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Differential influence of phytase supplementation on the balance of phosphorus and other elements in laying hens' feed

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Abstract: The aim of this study was to evaluate the impact of microbial phytase addition to laying hen diet on the balance of phosphorus, calcium, manganese and zinc. Phytase supplementation caused a decrease in phosphorus excretion by 8% in the group with low-phytase diet and 21% in the group with phytase addition of 1000 FTU (one unit of phytase activity) to a diet. Phytase supplementation increased the retention of phosphorus by 31% in laying hens receiving 500 FTU and 57% in the group with phytase addition of 1000 FTU to a diet, in comparison to the group without enzyme supplementation. The level of manganese in excretion was increased by 18% in the group receiving 1000 FTU phytase, and retention decreased by 24% compared with the control group. Zinc excretion was significantly increased in the group receiving 500 FTU ($P \leq 0.01$) and in the group receiving 1000 FTU phytase ($P \leq 0.05$). Retention of zinc was lower ($P \leq 0.01$) when the birds were fed with feed containing 500 FTU and 1000 FTU phytase ($P \leq 0.05$), compared with the control group. No effect on the quantity and retention of calcium excretion was found. There was no impact of phytase supplementation on egg production and egg weight.

Keywords: phytase, laying hens, phosphorus, calcium, manganese, zinc
JEL codes: I, Q

1. Introduction

Phosphorus is essential in laying hens for egg shell resistance as well as for bone strength. The problem is that only 30-40% of total phosphorus in plant feed is available for monogastric

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animals. 60-70% phosphorus is unavailable because it occurs in the form of phytic acid (Jalal and Scheideler 2001: 1463-1471, Rimbach et al. 2008: 131-144).

Phytic acid has a high potential as a chelating agent at neutral pH, and it forms a sparingly soluble complexes with divalent metal cations such as Ca^{+2}, Mg^{+2}, Zn^{+2}, Cu^{+2}, Fe^{+2}, Mn^{+2}, Mo^{+2} and Co^{+2}. Availability of phosphorus and other elements can be increased by the addition of enzyme – phytase (Mohammed et al. 2010: 649-659).

Coverage of phosphorus without phytase involves the addition of inorganic phosphorus to laying hen feed but undigested phosphorus is excreted into the environment (Ceylan et al. 2003: 789-795). It is possible to increase the degree of utilization of phytate phosphorus by adding a feed containing phytase, which is more efficient than plant enzymes releasing phosphorus from phytic acid (Kumar et al. 2012: 335-364). Phytase used as a feed additive for monogastric animals reduces excretion of phosphorus as well as divalent metals. This solution unable to reduce the supplementation of these elements in diets which is essential in livestock production (Kozłowski and Heinz 2011: 25-29).

In areas with a high concentration of livestock production, an excess of phosphorus excreted by animals contributes to eutrophication (Jalal and Scheideler 2001: 1463-1471, Jeppesen et al. 2009: 1930-1941). In order to protect aquatic ecosystems, the amount of phosphorus, that enters the environment, should be reduced (Conley et al. 2009:1014-1015). The use of phytase in laying hen feed decreases phosphorus excretion, thereby reducing the negative impact of laying hens on the environment (Lei et al. 2011: 202-213). Furthermore, the reduced amount of inorganic phosphate added to feed decreases feed costs (Czech 2007: 1034-1039).

In the present work we showed that the level of phytase supplementation to laying hens feed has significant role.

2. Materials and methods

The experiment was carried out with 27 Lohmann Brown-Classic laying hens at the age of 30 weeks. Each group consisting 3 cages with 3 birds was divided into 3 groups (9 birds). During the experiment the lighting program was constant within 16 hours. Hens were fed semi ad libitum (130 g/head/day of feed) (Table 1). The composed mixture was prepared according to dietary recommendations (Layer Management Guide 2011: 15-16). The control group received feed without added phytase, while the experimental groups received feed containing 500 and 1000 FTU (one unit of phytase activity) microbial phytase.

Hens were weighed at the beginning and the end of the experiment. Excreta were weighed daily and representative samples were subsequently frozen. Every day egg mass and number of egg laid was recorded. The eggs were sampled and distributed to contents of the eggs (white and yolk) and shells with membranes. Samples were frozen at -25 °C. After thawing the eggs and excreta, the samples were analyzed for total phosphorus, calcium, manganese and zinc using standard methods (AOAC 2005).

