [21]. For ease of presentation, the data were analyzed as 2 EXP. The AA subset included broilers fed diets 1, 2, 3, and 4. The ME subset included broilers fed diets 1, 5, 6, and 7. For the AA subset, treatment and sex were included in the model. There were no treatment × sex

TABLE 4. Description of diets used in experiment 2

Treatment	Description
1	C-SBM control diet
2	C-SBM diet with added phytase at 600 FTU/kg using the nutrient matrix values for Ca, aP, and ME
3	C-SBM diet with added phytase at 600 FTU/kg using the nutrient matrix values for Ca, aP, ME, and AA

interactions, so it was removed from the analysis. For the ME subset, treatment, sex, and the treatment × sex interaction were included in the model. Pen of broilers was the experimental unit for all data.

Experiment 2

In EXP 2, 1,575 broilers were allotted on d 0 to 3 treatments (Table 4) with 10 replications (5 male and 5 female) per treatment and 50 (male) or 55 (female) broilers per replication. The initial and final BW were 44 and 2,203 g, respectively, and the EXP lasted 42 d. The broilers were housed in 1.52- × 3.05-m pens at the LSU Poultry Farm in 1 room of a ventilated tunnel house equipped with cool cells and fans [22]. The litter was reused after raising 1 group of broilers and topped with 6 to 8 cm of new shavings before the experiment began. Feed and water were offered ad libitum throughout the experimental period. The broilers were fed a 3-phase feeding program consisting of starting (0 to 15 d), growing (16 to 35 d), and finishing (36 to 42 d) periods. At the end of EXP 2, all broilers were weighed by pen, and pen feed intake was measured.

TABLE 5. Mineral and amino acid content (%) of the ingredients used in experiment 2

Item	Corn	Soybean meal
Calcium	0.02	0.37
Phosphorus	0.29	0.62
Lysine	0.34	3.03
Methionine	0.21	0.68
Cystine	0.22	0.79
Tryptophan	0.08	0.69
Threonine	0.35	1.81
Valine	0.45	2.31
Isoleucine	0.32	2.16
Leucine	1.06	3.63
Arginine	0.51	3.48
Phenylalanine	0.48	2.41
Histidine	0.27	1.32

Natuphos 1200 was included in the diet at 0.037%, which added 600 FTU/kg of diet (actual analysis of the Natuphos 1200 indicated an activity of 1,620 FTU/kg). Actual analysis of diets indicated that phytase provided 878 FTU/kg for diet 2 and 600 FTU/kg for diet 3. Corn and SBM were analyzed for AA, Ca, and P [23], and their values were used in diet formulations (Table 5).

During the starting period (0 to 15 d), the diets (Table 6) were formulated to provide 3,075 kcal/kg, 0.95% Ca, 0.45% aP, 1.25% total Lys, and 0.94% TSAA. During the growing period (16 to 35 d), the diets were formulated to provide 3,150 kcal/kg, 0.85% Ca, 0.41% aP, 1.11% total Lys, and 0.87% TSAA. During the finishing period (36 to 42 d), the diets were formulated to provide 3,200 kcal/kg, 0.77% Ca, 0.35% aP, 0.94% total Lys, and 0.76% TSAA. All nutrients met or exceeded the requirement [19] for broilers. Because the AA matrix for phytase is based on digestible AA values, diet 3 was formulated to meet the true digestible Lys percentage as in diets 1 and 2. All diets were C-SBM and produced in mash form.

At the termination of the EXP, final weights were taken, and 6 broilers per pen were randomly selected for processing [24, 25]. In addition, litter samples were taken from 9 locations within each pen at the termination of the EXP to determine total P [26] and soluble P [27, 28] in waste from the broilers fed phytase compared with those fed a conventional diet.

Data were analyzed by ANOVA procedures appropriate for a completely randomized design [21, 29]. There were no treatment × sex interactions, so this parameter was removed from the model. Final BW was used as a covariate for the carcass data.

