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Effect of dietary phosphorus level and supplemental phytase on performance of Hisex Brown laying hens and egg shell quality

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ABSTRACT

The experiment was carried out on Hisex Brown hens aged 26-48 weeks divided into 12 groups of 18 birds kept in single cages. Layers were fed wheat-maize-soyabean meal diets containing 0.50, 0.55 and 0.60% total phosphorus (TP), 0.25, 0.30 and 0.35 % available phosphorus (AP) supplemented with 0, 150, 300 or 450 units of microbial phytase (FTU) per kg. Hens were fed diet containing 0.50% TP supplemented with 300 FTU showed the highest laying rate (93%) and good egg shell quality. However, the thickest egg shells and the highest breaking strenght were found when diets containing 0.30–0.35 % AP were supplemented with 150 FTU. Hens fed diet with 0.25% AP + 300 FTU excreted 100 mg/day/hen less P than those fed diet with 0.35 % AP (0.60% TP), not supplemented with phytase. As the optimal levels in the diet are considered 0.25 % AP + 300 FTU or 0.30 % AP + 150 FTU.

KEY WORDS: layers, phosphorus, phytase

INTRODUCTION

The results of studies published in recent years (e.g. Belyavin, 1991; Nys, 1995; Rao et al., 1996) point to considerable differences with respect to content of total phosphorus (TP) or available phosphorus (AP) in the diets of layers, and its effect on performance and egg shell quality. The published values for AP range from 0.28 to 0.53% and for TP from 0.57 to 0.70%.

On the other hand, the current trend is to reduce the content of phosphorus fed to animals, including poultry, in order to limit its excretion to the environment. The amount of TP excreted can be reduced either by the choice of components of diets or by increased its utilization through the addition of a phytase-containing enzyme preparation to the diet.

The aim of this study was determine the optimal level of phosphorus in diets, with or without phytase, as well as the minimum addition of phytase to feed mixtures used in practice in the feeding of high performance layers.

MATERIAL AND METHODS

The experiment was carried out with 216 Hisex Brown hens aged 26–48 weeks, divided into 12 groups of 18 birds kept individually in cages. The hens were fed *ad libitum* diets (Table 1) containing 0.5, 0.55 or 0.6% total phosphorus (TP) what corresponded to 0.25, 0.30 and 0.35% available phosphorus (AP). Each of the three diets was fed unsupplemented (control) or supplemented with 150, 300 or 450 units of phytase (FTU) in preparation Natuphos[D] 5000. Utilization of P by the birds was determined on 6 hens of each group on the 32nd week of life. Feed intake and excreta voided were recorded during five days.

Individual egg production was estimated daily and the weight of the eggs was determined once a month on five consecutive days, at 30th, 38th and 46th week of life from 12 layers of each group. A total of 432 eggs were examined. The weight

TABELA 1

Composition of mixtures

Ingredients	1	2	3
Ground wheat	42.7	42.4	42.1
Ground maize	20	20	20
Soyabean oilmeal, 42%	16	16	16
Wheat bran	10	10	10
Meat meal, 55%	3	3	3
Limestone	7.5	7.5	7.5
Dicalcium phosphate	–	0.3	0.3
Na-Cl	0.3	0.3	0.3
Vitamin-mineral premix DJ	0.5	0.5	0.5
ME kcal/kg, calculated	2601	2595	2590
Analysed, %			
crude protein	17.07	16.89	16.76
Ca	3.05	3.19	3.27
total P	0.53	0.57	0.62
phytic P	0.30	0.30	0.30

of the egg, specific gravity, breaking strength on the long axis, weight of yolk, white and dry shell as well as their proportion in the weight of the whole egg, shell thickness at three points and its density were measured.

Total phosphorus was determined colorimetrically according to Fiske and Subbarow (1925), phytin phosphorus as described by Antoniewicz et al. (1992).

Statistical evaluation of the results was by analysis of variance using SAS method in two systems: a. two-factors: three levels of phosphorus and 4 levels of phytase and b. one-factor for 12 groups.

RESULTS

The initial body weight of the hens was 1.82 kg and final 2.06 kg. Daily feed intake was from 110 to 140 g, and averaged 128 g. Feed intake was the highest in hens of the control group, when the feed mixtures were not supplemented with phytase (131.7 g), and the lowest (125.2 g) when the diets contained 300 FTU.