All data were evaluated statistically using one-way analysis of variance (ANOVA). The differences between parameters were tested accordingly to the statistical model:

$$y_{ij} = \mu + \alpha_i + e_{ij}$$

with: y_{ij} – observation of the j-th element in the i-th group, μ - the overall mean, α_i – effect of addition of phytase in the diet; e_{ij} –an error term

Differences between treatment means were evaluated using the Duncan test. Two levels of significance were presented ($P \leq 0.05$ and $P \leq 0.01$). All statistical analyses were performed with commercial software (StatSoft Inc. 2011).

3. Results and discussion

The body weight of laying hens was similar and averaged 1.72 kg, during the follow-up period. During the experiment, egg production averaged 83.57% in the control group and in the group receiving 500 FTU phytase. Egg production was higher (89.86%) in the group supplemented with 1000 FTU phytase. This difference could not be confirmed statistically, and there are in accordance with studies of Snow et al. (2003: 474-477) and Keshavarz (2000: 748-763). However, Lim et al. (2003: 92-99), Mustafa et al. (2012: 181-189) and Scott et al. (1999: 1742-1749) showed increased egg production in laying hen diet containing phytase.

An average egg weight oscillated from 53.63 g to 55.40 g, and there was no significant difference between treatments. In this experiment, similar results were presented by Um and Paik (1999: 75-79), where the addition of phytase did not affect the weight of the eggs. However, Keshavarz (2000: 748-763) observed a marked increase in the mass of eggs when phytase was added to the feed.

The results of phosphorus balance are presented in Table 2. The intake of phosphorus in all groups was very similar and a slight difference between the groups could be caused by the administration of 130 g/head/day feed. The hens receiving no phytase supplemented diet excreted about 8% and 21% more phosphorus compared to the hens treated with 500 FTU and 1000 FTU phytase in feed, respectively. The significant differences ($P \leq 0.05$) in the amount of excreted phosphorus were observed between the two groups with different levels of phytase in feed, and between the group receiving 1000 FTU phytase in feed and the control group ($P \leq 0.01$). The amount of phosphorus excreted in the shells, the content of eggs and in the total eggs was similar in all groups. These results suggest that the main cause of differences in the amount of phosphorus, excreted by laying hens into the environment, is the amount of the element contained in the excreta.

Excretion of phosphorus by laying hens was highest in the control group compared to the groups that were fed with diet supplemented with phytase. Compared to the control group, the decrease of phosphorus quantity amounted to about 10% in the group receiving 500 FTU, and almost 18% in the group with 1000 FTU phytase in feed. Only the difference between the birds in the control group and the birds receiving feed with 1000 FTU phytase was statistically significant ($P \leq 0.01$). A beneficial effect of the addition of phytase on phosphorus balance was confirmed in many studies (Ceylan et al. 2003: 789-795; Abudabos 2012: 41-46; Gordon and Roland 1997: 1172-1177), which showed that the higher the addition of phytase, the smaller the phosphorus excretion by laying hens. Um and Paik (1999: 75-79) found that the addition of 500 units of phytase/kg to feed reduces phosphorus excretion into the environment by 41%, and it may reduce the amount of phosphorus in the feed to 0.12 g/head/day. However, Ahmadi and Rodehutscord (2012: 2072-2078) reported that inorganic phosphorus supplemented in feed may amount to 0.14 g/head/day after the addition of 400 FTU phytase to feed, and it does not have any negative impact on the performance and health of the birds. In the experiment of Casartelli et al. (2005: 93-98), the supplementation of 1000 FTU allowed to reduce phosphorus excretion in the environment by 47.1%.

In the present study, phosphorus retention increased with increasing addition of phytase to the laying hen feed (Table 2). Phosphorus retention was increased by 31% in the group receiving 500 FTU, and by 57% in the group with 1000 FTU phytase addition to feed. Important differences were seen between the control group and the group receiving phytase of 1000 FTU.

These results are confirmed by the studies of Keshavarz and Austic (2004: 75-83) and Tahmasbi et al. (2012: 204-214), in which the authors noted a higher retention in the groups of hens receiving phytase addition to feed.

The results of the calcium, mangnesium and zinc balance in laying hen feed with the addition of phytase are presented in Table 3. The small differences in the intake of all the elements were caused by residual feed. There was a downward trend in the level of calcium in the shells, which was reduced by 2% with the addition of 500 FTU phytase to feed and almost by 5% with the addition of 1000 FTU to feed in laying hens. The amount of calcium in the content of eggs in the control group and the group receiving 500 units of phytase was similar (0.011 g). Lower excretion of calcium was observed in the group receiving 1000 FTU phytase, and this decrease amounted to approximately 20% compared to the group receiving 500 FTU phytase. Both calcium excretion and retention in all groups did not significantly differ from each other. Only between the control group and the group receiving 1000 FTU phytase, the retention was higher by 4%. In the present experiment, addition of phytase to chicken diets did not significantly affect the amount of calcium excretion in excreta and eggshells. In the studies of Kozłowski et al. (2011: 25-29), Ebrahim-Nezhad et al. (2008: 351-356), Liebert et al. (2005: 1576-1583), Lim et al. (2003: 92-99) and Ceylan et al. (2003: 789-795), no effect of phytase on calcium retention was also reported in laying hens.