RESULTS AND DISCUSSION

Experiment 1

Table 7 presents the performance data of the AA portion of EXP 1. Daily gain and gain:feed were decreased ($P < 0.03$) in broilers fed the diet

TABLE 6. Diet composition for the starter phase in experiment 2[A]

Diet Ingredient	1 Control[B]	2 ME[B]	3 ME and AA[B]
Corn	58.53	60.21	60.88
Soybean meal (47.5% CP)	33.38	33.19	32.62
Tallow	3.52	2.55	2.45
Monocalcium phosphate	1.56	1.11	1.11
Limestone	1.15	1.09	1.09
Salt	0.50	0.50	0.50
BMD+3[C]	0.50	0.50	0.50
Mineral premix[D]	0.25	0.25	0.25
Vitamin premix[E]	0.05	0.05	0.05
Choline chloride[F]	0.14	0.14	0.14
DL-Methionine	0.20	0.19	0.19
L-Lysine·HCl	0.05	0.05	0.05
Monteban[G]	0.08	0.08	0.08
Rendox[H]	0.05	0.05	0.05
Rice hulls	0.04	—	—
Phytase[I]	—	0.04	0.04
Calculated composition[J]			
ME, kcal/kg	3,075	3,075/(3,044)	3,075/(3,044)
Crude protein, %	21.33	21.38	21.37/(21.16)
Lysine, %	1.25	1.25	1.25/(1.24)
Sulfur amino acids, %	0.94	0.94	0.94/(0.93)
Tryptophan, %	0.28	0.28	0.27/(0.27)
Threonine, %	0.81	0.81	0.80/(0.79)
Calcium, %	0.95	0.95/(0.86)	0.95/(0.86)
Available phosphorus, %	0.45	0.45/(0.45)	0.45/(0.45)
Phosphorus, %	0.71	0.61/(0.52)	0.61/(0.52)

[A]AA = amino acid. The ME diet used the phytase matrix values for ME. The ME and AA diet used the phytase matrix values for ME and AA.

[B]The control diets during the growing and finishing phases were similar to the starter diet but contained the following: corn, 63.91 and 71.64%; soybean meal, 28.03 and 21.68%; tallow, 3.82 and 3.19%; limestone, 1.00 and 1.03%; monocalcium phosphate, 1.41 and 1.16%; DL-Met, 0.18 and 0.13%; monteban, 0.08 and 0%; bacitracin methylene disalicylate (BMD)+3 nitro, 0.50 and 0%, respectively. The diets using the phytase nutrient matrix values for ME during the growing and finishing phases were similar to the starter diet but contained the following: corn, 65.79 and 73.52%; soybean meal, 27.82 and 21.47%; tallow, 2.74 and 2.10%; limestone, 0.93 and 1.06%; monocalcium phosphate, 0.90 and 0.65%; DL-Met, 0.17 and 0.13%; monteban, 0.08 and 0%; BMD+3 nitro, 0.50 and 0%, respectively. The diets using the phytase nutrient matrix values for AA and ME during the growing and finishing phases were similar to the starter diet but contained the following: corn, 66.54 and 74.24%; soybean meal, 27.17 and 20.86%; tallow, 2.63 and 2.00%; limestone, 0.93 and 1.06%; monocalcium phosphate, 0.91 and 0.66%; DL-Met, 0.17 and 0.12%; monteban, 0.08 and 0%; BMD+3 nitro, 0.50 and 0%, respectively.

[C]Provided per kilogram of diet: BMD, 0.022 g and 3-nitro-4-hydroxyphenylarsonic acid, 0.025 g. Nutra Blend Corporation, Neosha, MO.

