Egg Production, Fertility, and Hatchability of Breeder Hens Receiving Dietary Phytase

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Primary Audience: Broiler Breeder Managers, Nutritionists, Researchers

SUMMARY

An experiment was conducted to determine whether supplemental dietary phytase could support egg production, egg shell quality, fertility, and hatchability in broiler breeder hens on a diet with marginal available phosphorus. During the production period, 27 to 60 wk of age, individually caged broiler breeder hens were fed four diets with two available phosphorus (AP) concentrations (0.1 and 0.3%) and two phytase levels [0 and 300 phytase units (FTU)/kg]. Phytase increased overall hen-day egg production by 9.8%, as compared with hens consuming a low phosphorus diet without added phytase. Addition of phytase significantly reduced hen mortality regardless of AP levels. Phytase improved bone mineral content and bone density of hens at both AP levels. Supplemental phytase had no significant effect on egg weight or egg specific gravity. The results suggest the possibility of a detrimental interaction of phytase with the 0.1 AP level on hatchability.

Key words: broiler breeder hen, phytase, phytate phosphorus

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DESCRIPTION OF PROBLEM

In an effort to reduce phosphorus in poultry waste, diets for commercial egg laying flocks and broilers have been formulated with reduced levels of inorganic phosphate and supplemented with phytase to increase phosphorus availability. Addition of 200 to 300 phytase units (FTU)/kg [1] to diets containing 0.1% available phosphorus (AP) has been demonstrated to satisfy the P requirement of Leghorn laying hens. Supplementation of diets containing 0.12% AP (0.33% total P) with 200 to 2,000 FTU phytase/kg were found to support normal 24- to 52-wk egg production (EP), egg weight (EW), feed intake (FI), and tibia weight in commercial layers [2]. Phytase supplementation at 200 FTU/kg to a basal diet (no added P) was enough to maintain normal EP, EW, and feed intake, whereas an additional increase in either P or phytase produced no further benefit in performance [3]. Addition of phytase at 300 FTU/kg to diets containing 0.1% AP (0.3% total P) corrected P-deficiency in EP, EW, egg specific gravity (ESG), and decreased mortality of 21- to 39-wk laying hens [4].

Little information is available about the response of broiler breeder hens to supplemental dietary phytase. The current study was conducted to determine whether broiler breeder hens would respond to supplemental phytase in a manner similar to Leghorns.

MATERIALS AND METHODS

Four hundred Ross 308 [5] broiler breeder females were reared to 21 wk of age in a commercial light-proof pullet rearing facility. Man-

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TABLE 1. Composition of diets

Ingredient	Diet 1	2	3	4
	(%)			
Corn	69.81	69.74	70.72	70.65
Soybean meal (48% protein)	21.58	21.58	21.51	21.51
Poultry oil	0.36	0.39	0.00	0.03
Dibasic calcium phosphate	1.09	1.09	0.00	0.00
Calcium carbonate	4.16	4.15	4.77	4.76
Hard shell[A]	2.00	2.00	2.00	2.00
Salt	0.41	0.41	0.41	0.41
Vitamin premix[B]	0.25	0.25	0.25	0.25
Mineral premix[C]	0.25	0.25	0.25	0.25
DL-Methionine	0.10	0.10	0.10	0.10
Natuphos 5000	0.00	0.05	0.00	0.05
Calculated analysis				
Protein	15.94	15.94	15.98	15.98
Calcium	2.75	2.75	2.75	2.75
Available P	0.30	0.30	0.10	0.10
Total P	0.52	0.52	0.32	0.32
ME, kcal/kg	2,919	2,919	2,919	2,919

[A]Large-partical calcium carbonate (passing through US mesh #4 and retained by mesh # 6). Supplied by Franklin Industrial minerals, Lowell, FL.
[B]Vitamin premix provided per kilogram of finished feed: vitamin A, 7,350 IU; vitamin D_3, 2,200 ICU; vitamin E, 8 IU; riboflavin, 5.5 mg; d-pantothenic acid, 13.0 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; menadione, 2 mg; folic acid, 0.5 mg; thiamine mononitrate, 1.0 mg; pyridoxine, 2.2 mg; d-biotin, 0.05 mg.
[C]Mineral premix provided in mg/kg of finished feed: Cu, 6.0; Fe, 54.8; I, 1.0; Mn, 65.3; Se, 0.3; Zn, 55.