The flock was healthy, with low mortality, unrelated to the experimental factors.

Laying rate

Hisex Brown hens not receiving addition of phosphorus in their feed (mixture 1) laid less eggs ($P \leqslant 0.05$) with thinner shells ($P \leqslant 0.01$). The addition to the feed containing 0.50% TP (0.25% AP) of 300 FTU/kg resulted in increased laying rate from 85.5 to 93.3%, corresponding to 15 eggs per layer. Besides the mentioned group, high performance (average 92%) was found for hens receiving in their feed: 0.25% AP + 450 FTU; 0.30% AP + 450 FTU or 0.35% AP + 150 FTU/kg (Table 2).

Eggs weight

The heaviest eggs (61.4–61.6) were laid by hens fed mixture 1 with lowest phosphorus content (0.25 and 0.30% AP, without phytase, and 0.25% AP + 450 FTU). The average weight of eggs from hens fed mixture 3, containing 0.35% AP was significantly lower (59.5 g) than from hens receiving mixtures 1 and 2 (60.6 g). The smallest eggs (59.1 g) were laid by hens receiving 0.35% AP + 450 FTU (Table 2).

Egg content

The proportion of yolk in the eggs averaged 26.6% in all groups throughout the experiment. The level of P in the diets and supplemental phytase did not affect the proportion of white and yolk in the eggs.

TABLE 2

Effect of dietary phosphorus (P) level and phytase supplement on performance of laying hens

Dietary P level %	Phytase supplement FTU/kg diet						
P total (P available)	0	150	300	450	Mean	SEM	P x FTU
Laying rate,							
0.50 (0.25)	85.5^{c}	90.8^{ab}	93.3^{a}	91.7^{ab}	09.5^{a}	0.81	
0.55 (0.30)	89.4^{ab}	90.8^{ab}	87.9^{bc}	92.0^{ab}	90.0^{a}	0.75	
0.60 (0.35)	91.2^{ab}	92.6^{ab}	91.2^{ab}	90.1^{abc}	90.8^{a}	0.93	
Mean	89.2^{a}	91.4^{a}	90.8^{a}	91.3^{abc}	90.4	0.48	x
SEM ±	1.10	0.77	1.04	0.85			
Egg weight, g							
0.50 (0.25)	61.6	59.8	59.7	61.5	60.6^{a}	0.41	
0.55 (0.30)	61.4	60.4	60.2	60.6	60.6^{a}	0.36	0
0.60 (0.35)	59.4	59.5	60.0	59.1	59.5^{b}	0.50	
Mean	60.8^{a}	59.9^{b}	60.0^{ab}	60.4^{ab}	60.3	0.25	NS
SEM ±	0.51	0.47	0.56	0.42			
Egg mass, kg							
0.50 (0.25)	8.17	8.31	8.54	8.66	8.43	0.08	
0.55 (0.30)	8.40	8.38	8.07	8.52	8.34	0.07	
0.60 (0.35)	8.29	8.38	8.37	8.13	8.29	0.10	
Mean	8.30	8.36	8.33	8.44	8.35	0.05	NS
SEM ±	0.07	0.08	0.07	0.09			

a, b – $P \leqslant 0.05$
NS – not significant

Egg shell quality

Eggs with the thickest shell (0.381 – 0.386 mm), high breaking strength (4.06 – 4.19 kg), high specific gravity (1.092 mg/cm^3) and high density (84.4 – 84.9 mg/cm^2) were laid by hens feed mixtures with 0.30% AP supplemented with 150 or 450 FTU or 35% AP + 150 FTU/kg. The quality of the egg shell from hens fed a diet containing 0.25% AP, supplemented with 150 or 300 FTU/kg was also good (Table 3).

The largest number of broken and cracked eggs (8.0 – 10.4%) was laid by hens fed diets without phytase or with the mixture containing 0.50% TP supplemented with 150 FTU. The addition of 300 FTU to the mixture 1 reduced the number of cracked eggs to 1.6%, whereas the addition of 150 FTU to the mixtures containing 0.55 to 0.60% TP reduced the number of cracked eggs to 3.1 – 3.3%.

Phosphorus balance

The amount of phosporus intake was calculated on the basis of chemical analysis which were slightly higher than tabular data (Table 1).

