Effect of Two Dietary Phosphorus Levels on the Performance of Laying Hens and Eggshell Quality over the Common Laying Period

Annamária TISCHLER (✉)
János TOSSENBERGER
Veronika HALAS

Summary

The aim of the present trial was to study the effect of two different dietary phosphorus (P) levels on the laying performance in long-term (17 months) egg production and egg shell quality in terms of strength and thickness from the 7th to 17th month of laying. In case of eggshell quality parameters the time effect as well as the interaction between dietary P levels and time were also examined. Sixty Tetra-SL layers were fed diets with two different levels of P (4.9 or 4.4 g/kg total phosphorus) at constant 38.5 g/kg calcium level. In the course of the trial egg production %, egg weight, feed intake and body weight were recorded. At every 4th weeks 20 eggs per treatment were broken to deretmine the strength and thickness of eggshell. Results showed that the examined two levels of dietary P did not affect the percentage of egg production and the feed conversion ratio (kg feed/kg egg mass). The egg weight significantly increased and eggshell strength was significantly lower when hens received the lower dietary P feed. During the laying period, both the eggshell strength and thickness gradually decreased as laying period time went on. In conclusion phosphorus content of the layer diet can be lowered, without reducing the egg production, nevertheless approaching the end of the long laying period, higher P-content feed suggested, whereby eggshell strength can be improved.

Key words

hen, diet, phosphorus, long laying period, eggshell quality

University of Kaposvár, Science of Animal, Department of Animal Nutrition,
Guba S. str. 40, 7400 Kaposvár, Hungary
✉ e-mail: tischler.annamaria@ke.hu

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Background and aim

The main goals of laying hens' genetic selection are to extend the laying period keeping egg production above 90%, as well as to improve eggshell quality towards the end of the term, considering that hair cracked or broken eggshells can be used neither as food nor as hatching egg. It is well known that the shell of the older hens' eggs are weaker than the younger ones' (Rodriguez-Navarro, 2002). In general, eggshell quality problems occur at the second half of the common laying period. From economical point of view, quality of eggshell plays a key role in profitability of the poultry industry. According to Swiatkiewicz et al. (2010) the loss of production due to egg shell problems is considerable being 8-10% of worldwide produced eggs'. Aside from the genetic background, nutrition has essential importance in the eggshell quality that is particularly affected by mineral (principally Ca and P) supply. Decreasing breaking strength indicates thinner eggshell that is usually caused by inadequate P supply (Meyer and Parsons, 2011). Leeson et al. (1993) reported that in the common laying period (from 19 to 71 weeks of age) 0.35% dietary total P was sufficient for egg production and shell quality. Numbers of studies have reported the optimal P supply of layers in the 12 months laying period (Hurwitz and Griminger, 1962; Boorman and Gunaratne, 2001; NRC, 1994; Rao Rama et al., 2003; Ahmad, 2004; Snow et al., 2004; Kebreab, 2009). However, there is no available literature data at all about the P requirement of hens over the common one-year laying term with particular emphasise on the eggshell quality.

Therefore, the aim of our trial was to study the effect of two different levels of dietary P levels on the production of layers and the quality of eggshell in an elongated (17 month long) laying term. In case of eggshell quality parameters the time effect as well as the interaction between dietary P levels and time were also examined.

Material and methods

In the experiment, 60 Tetra-SL layers were assigned equally to each of two dietary treatments and kept by three in metabolic cages. The birds were 20 weeks of age at the beginning of the trial. Light program was according to the reference of the breeder. Dietary treatments varied in dietary phosphorus level containing 4.9 g/kg total P as recommended by NRC (1994) or 4.4 g/kg of P per kg of feed, with constant dietary energy (11.5 MJ AMEn/kg), protein (160 g/kg), Ca (38.5 g/kg), and amino acid content (8.8 g Lys, 7.8 g Met+Cys per kg feed). The composition and the nutrient content of experimental diets are showed in Table 1. Performance of the layers was examined in a long-term (17 months, M1-M17) laying period, likewise eggshell quality was determined from M7 to M17 of laying. Eggshell quality problems occur at the second half of the laying period therefore we determined the eggshell strength and thickness only for the last 11 months of production. The eggproduction and the egg weight were daily recorded by cages, the feed intake was measured weekly, and the birds were weighed monthly. Performance of the hens were characterized by average daily feed intake (g/d/bird), egg weight (g/egg), egg production (%) and feed conversion ratio (kg feed/kg egg mass). Monthly 20 eggs per treatment were collected and broken to determine the strength and thickness of eggshell. Egg was placed horizontally in Zwick Roell Z005 type of instrument and the breaking power was determined in N, that was converted into kilogram (1N = 0.102 kg). Eggshell thickness was measured by an electronic micrometer (Mitutoyo) with 0.001 mm accuracy based on average of three measurement per egg. Productive traits (egg production %, feed intake, feed conversion, egg weight) were analysed by one-way ANOVA with dietary P level as fixed effect. The statistical reliability of deviance of egg weight from 63 g was tested by unpaired Students' T-test. Data of eggshell strength and thickness were analysed by two-way ANOVA (SAS, 2004), as follows:

$$Y_{ijk} = \mu + P_i + T_j + P_i{*}T_j + e_k$$

where: Y_{ijk} = dependent variable, μ = general mean, P_i = effect of P levels (i=2; 4.9, 4.4 g/kg), T_j = effect of the laying time (j=11; M7-M17), $P_i{*}T_j$ = effect of interactions, e_k = undefined error.