agement and feeding during rearing followed the primary breeder's guidelines for this strain. Daylength was maintained at 8 h light from 3 wk of age until transfer to the breeder house. The birds were transferred at 21 wk of age to individual layer cages in a curtain-sided house. Each cage was equipped with nipple waterers and a trough feeder. Day length was increased at that time to 14 h light to photostimulate the birds. Daylength was further increased to 15 h at the beginning of wk 22, and to 16 h at the beginning of wk 24. From 21 wk of age onward, the hens were fed four diets in a factorial arrangement with two levels of AP (0.1 and 0.3%) and phytase (0 and 300 FTU/kg; Table 1). All diets were isocaloric (2,919 ME/kg), isonitrogenous (15.9% CP), and contained 2.75% Ca. The four treatments were arranged into randomized complete blocks, with 10 replicates of 10 hens each. Each hen was provided with a measured amount of feed based on maintaining hen BW at the target BW recommended in the management guide for Ross 308 hens. Hens were individually fed 106 g per hen per day at 21 wk (23.3 lb/100), increasing by approximately 5 g per hen each week until 30 wk of age (151 g per bird per day, 33.3 lb/100). After 30 wk, feed allocations were based on maintaining the average BW of "control" (0.3 AP group without phytase) hens on the growth curve in the primary breeder management guide. As it turned out, feed amounts were essentially constant after 30 wk of age. To 52 wk of age, these feed allocations were less than the amounts listed in the management guide. Feed allocations to the hens were slightly above the management guide recommendations after 52 wk of age. Water was consumed ad libitum.

Body weights of all hens were recorded every 4 wk. Mortality was recorded as it occurred. Egg production was tabulated weekly. Egg weight and ESG were determined from a 3-day collection of eggs every 4 wk. Egg specific gravity was determined using a series of saline solutions (1.060 to 1.100 incremented by 0.005). Fertility was determined at 39 and 49 wk of age. All hens from each treatment group were inseminated twice in 3 d with pooled broiler breeder semen. Eggs were collected from the third through twelfth day following insemination

TABLE 2. Mean hen-day egg production during early (27 to 36 wk), middle (37 to 46 wk), and late production (47 to 60 wk) of broiler breeder hens fed diets containing two levels of available phosphorus (AP) and phytase

AP (%)	Phytase (FTU/kg)	Early	Mid	Late	Overall
0.1	0	59.84^{b}	52.47^{b}	40.14^{b}	50.37^{b}
0.1	300	62.67^{ab}	58.64^{ab}	46.29^{ab}	55.33^{ab}
0.3	0	64.16^{a}	60.46^{ab}	48.01^{ab}	56.94^{ab}
0.3	300	66.74^{a}	64.12^{a}	51.49^{a}	60.19^{a}
SEM		1.37	2.13	1.55	1.51
Probability					
ANOVA					
AP		0.037	0.010	0.001	0.001
Phytase		0.180	0.065	0.035	0.043
AP × phytase		0.098	0.017	0.001	0.002

^{a,b}Means within the same column with different superscripts differ significantly ($P \leq 0.05$).

and incubated. Upon hatching of the chicks, unhatched eggs were broken out and examined to determine the number of infertile eggs. Hatchability was calculated as hatchability of fertile eggs. Tibias were removed from 20 hens per treatment at termination of the study and analyzed for bone mineral content (BMC) and bone density (BD) using a Norland 2780 bone densitometer [6]. Bone measures were made by single-photon absorptiometry from an I^{125} source [7].

Data were subjected to analysis of variance using general linear models procedures [8] with pooled cages of each replication as an experimental unit. The model included replication, AP, phytase, and interaction of AP and phytase. Percentage egg production, fertility, hatchability, and mortality were arcsine-transformed prior to analysis.