TABLE 3

Egg specific gravity (g/cm^3), breaking strength (kg), shell thickness (μm), shell density (mg/cm^2) and shell percent

Dietary P, % P total (P available)	Phytase supplement FTU/kg diet 0	150	300	450	Mean	P x FTU
Specific gravity						
0.50 (0.25)	1.085	1.091	1.089	1.038	1.088^{B}	
0.55 (0.30)	1.090	1.092	1.089	1.092	1.091^{A}	
0.60 (0.35)	1.039	1.0921	1.091	1.090	1.090^{A}	
Mean	1.088^{B}	1.091^{A}	1.090	1.090^{AB}	1.090^{AB}	NS
Breaking strength						
0.50 (0.25)	3.69	3.93	4.01	3.81	3.86^{b}	
0.55 (0.30)	4.04	4.06	4.09	4.10	4.07^{a}	
0.60 (0.35)	3.75	4.19	4.02	4.10	4.01^{ab}	
Mean	3.82^{b}	4.06^{a}	4.04^{a}	4.00^{ab}	3.98	NS
Shell thickness						
0.50 (0.25)	347	374	369	366	364^{B}	
0.55 (0.30)	366	381	369	386	375^{A}	
0.60 (0.35)	368	384	378	373	376^{A}	
Mean	361^{B}	379^{A}	372^{A}	375^{A}	372	NS
Shell density						
0.50 (0.25)	77.3^{B}	82.5^{A}	82.0^{A}	81.2^{AB}	80.7^{B}	
0.55 (0.30)	82.0^{A}	84.4^{A}	80.8^{AB}	84.9^{A}	83.0^{A}	
0.60 (0.35)	81.6^{AB}	84.9^{A}	83.0^{A}	81.6^{AB}	82.8^{AB}	x
Mean	80.3^{b}	83.9^{A}	81.9^{AB}	82.5^{AB}	82.2	
Shell percent						
0.50 (0.25)	9.15	9.83	9.71	9.65	9.58^{B}	
0.50 (0.30)	9.76	10.05	9.67	10.10	9.89^{A}	
0.60 (0.35)	9.71	10.13	9.95	9.81	9.89^{A}	
Mean	9.54^{B}	10.00^{A}	9.78^{AB}	9.85^{A}	9.79	NS

a, b – $P \leqslant 0.05$; A, B – $P \leqslant 0.01$
NS – not significant

When the P intake increased from 674 to 857 mg/day/hen the P excreted rose from 134 to 233 mg/day/hen, i.e. the P retained increased from 20 to 27% (Table 4). The addition of 300 FTU to the mixture containing 0.50% TP resulted in an increase of retained phosphorus from 134 to 186 mg/day/hen. The addition of 300 FTU to a diet containing 0.55% TP resulted in increase of P retained from 186 to 217 mg. The supplementation the mixture containing 0.60% TP of phytase did not cause further increase of P retention.

TABELA 4

Phosphorus balance

Total P in feed PT (%)	Phytase supplement FTU/kg	P mg/day/hen intake	output	retained	egg weight day/hen	P in eggs*
	0	674	540	134	51.7	115.8
	150	639	502	137	49.5	110.8
0.50	300	708	522	186	61.8	138.4
	450	719	543	176	57.6	129.0
	0	824	638	186	60.6	135.7
	150	769	564	205	57.3	128.3
0.55	300	745	528	217	51.8	116.0
	450	749	519	230	56.7	127.0
	0	857	624	233	54.2	121.4
	150	845	612	612	54.7	122.5
0.60	300	775	583	192	49.4	110.6
	450	822	567	225	53.0	118.7

* for calculation 130 mg P/egg of 58 g weight was taken as a standard

DISCUSSION

Optimum amount of phosphorus in diet not supplemented with phytase

The feed mixture used in the experiment, employed in practical conditions, contained a small amount of feed of animal origin : meat meal containing 24 g of P. This mixture, not supplemented with phosphorus, contained 0.50% TP (0.25% AP). On this feed the laying rate of hens averaged 85.5% over a period of 5 months. Similar results were obtained earlier in an experiment on Hisex White hens (Kamińska et al., 1994).

The amount of P in this diet, used in our experiment, was probably insufficient to obtain maximal laying rate according to genetic potential of Hisex Brown hens. This is confirmed by the results obtained for group of layers receiving 0.60% TP (0.35% AP) whose laying rate during the same period was 91.2%.