[D]Provided the following per kilogram of diet: Fe, 50 mg; Mn, 100 mg; Cu, 7 mg; Se, 0.15 mg; Zn, 75 mg; I, 1 mg, as ferrous sulfate monohydrate, manganese sulfate, copper sulfate, sodium selenite, zinc sulfate, ethylenediamine dihydriodide, respectively with calcium carbonate as the carrier.

[E]Provided the following per kilogram of diet: vitamin A (retinyl palmitate), 8,000 IU; vitamin D_3, 3,000 IU; vitamin E (DL-α-tocopherol acetate), 25 IU; vitamin K, 1.5 IU; riboflavin, 10 mg; pantothenic acid, 15 mg; niacin, 50 mg; vitamin B_{12}, 0.02 g; biotin, 0.1 μg; folic acid, 1 mg; pyridoxine, 4 mg; thiamin, 3 mg.

[F]Contains 600,000 mg/kg choline.

[G]Active ingredient is 0.825 g/kg narsin.

[H]Used as an antioxidant (Kemin Industries, Des Moines, IA).

[I]Phytase (Natuphos 1200) provided 878 phytase units (FTU)/kg in diet 2 and 600 FTU/kg in diet 3.

[J]Numbers not in parentheses are the calculated composition using the analyzed values for the ingredients and the nutrient matrix values for phytase. Numbers in parentheses are the calculated composition using the analyzed values for ingredients but as if phytase was not added.

TABLE 7. Growth performance of broilers in the AA portion of experiment 1[A]

Treatment	ADG	ADFI	GF
1. C-SBM control diet	41.35[a]	51.39[a]	0.805[a]
2. C-SBM deficient in AA	33.86[b]	49.02[a]	0.691[b]
3. C-SBM diet deficient in AA but with 600 FTU/kg	33.24[b]	48.98[a]	0.679[b]
4. Diet 3 without phytase but adequate in Ca and aP	33.08[b]	48.59[b]	0.682[b]
SEM	0.67	0.82	0.009

[a,b]Data in columns with different superscripts differ, $P < 0.03$.
[A]Data are means of 7 replications of 6 broilers per replication with an initial and final BW of 72 and 574 g. AA = amino acid; ADG = average daily gain; ADFI = average daily feed intake; GF = gain:feed; C-SBM = corn-soybean meal; FTU = phytase units; aP = available phosphorus. The Ca and aP was reduced by 0.094% in the diet with phytase.

deficient in AA with or without added phytase relative to those fed the control diet. Daily feed intake was decreased ($P < 0.03$) in broilers fed the diet deficient in AA with no added phytase but adequate in Ca and aP (treatment 4) relative to those fed the C-SBM control. Table 8 presents the performance data of the ME portion of EXP 1. Daily gain and gain:feed were decreased ($P < 0.04$) in broilers fed the diet low in energy with or without added phytase relative to those fed the control diet. Broilers fed the diets with phytase using the nutrient matrix for ME or AA resulted in similar growth performance compared with broilers fed the deficient diets. Removing the phytase from the diets low in AA or ME did not decrease the AA or ME content low enough to cause a significant decrease in growth performance in the broilers.

Experiment 2

Diet did not affect ($P > 0.05$) final BW, daily gain, daily feed intake, gain:feed, mortality, or tibia ash percentage, when broilers were fed the control diet or the diets with added phytase (Table 9). This response suggests that the nutrient matrix values used for phytase are accurate when growth performance and tibia ash are used as response variables. The nutrient matrix values for phytase used in this EXP included Ca, aP, ME, and AA. The availability of calcium [30, 31, 32], aP [6, 7], energy [8, 9], and AA [10, 11, 12] has been reported to be increased in broilers when phytase is supplemented to the diet.