Results and discussion

Live weight of the birds was according to the technological guidance of the breeder and it was not affected by dietary P level. Effect of dietary treatments on the layers' performance is showed in Figure 1. There was no difference in the egg production of hens in two treatments (P>0.05). Egg production attained 80% in the first month, reached the maximum production

Table 1. Ingredients and analysed chemical composition of the diets (g/kg)

Composition	High P level	Low P level	Nutrient content	High P level	Low P level
Corn	631	635	Dry matter	806	806
Soybean meal (CP: 47%)	252	252	AMEn (MJ/kg)[3]	11.5	11.5
Oil	2.0	0.0	Crude protein	160.3	160.6
MCP[1]	8.0	5.5	Lysine	8.8	8.8
Limestone	94.0	94.0	Met+Cys	7.5	7.8
Sodium Chloride	4.0	4.0	Threonine	6.8	6.9
Lysine-HCl	1.0	1.0	Tryptophan[3]	2.1	2.1
DL-Metionine	2.7	2.7	Ca	38.5	38.5
L-Treonine	0.5	0.5	P (total)	4.9	4.4
L-Tryptophan	0.2	0.2	P (non phytin)[3]	2.5	2.0
Premix[2]	5.0	5.0	Na[3]	1.6	1.6

[1] Mono calcium phosphate, [2] 1 kg premix contain: Zn: 7974 mg, Cu: 1100 mg, Fe: 1100 mg, Mn: 10980 mg, I: 350 mg, Se: 40 mg, Co: 75 mg, Vit. A: 1600800 IU, Vit. D3: 370000 IU, Vit. E: 9700 mg, Vit K3: 990 mg, Vit. B1: 495 mg, Vit. B2: 1280 mg, Vit. B3: 5000 mg/kg, Vit. B5: 1985 mg, Vit. B6: 600 mg, Vit B12: 6 mg, Cholin: 45900 mg, Folic acid: 450 mg, Biotin: 50 mg; [3]calculated values

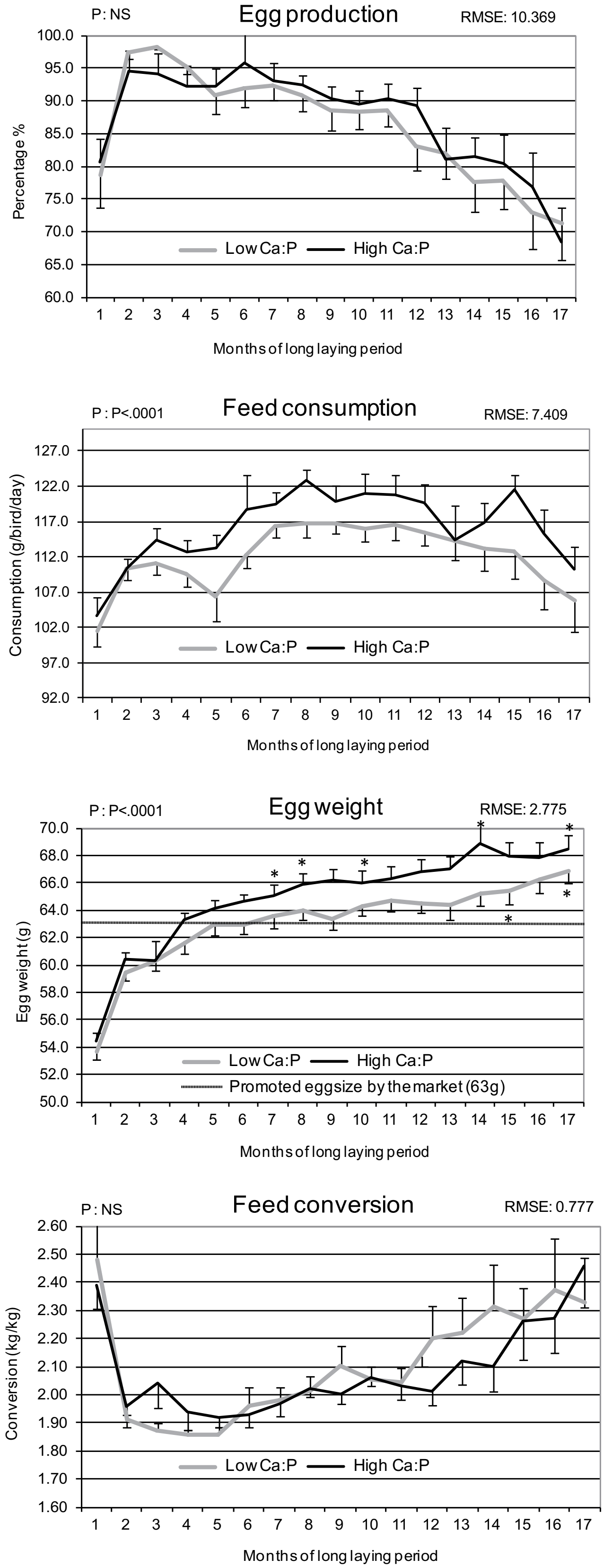

Figure 1. Effect of dietary phosphorus level (P) on the egg production

Table 2. Effects of dietary phosphorus level and time of the trial period on the eggshell strength (kg) and thickness (mm)