In the experiment of Usayran and Balnave (1995) the laying rate of New Hampshire x White Leghorn hens fed a mixture containing wheat, sorgo, soyabean meal and soya oil with 0.12% AP was 85.9%. An increase in phosphorus content did not cause any increase in the laying rate. The hens probably were not genetically predisposed to lay more eggs and their requirement for phosphorus was low. Similarly in studies by Rodriguez et al. (1984) hens fed maize-soyabean mixtures containing 0.15% AP laid fewer eggs (laying rate 74%) than hens receiving 0.30–0.40% AP, whose laying rate was 76–79%.

Similar results of laying rate (81.3%) were obtained by Summers et al. (1976) when hens were fed a diet containing 0.35% AP; the level of phosphorus from 0.15 to 0.55% did not significantly affect the weight of the eggs. Daghir et al. (1985) feeding hens a maize-soyabean diet also found that at 0.15% AP the laying rate was significantly lower (73.4%) than in the groups receiving 0.25, 0.35 or 0.45% AP (76.5%). The level of phosphorus did not influence the weight of the eggs (60.6 g) in this experiment but the shells were thinner when the hens were fed a diet containing 0.45% AP. Similar results have been presented by El Boushy (1979); laying rate was low (52.9%) when AP content was 0.16% and the largest number of eggs was obtained from hens fed a diet containing between 0.20 and 0.40% AP. The egg shell quality was the best when a diet with low AP content (0.16%) was used and the heaviest eggs (62.2 g) were at 1.0% AP, what its in conflict with our results. According to Miles et al. (1983) the use of a diet containing less than 0.30% TP resulted in reduced feed intake and lowered laying rate of hens. Also Owings et al. (1977) found reduced egg shell thickness when maize-soyabean diet not supplemented with feed of animal origin or phosnhorus, containing 0.30% TP (0.10% AP) was fed. When the diet was supplemented with 0.18% inorganic phosphorus to reach the values of 0.48% TP (0.28% AP) the laying rate increased to 85.5% and the egg shells also became thicker. These results have been confirmed by Rao et al. (1995) who showed that the use of a diet containing less than 0.23% AP negatively affects the laying rate.

The results of the studies mentioned above indicate that the best results are obtained with 0.35% available phosphorus in the diet. In our experiments, in which the mixture containing 42% wheat and 10% wheat bran was used, the best laying rate (Table 2) and best egg shell quality (Table 3) were obtained for hens fed a diet containing 0.55% TP, corresponding to 0.30% AP.

Optimal level of phytase

Most studies on the use of phytase in feed mixtures for hens were carried out with broilers but relatively few experiments were made with layers. Peter (1992) points to a significant improvement in laying rate and feed intake when phytase of microbial origin was added to a maize-soyabean diet containing 0.12% of nonphytin phosphorus but does not give the amount of phytase used. Similarly, Simmons et al. (1992) found that the addition of 200 U of microbial phytase was sufficient. Nys (1995), after Sauveur (1989), mentions that for a diet containing 300 units of plant origin phytase the amount of mineral phosphorus added to the diet can be reduced to 0.12%. Similar results were obtained by Usayran and Balnave (1995) who found that when a diet containing over 40% wheat and 200 U of plant origin phytase was used no insufficiency of phosphorus was observed even at 0.12% AP in the diet. In the experiments of these authors the addition of

500 U of microbial phytase to a diet containing 0.32 or 0.46% TP (0.12 or 0.24% AP, respectively) has a negative effect on laying rate and egg shell quality from hens consuming 125–128 g of feed with laying rate below 80%. In our experiments hens taking up approx. 128 g of mixture increased their laying rate from 85.5 to 90.8% as a result of the addition of 150 FTU to a diet containing 0.50% TP (0.25% AP), not supplemented with phosphorus. The supplementation the feed mixture of 300 FTU resulted in maximum laying rate (93.3%) but a further increase of phytase to 450 FTU did not enhanced the laying rate.