RESULTS AND DISCUSSION

There is little published information about effectiveness of phytase on performance of broiler breeder hens. Wilson and Harms [9] demonstrated that broiler breeder hens in floor pens, fed diets containing 610 to 750 mg total P daily, did not show differences in 24- to 64-wk EP, EW, and ESG. In the present study, egg production tended to be lower in hens receiving the 0.1 AP (780 mg total P, 450 mg AP) as compared with hens receiving the 0.3 AP diet (Table 2). Phytase supplementation tended to increase EP in both the 0.1 and 0.3 AP diet hens. Hens receiving both 0.3 AP and phytase supplementation had significantly higher EP as compared with the 0.1 AP hens that received no phytase. These results suggest that even the 0.3 AP level may have been limiting for EP in the caged breeders in this study that were unable to consume feces and litter to obtain or "recycle" phosphorus as would birds in floor pen trials. This type of phosphorus recycling has been shown to provide enough additional dietary P to significantly affect egg shell quality [10, 11]. Besides direct effects of AP and phytase, other factors such as differences in gut microflora or variation in activity of endogenous phosphatases [12] may contribute to the effects of AP and phytase on EP. As stated by Summers [13] and Roland and Gordon [14], accurately determining P requirement in poultry is a difficult task, as puzzling results are often encountered due to numerous interacting factors.

Body weight for each of the treatment groups tended to be below the management guide recommendations for this strain prior to wk 56 (Figure 1). This was due to the investigators' reluctance to increase feed allotments too quickly for fear of rapid weight gains once the birds were placed in cages. However, during the course of production, BW were not significantly different among the treatments (Table 3).

Overall EP of the highest producing groups in this study (77%, Figure 2) was below the expected peak EP (84%) listed in the management guide. It is likely that keeping the birds lighter than the target weight restricted their EP. Lower EP would obviously reduce the hen's demand for phosphorus and other minerals. Lower demand for phosphorus in these hens

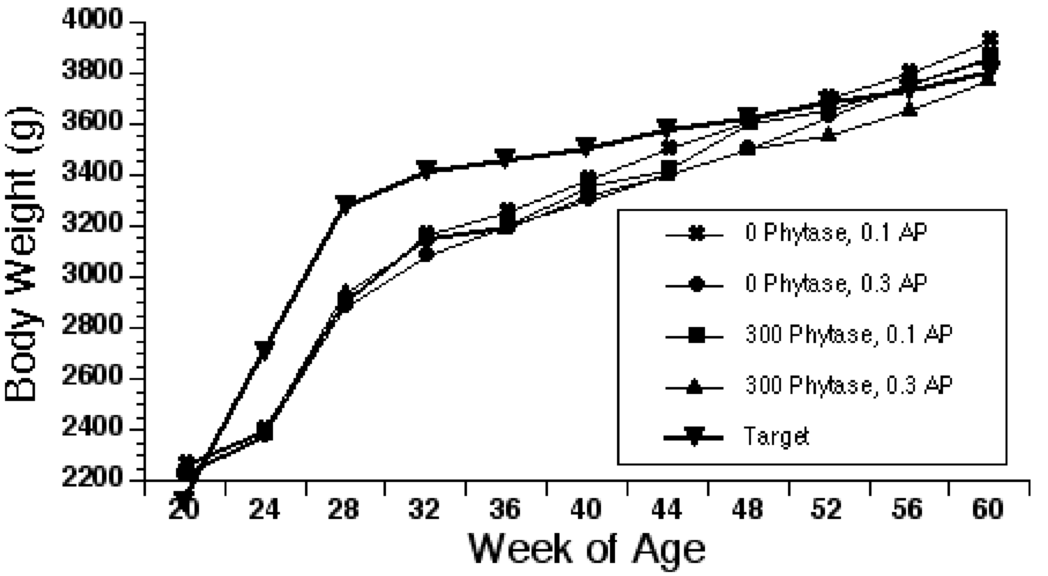

FIGURE 1. Mean body weight of broiler breeder hens when fed diets containing two levels of available phosphorus (AP) and phytase.

would be mitigated to some extent because the caged birds in this study were unable to obtain phosphorus from consuming litter.

Total average hen-day EP increased as the apparent availability of phosphorus increased. Overall (wk 27 to 60) hen-day EP tended to increase with increased AP or phytase (Table 2), and these factors interacted to significantly increase EP at the 0.3 AP and 300 unit phytase level. The 0.1 AP, 0 FTU phytase group exhibited the lowest overall EP and the 0.3 AP, 300 FTU phytase group had the highest EP (9.8% difference). Average EP for the 27 to 60 wk production period was 5.7% higher in the 0.3 AP group as compared with the 0.1 AP birds. Average EP for the 27 to 60 wk production period was 4.1% higher with phytase than without added phytase.