Diet did not affect ($P > 0.05$) live weight, eviscerated weight, chill weight, carcass yield, moisture gain due to chill, breast weight as a percentage of live weight, or 24-h moisture loss in broilers fed the control diet or diets with added phytase using the nutrient matrix values (Table 10). Broilers fed the diets with phytase using the matrix values for ME, Ca, and aP had a decreased ($P < 0.03$) breast weight as a percentage of chill weight compared with those fed the diet with phytase using the matrix values for ME, AA, Ca, and aP. This response in breast weight was unexpected because the diet using the matrix values for ME, Ca, and aP actually had more AA in the diet than the diet using the nutrient matrix values for ME, AA, Ca, and aP.

No effect on moisture loss in the breast meat was observed when broilers were fed the diets

TABLE 8. Growth performance of broilers in the energy portion of experiment 1[A]

Treatment	ADG	ADFI	GF
1. C-SBM control diet	41.26[a]	51.36	0.804[a]
5. C-SBM low in energy	38.08[b]	51.87	0.735[b]
6. C-SBM low in energy but with 600 FTU/kg	39.26[b]	52.63	0.746[b]
7. Diet 6 without phytase but adequate in Ca and aP	38.79[b]	52.66	0.737[b]
SEM	0.61	0.91	0.007

[a,b]Data in columns with different superscripts differ, $P < 0.04$.
[A]Data are means of 7 replications of 6 broilers per replication with an initial and final BW of 72 and 574 g. ADG = average daily gain; ADFI = average daily feed intake; GF = gain:feed; C-SBM = corn-soybean meal; FTU = phytase units; aP = available phosphorus. The Ca and aP was reduced by 0.094% in the diet with phytase.

TABLE 9. Effect of phytase on growth performance of 42-d-old broilers, experiment 2[A]

Diet Item	1 Control	2 ME	3 ME and AA	SEM
Final weight, g	2,219.7	2,200.9	2,188.8	13.2
Average daily gain, g	51.7	51.3	51.0	0.3
Feed intake, g	94.1	92.8	92.0	1.0
Gain:feed, g:kg	549	550	552	5
Mortality, chicks/replication[B]	0.60	1.00	0.80	0.25
Tibia ash, %	57.27	58.02	57.12	0.56

[A]Data are means of 10 replicates of 50 or 55 broilers per replicate. Average initial BW was 44 g. AA = amino acids. The ME diet used the phytase matrix values for ME. The ME and AA diet used the phytase matrix values for ME and the AA.
[B]Mortality was analyzed using the square-root transformation of (y + 0.5). Treatment means are actual means from original data.

TABLE 10. Effect of phytase on carcass traits of 43-d-old broilers, experiment 2[A]

Diet Item	1 Control	2 ME	3 ME and AA	SEM
Live weight, kg	2.20	2.15	2.17	0.03
Eviscerated weight, kg	1.58	1.53	1.55	0.02
Chill weight, kg	1.62	1.57	1.58	0.02
Carcass yield, %[B]	72.1	71.8	71.3	0.3
Moisture gain due to chill, %[C]	2.54	2.35	2.32	0.27
24-h moisture loss, %[D]	1.10	1.07	1.05	0.08
Breast weight PLW, %[E]	13.0	12.7	13.1	0.14
Breast weight PCW, %[E]	17.6[a,b]	17.4[b]	17.9[a]	0.18

[a,b]Means in a row with different superscripts differ, $P < 0.03$.
[A]Data are means of 10 replicates of 6 broilers per replicate. The growth trial lasted 42 d. The broilers were processed on d 43 after a 12-h fast. AA = amino acids. Average initial BW was 44 g. The ME diet used the phytase matrix values for ME. The ME and AA diet used the phytase matrix values for ME and the AA.
[B]Carcass yield calculated as eviscerated weight divided by live weight × 100.
[C]Moisture gain calculated as chill weight minus eviscerated weight divided by eviscerated weight × 100.
[D]Moisture loss calculated as 24-h breast weight minus initial breast weight divided by initial breast weight × 100.
[E]PLW = percentage of live weight; PCW = percentage of chill weight.