Taking, after Cromwell and Coffrey (1993) and Usayran and Balnaven (1995), the content of plant phytase in wheat as 300 U, in bran 700 U and in soyabean meal 150 U, its content in the diets used in our experiment was 220 FTU/kg feed. This amount was, however, insufficient for highly productive layers. Only when 300 FTU were added to the diet the maximum laying rate was obtained by hens fed a diet containing 3% meat meal, without additional phosphate, containing 0.50% TP (0.25% AP). Maximum thickness of the shells (381–0.386 mm), greatest breaking strength (4.06–4.19 kg) and greatest specific gravity of the eggs (1.092 g/cm^3) were obtained with a diet containing 0.55 and 0.60% TP (0.30 and 0.35% AP), supplemented with 150 FTU or feed mixture containing 0.55% TP (0.30% AP) supplemented with 450 FTU.

The amount of added phytase of microbial origin should be adjusted to the content of available phosphorus in the diet and amount of phytase of plant origin, as well as to the production potential of the birds and amount of phosphorus needed for egg production.

Phosphorus balance

The studies of many authors (e.g. Owing et al.,1977; Roland and Farner, 1982; Miles et al., 1983), have shown that the intake of relatively small amounts of P (approx. 300–400 mg/day) by the hens enables satisfactory laying rate. However, basing on the results of many experiments, Roland (1986) considers that the intake of P by hens should be higher, reaching about 700 mg/hen/day at the peak of laying and between 500 and 600 mg later on. This assumption seems to confirm the results obtained by Keshavarz (1986) who found that, depending on P intake from the diet (540–880 mg), the utilization of P ranged from 21.1 to 30.5%. According to Usayran and Balnave (1995), with daily intake of P between 352 and 837 mg, the utilization of this element ranged from 19 to 29% and was therefore similar to that observed by Keshavarz (1986).

In our experiment the intake of phosphorus by hens receiving the feed mixture not supplemented with phosphorus (0.50% TP) was 650 mg per day, and in the group with highest level of phosphorus in the diet – 857 mg/day.

The content of phosphorus in an egg, adopted as an average of 130 mg, was as high as the average daily phosphorus retention by hens in the deficiency group (134 mg). The addition of 150 FTU to feed containing 0.50% TP did not affect phosphorus retention, whereas the addition of 300 FTU increased its retention to 186 mg/day, that is to the same amount as with 0.55% TP in the feed. The retention of phosphorus was the highest in hens fed a diet containing 0.55% TP + 450 FTU and 0.60% TP with or without 150 FTU. In the case of a diet containing 0.60% TP, the addition of 300 or 450 FTU did not have any effect on the phosphorus retention. The supplementation of the mixture, without feed phosphate, with 300 FTU reduced the excretion of phosphorus by 100 mg/day/bird compared to the amount excreted by layers receiving 0.60% TP (0.35% AP). These data are compatible with the results of Klis et al. (1991) who indicates the reduction of P excretion by 42 mg/day/hen after the addition of 500 FTU to the feed containing 0.30% TP (0.25% phytin P).

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STRESZCZENIE

Wpływ poziomu fosforu i dodatku fitazy do mieszanek na wyniki produkcyjne kur nieśnych Hisex Brown oraz jakość skorupy jaj

Doświadczenie wykonano na kurach Hisex Brązowy, od 26 do 48 tygodnia życia, podzielonych na 12 grup po 18 ptaków, trzymanych w indywidualnych klatkach przez 5 miesięcy. Kury żywiono mieszankami pszenno-kukurydziano-sojowymi zawierającymi 0,50, 0,55 i 0,60% P ogólnego (TP), (0,25, 0,30 i 0,35% P przyswajalnego – AP) uzupełnionymi o 0, 150, 300 lub 450 jednostek fitazy na kg (FTU/kg). Kury otrzymujące w paszy 0,50% TP (0,25% P), nie zawierającej fosforanu paszowego, lecz uzupełnionej 300 FTU uzyskały najwyższą nieśność (93%) przy dobrej jakości skorup jaj. Najgrubsze skorupy, o największej wytrzymałości na zgniatanie, uzyskano przy skarmianiu paszy zawierającej 0,55 – 0,60 TP (0,30 – 0,35% AP) uzupełnionej 150 FTU. Nioski żywione mieszanką zawierającą 0,50 TP (0,25% AP) + 300 FTU wydalały o 100 mg/dobę/kurę mniej fosforu niż otrzymujące paszę zawierają 0.60 TP (0,35 AP), nie uzupełnioną fitazą. Za optymalną można uznać paszę zawierającą 0.55 TP (0,25% AP) + 300 FTU/kg lub 0.55 TP (0,30% TP) + 150 FTU/kg.