The excretion level of manganese (Table 3) in excreta increased significantly between the control group and the group receiving 1000 FTU phytase, which resulted in a significant increase of total excretion of mangnesium in laying hens. There were no differences in the excretion of mangnesium in the content of eggs and eggshells between the diet groups. Retention of mangnesium decreased significantly ($P \leq 0.01$) between the control group and the group receiving 1000 FTU phytase. The amount of zinc in excreta and the total excretion was increased in the group receiving 500 FTU ($P \leq 0.01$) and in the group receiving 1000 FTU phytase ($P \leq 0.05$). A significant ($P \leq 0.01$) increase of zinc content of eggshells was observed in the group receiving 500 FTU phytase and a significant decrease was shown in the group receiving 1000 FTU phytase compared to the control group. No differences in zinc content were found in the contents of eggs. Retention of zinc decreased in the both experimental group as compared with the control group. There were significant differences ($P \leq 0.01$) in the group receiving 500 FTU phytase and in the group with 1000 FTU phytase in a feed ($P \leq 0.05$). In the experiment conducted by Lim et al. (2003: 92-99), the supplementation of phytase also resulted in a decrease of zinc retention but did not affect the amount of zinc excreted by laying hens. However, in the study Ceylan et al. (2003: 789-795), no effect of phytase on the retention of zinc and manganese was observed.

4. Conclusion

The results of the experiments showed that the addition of phytase to the laying hen feed:

1. reduced the amount of phosphorus excreted by the laying hens and increased the retention of this element ($P \leq 0.01$)
2. 1000 FTU of phytase reduced the phosphorus excretion when compared to hens fed with feed containing 500 FTU phytase ($P \leq 0.05$)
3. had no significant effect on the retention and excretion of calcium
4. increased the excretion of zinc and mangnesium and the reduction of retention of above-mentioned elements
5. did not affect egg production and egg weight

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Wpływ dodatku fitazy mikrobiologicznej w żywieniu kur nieśnych na bilans fosforu oraz innych pierwiastków

Streszczenie

W prezentowanej pracy przedstawiono badania dotyczące wpływu dodatku fitazy mikrobiologicznej do mieszanki pełnoporcjowej przeznaczonej dla kur nieśnych na bilans fosforu, wapnia, manganu i cynku. Dodatek fitazy wpłynął na obniżenie wydalania fosforu w kałomoczu o 8% w grupie otrzymującej paszę z mniejszym dodatkiem oraz o 21% w grupie z dodatkiem 1000 FTU fitazy. Dodatek enzymu do mieszanki zwiększył także retencję fosforu o 31% u kur nieśnych otrzymujących 500 FTU i o 57% w grupie z dodatkiem 1000 FTU fitazy w porównaniu do grupy ptaków nie otrzymujących tego enzymu. Ilość fosforu wydalanego w jajach była wyrównana we wszystkich grupach i nie zaobserwowano istotnych różnic pomiędzy nimi. Kury nioski otrzymujące 1000 FTU fitazy w paszy wydalały o 18% więcej manganu w pomiocie i jednocześnie o 24% spadła jego retencja w porównaniu z grupą kontrolną. Ilość cynku wydalanego przez ptaki zwiększyła się w grupie otrzymującej 500 FTU ($p \leq 0.01$) oraz w grupie otrzymującej 1000 FTU fitazy ($p \leq 0.05$). Retencja cynku była niższa ($p < 0.01$) w porównaniu z grupą kontrolną zarówno gdy ptaki żywiono paszą z dodatkiem 500 FTU fitazy, jak i w grupie dostającej 1000 FTU ($p \leq 0.05$). Niezależnie od ilości dodatku badanego enzymu nie obserwowano jego wpływu na ilość oraz retencję wapnia wydalanego przez kury nioski. W doświadczeniu nie stwierdzono wpływu dodatku fitazy na nieśność oraz masę jaj.

Słowa kluczowe: fitaza, kury nioski, fosfor, wapń, mangan, cynk