		Eggshell strength	Eggshell thickness
P levels	High	3.5^{a}	0.344^{a}
	Low	3.3^{b}	0.341^{a}
Months[1]	M7	4.1^{a}	0.354^{a}
	M8	4.1^{a}	0.348^{ba}
	M9	3.9^{ba}	0.348^{ba}
	M10	3.8^{bc}	0.346^{bac}
	M11	3.7^{dc}	0.344^{bdc}
	M12	3.4^{d}	0.344^{bdc}
	M13	3.4^{d}	0.342^{bedc}
	M14	3.1^{e}	0.340^{edc}
	M15	2.8^{fe}	0.338^{ed}
	M16	2.8^{fg}	0.336^{e}
	M17	2.5^{g}	0.327^{f}
RMSE[2]		0.842	0.025
P-values	Treats[3]	<0.0001	NS
	Months[1]	<0.0001	<0.0001

[1]Months of the laying period (M7-M17), [2]Root mean square error, [3]Two levels of P

rate (above 95%) at the second month, then it progressively decreased. From M9 production rate went below 90%, and from M13 it decreased by 80%.

Dietary P level significantly affected the egg weight (P<0.0001), namely lower P supply accompanied with higher egg weight. The desirable egg size (category of M) is within a range of 53-63 g in European Union, up to 62 g and 64 g in Canada and in US, respectively. The bigger eggs, in general, are not preferred either by the consumers (Bejaei, 2009). Therefore the statistical reliability of deviance of egg weight from 63 g was tested to determine the time length of the so called normal size (medium) eggs' production. Due to the positive effect of low P treatment on the egg weight, the eggs were within the preferred range for only 7 months when dietary P was 4.4 g/kg, meanwhile it was 13 months period when diet contained 4.9 g/kg of total P. The reason for the higher egg weight is likely the higher feed intake in low P treatment. Although the difference was only 3%, it was statistically significant (P<0.0001). The birds seemed to compensate somewhat for the 10% lower dietary P level, by which the energy and protein supply available for egg production was increased. Experimental feeds showed no significant effect on the feed conversion in terms of kg feed consumption per kg egg mass production. The effect of the experimental treatments on the eggshell quality (strength and thickness) is showed in Table 2. Effects of dietary P levels and time were significant (P<0.0001), and interaction between the considered factors was not observed (P>0.05). Egg shells were weaker at low P level (4.4 g/kg) compared to the high P level (4.9 g/kg), which is in line with the bigger egg size. It is well known that the bigger eggs at the second half of the laying period usually have thinner eggshell disposing to hair cracked eggs. The 4.1 kg of eggshell strength found at the beginning of the experimental period progressively decreased reaching 2.5 kg at the end of the laying period. Unlike dietary P level and interaction between dietary P and time (P>0.10), the time of the long laying period had significant effect on the eggshell thickness (P<0.0001). Approaching the end of the long laying period, as the eggshell strength, also its thickness decreased from the initial 0.354 mm to 0.327 mm ($P<0.001$). Contrary to our data, several studies report moderately strong correlation between eggshell strength and thickness (Zhang et al., 2005; Sun et al., 2012). Nevertheless, the egg strength is more important trait of eggshell quality than eggshell thickness, since it has direct practical consequences. At the beginning of our examinations, the measured eggshell strength and thickness indicated a good quality eggs (Jacob et al., 2000). In the 17th month measured 2.5 kg cracking power was much less than the values at the opening measurement; however, according to Arpasova et al. (2010) it is still acceptable. The 2.5 kg or lower values for breaking power are common in the second laying cycle after moulting (Cath et al, 2012). Although, number of studies have shown that with the NRC (1994) recommended dietary total P content the P requirement of laying hens in intensive production is oversupplied particularly in the first part of laying period (Kucukyilmaz, 2012; Rodehutscord and Shastak, 2013), our data suggest that over the common one-year laying term, 10% reduction of the recommended P reduces the eggshell strength. However, we hypothesize that if dietary energy and protein content was adjusted in diet formulation from the second part of the laying period according to the higher intake than large and weak eggshell might be avoided.

Conclusions

On the base of our data, dietary phosphorus content of layers' diet can be lowered from 4.9 to 4.4 g/kg without compromising the egg production, nevertheless this 10% reduction of dietary P is not recommended in the second part of egg production term since it resulted in non-preferred big size eggs and thus weaker eggshell quality.

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