Analysis of EP as early (27 to 36 wk), middle (37 to 46 wk), and late production (47 to 60 wk)

TABLE 3. Mean egg weight (EW), egg specific gravity (ESG), combined 39 through 49 wk fertility (FERT) and hatchability of fertile eggs (HATCH), BW gain (GAIN), and mortality (MORT), bone mineral content (BMC), and bone density (BD) of Ross broiler breeder hens after feeding diets containing two levels of available phosphorus (AP) and phytase

AP (%)	Phytase (FTU[A]/kg)	EW (g)	ESG	FERT (%)	HATCH (%)	GAIN (g)	MORT (%)	BMC (g/cm^2)	BD (g/cm^2)
0.1	0	63.5	1.085	79.6	84.2[a]	1,660	17.0[a]	0.307[b]	0.340[c]
0.1	300	64.0	1.085	76.6	71.9[b]	1,628	9.0[b]	0.325[ab]	0.372[b]
0.3	0	64.1	1.084	79.8	85.3[a]	1,634	11.0[ab]	0.318[b]	0.367[bc]
0.3	300	64.3	1.084	82.1	85.0[a]	1,508	5.0[b]	0.349[a]	0.399[a]
SEM		1.3	0.0012	2.3	5.6	68	5.0	0.018	0.024
Probability									
ANOVA									
AP		0.37	0.09	0.45	0.01	0.13	0.12	0.14	0.04
Phytase		0.50	0.61	0.92	0.01	0.11	0.03	0.04	0.02
AP × phytase		0.78	0.67	0.47	0.02	0.33	0.75	0.58	0.10

[a–c]Means in the same column with differing superscripts differ significantly ($P \leq 0.05$).
[A]Phytase units.

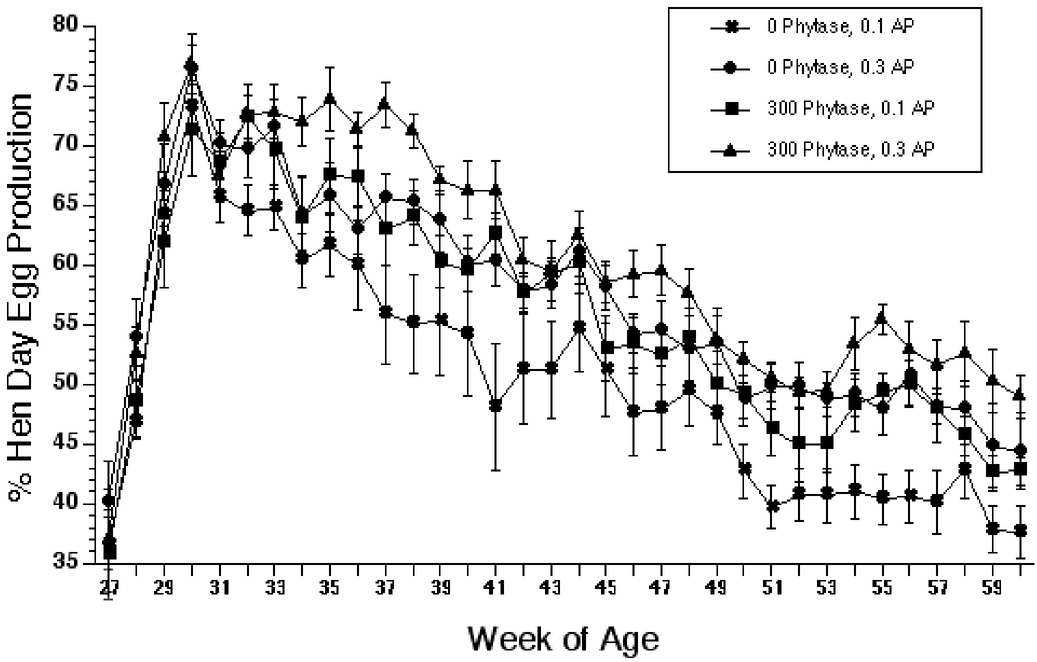

FIGURE 2. Mean weekly egg production of broiler breeder hens when fed diets containing two levels of available phosphorus (AP) and phytase.

indicated that EP tended to increase with the apparent AP level from early in production (Table 2). This effect became more pronounced later in production. The interaction of AP and phytase supplementation became significant during middle production and remained so during late production.