TABLE 11. Effect of phytase on P levels in the litter, experiment 2[A]

Item	1 Control	2 ME	3 ME and AA	SEM
Total P, mg/kg	14,295[a]	12,928[b]	12,411[b]	233
Inorganic soluble P, mg/kg	1,563[a]	1,348[b]	1,223[b]	93
Total soluble P, mg/kg	1,881[a]	1,664[b]	1,525[b]	90

[a,b]Phytase, $P < 0.03$.
[A]Data are means of 10 replicates. Litter samples were taken from 9 locations within each pen at the termination of the experiment. AA = amino acids. Average initial BW was 44 g. The ME diet used the phytase matrix values for ME. The ME and AA diet used the phytase matrix values for ME and the AA.

with phytase. This response disagrees with a report by Rienstra et al. [33] who reported a decrease in drip loss of loin chops when phytase was added to diets for swine. On the other hand, Gebert et al. [34] reported no effect on water-holding capacity when phytase was added to diets for swine.

Total P, soluble P, and inorganic soluble P in the litter were decreased ($P < 0.03$) in the litter of broilers fed the diets with added phytase relative to those fed the control diet (Table 11). DeLaune et al. [35] reported an increase in soluble P in the litter of broilers fed phytase. However, it is well documented that phytase in-

creases P retention in broilers [36, 37, 38]. In addition, our data agree with data by Moore et al. [39] who reported numerical decreases (not always significant) in both total and soluble phosphorus content in litter from broilers fed diets with added phytase compared with litter from broilers fed diets without added phytase.

CONCLUSIONS AND APPLICATIONS

1. Reducing the AA or ME concentrations in the diets for broilers in EXP 1 resulted in a decreased growth performance. The addition of phytase did not affect growth performance of broilers fed diets deficient in AA or ME.
2. In EXP 2, using the nutrient matrix values for phytase in formulating C-SBM diets for commercial broilers resulted in similar growth performance, carcass traits, meat quality, and tibia ash percentage compared with broilers fed a conventional C-SBM diet.
3. Phytase addition to broiler diets reduces the levels of total and soluble P in the litter.
4. The nutrient matrix values presented in these EXP are accurate and can be used in formulating diets for commercial broilers that incorporate Natuphos 1200.

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22. The lighting system consisted of 3 d of 24-h light, followed by 16 h of light and 8 h of dark for the remainder of the project. The broilers were conditioned to the dark period over 3 d by increasing the periods of dark until 8 h of dark were reached. The temperature in the house was 31 to 33°C for the first week and was dropped each week until 24 to 27°C was reached.

23. The AA composition (Table 5) of C and SBM was determined after acid hydrolysis [40], whereas Met and Cys content were determined after performic acid oxidation followed by acid hydrolysis [40]. Tryptophan content was determined after alkaline hydrolysis [40]. The mineral composition (Table 5) of C and SBM was determined by inductively coupled plasma emission spectroscopy (Model Optima 3000, Perkin Elmer, Norwalk, CT) after digestion in nitric acid and peroxide.

24. The broilers were held without feed for 12 h then transported to the LSU Muscle Foods Laboratory. The broilers were slaughtered by severing the jugular. The broilers were then scalded, defeathered, eviscerated, and placed in an aerated chill tank (ice and water). After the broilers were chilled to 6 to 8°C, they were removed and allowed

to drain for at least 15 min and then weighed. The broilers were then deboned and individual breast weights were recorded. After the chilled breast weight was recorded, the individual breasts were placed into a poultry meat tray that contained 2 absorbent pads, sealed, and placed in a refrigerator (4 to 6°C). After approximately 24 h, the breasts were removed from the tray, blotted with a paper towel, and weighed.

25. The left tibia from each broiler was removed for determination of bone ash percentage. Bone ash percentage was determined after refluxing in ethanol and ether for 36 h each using a Soxhlet Extracting Apparatus (Lab Glass, Vineland, NJ) and being placed in an ashing oven at 550°C for 24 h.

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