These results suggest that 0.1% AP was significantly limiting for EP, whereas 0.3 AP tended to be limiting for EP in caged breeders in this study. Phytase supplementation improved EP at both levels of AP. This effect became more pronounced later in production. Increasing egg size, decreasing bone reserves, and impaired nutrient uptake with aging were likely contributors to this effect, while decreasing EP would have been a mitigating factor. It is difficult to predict how the birds would have responded to larger feed allotments. More feed would have provided more P to the hens. However, assuming that feed increases were based on increased EP with control of BW gain, then the additional resources would have been allocated to EP. In that case, the overall effects may not have been significantly different from what was observed in the present study.

The demands of a high rate of EP in commercial layers limit BW gain or may result in weight loss, even though the hens are fed free choice. Clearly EP in commercial layers can outstrip the hen's resources and ability to take in nutrients and energy. Studies of phytase supplementation of commercial layer diets have demonstrated a gain in BW in addition to an increase in EP [2, 15]. Increased nutrient availability due to phytase supplementation improved the ability of commercial layers to meet the demands of increased EP with less depletion of body reserves, thus allowing increased BW. Broiler breeder hens have a much lower rate of lay and start producing eggs at a higher BW. Moreover, broiler breeder hens gain weight during production. Therefore, broiler breeder hens should have greater body reserves while their EP puts less demand on reserves and nutrient uptake. It was expected that phytase supplementation would increase weight gain of the breeder hens during production. Unexpectedly, phytase-supplemented hens in the present study gained BW at a reduced rate, in comparison with the hens that did not receive phytase, although the differences in weight gain were not significant overall. Improved nutrient availability may have allowed for increased EP by the phytase-supplemented hens; however, without the ability to increase food intake due to controlled feeding, BW did not increase as quickly as that of the hens with lower EP. The lower BW, in turn, may have directly improved laying persistency. A more intriguing possibility is that there may be an interaction between AP (and/or other nutrients) and energy that favors the allocation of resources to EP over weight gain.

The trend towards reduced mortality in the phytase supplemented hens is consistent with the results of studies in layers [4, 16] and broilers. Mortality was significantly reduced in hens receiving phytase, as compared with the 0.1 AP hens that did not receive phytase. Hens on the 0.3 AP diet without phytase had a mortality rate intermediate to that of the 0.1 AP hens and the phytase-supplemented hens. Mortality of hens from 27 to 60 wk of age was reduced by an average of 7% due to the addition of phytase (Table 3).

In the current study, EW (Table 3) did not differ between AP and phytase levels, which is consistent with results from commercial layers [15]. However, in the same study of commercial layers, phytase increased ESG. In the present study, ESG was not affected by AP or phytase. Leghorns have lower feed intake and higher EP, so it is possible that commercial layers could be more responsive to phytase supplementation than broiler breeder hens fed diets with marginal or subnormal P level.

No published information is available about the influence of phytase on the hatchability of eggs in commercial layers or broiler breeders. The results of this study indicate that, within the levels of phosphorus fed, fertility in broiler breeders is not sensitive to dietary AP (Table 3). For this reason, differences in fertility due to phytase would not be expected, and none was observed. Hatchability, like fertility, did not appear to be sensitive to AP levels as fed in this experiment. Hens on 0.1% AP without phytase were able to package sufficient resources for embryonic development. It is possible that higher EP would have consumed resources at a rate that would have resulted in insufficient phosphorus for the production of viable embryos. The results do suggest the possibility of a detrimental interaction of phytase with the 0.1 AP level on hatchability. This was an intriguing result and may be the effect of phytase interactions with the uptake of other nutrients such as iron. However, to date, similar studies currently underway by the authors have not reproduced this effect.

Addition of phytase increased BMC and BD, regardless of dietary P levels (Table 3). This is consistent with results obtained in studies of commercial layers [15] and broilers [17]. Histological observations of tibial bones in phytase-supplemented broilers demonstrated increased width of cartilaginous and proliferative zones, increased density of trabecular bone, and improved mineralization of cartilage and bone cells [17].

CONCLUSIONS AND APPLICATIONS

1. Supplementing breeder hen diets with phytase at 300 FTU/kg in a diet containing 0.1% available phosphorus is sufficient to support EP in broiler breeders.
2. Egg production was increased by phytase supplementation with no decrease in EW or ESG.
3. Phytase supplementation decreased mortality regardless of available phosphorus levels.
4. Phytase supplementation can replace added inorganic phosphate in breeder diets down to the 0.1% available phosphorus level with an increase in livability and egg production.

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