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Effects of Dietary Magnesium Concentrations on Performance and Eggshell Quality of Laying Hens

C.H. Kim, I.K. Paik, D.Y. Kil and M.B. Chang
Department of Animal Science and Technology, School of Bioresource and Bioscience,
Chung-Ang University, 456-756 Anseong-Si, Gyeonggi-Do, Republic of Korea

Abstract: The objective of this experiment was to investigate the effect of dietary Magnesium (Mg) concentrations on productive performance and eggshell quality of laying hens. A total of 800 Hy-Line Brown laying hens (46 weeks old) were randomly allotted to 1 of 5 dietary treatments with 4 replicates per treatment. A commercial-type basal diet (1.7 g kg^{-1} Mg) was prepared and 4 additional diets were formulated to contain 2.3, 3.0, 3.5 or 4.2 g kg^{-1} Mg in diets by adding 1.0, 2.0, 3.0 or 4.0 g of MgO (600 g kg^{-1} Mg) to the basal diet. The diets were fed to hens as *ad libitum* basis for 6 weeks. Results indicated that increasing concentrations of Mg in diets increased Mg concentrations in eggshells (linear and quadratic, $p<0.05$). Increasing concentrations of Mg in diets increased eggshell strength (quadratic, $p<0.05$) and eggshell thickness (linear, $p<0.05$) but decreased Hunter a* values for eggshell (linear, $p<0.01$). Hen-day egg production, feed intake, feed conversion ratio, egg weight and Haugh unit were not affected by Mg concentrations in diets. In conclusion, feeding diets containing increasing concentrations of Mg up to 4.2 g kg^{-1} to laying hens improves eggshell strength and eggshell thickness but has no effects on productive performance of laying hens.

Key words: Eggshell quality, laying hens, magnesium, productive performance, effect of dietary

INTRODUCTION

Magnesium (Mg) is an essential mineral for a wide variety of physiological functions in humans and animals (Gaal *et al*., 2004). It is an important nutrient for laying hens in terms of eggshell formation and quality because Mg is the second highest mineral in eggshells (Romanoff and Romanoff, 1949). The current Mg requirement of laying hens has been reported to be 0.4 g kg^{-1} in diets (NRC, 1994). However, the supplementation of excess amounts of Mg in diets above the requirement has often shown to improve eggshell quality of laying hens. Mehring and Johnson (1965) and West reported that feeding the diets containing 5.0 g kg^{-1} laying hens increased eggshell strength and thickness. Similar improvement for eggshell quality was also observed by Seo *et al*. (2010) and Kim *et al*. (2013) who fed the diets containing 3.0-4.7 g kg^{-1} Mg to laying hens. On the contrary, excess amount of Mg in diets has been report to have negative impacts on eggshell quality and productive performance of laying hens. Mehring and Johnson (1965) reported that feeding the diets containing >8.7 g kg^{-1} to laying hens decreased eggshell strength. McWard (1967) observed a reduction in egg production and feed efficiency when diets contained 12.0 g kg^{-1} Mg. Insufficient data pertaining to the effects of Mg concentrations in diets on laying performance and egg quality have led to a difficulty for egg producers to determine the Mg concentrations in the diets fed to laying hens. Therefore, the objective of this experiment was to evaluate the effects of Mg concentrations in diets on productive performance and eggshell quality of laying hens.

MATERIALS AND METHODS

Experimental design and diets: A total of 800, 46 weeks old Hy-Line Brown laying hens were randomly allotted to 1 of 5 dietary treatments. Each treatment had 4 replicates with 20 cages and 2 hens per cage (30×37×40 cm = Width×length×height). A commercial-type basal diet was formulated to meet or exceed nutrient recommendations of NRC (1994) for laying hens and the concentrations of Mg in the basal diet were estimated to be 1.7 g kg^{-1} (Table 1). Four additional diets were prepared by supplementing 1.0, 2.0, 3.0 or 4.0 g of MgO (600 g kg^{-1} Mg; Samchun Pure Chemical Co., Ltd., Pyeongtaek, South Korea) to the basal diet at the expense of inert zeolite (Handu Co. Ltd., Gyeongju, Korea). The analyzed concentrations of Mg in these 4 diets were 2.3,

Corresponding Author: Moon Baek Chang, Department of Animal Science and Technology, School of Bioresource and Bioscience, College of Natural Sciences, Chung-Ang University, 456-756 Anseong-Si, Gyeonggi-Do, Republic of Korea

Table 1: Composition and nutrient content of experimental diets

	Mg concentrations in diets (g kg^{-1})				
Items	1.7	2.3	3.0	3.5	4.2
Ingredients (g kg^{-1})					
Corn	408.0	408.0	408.0	408.0	408.0
Soybean meal	250.0	250.0	250.0	250.0	250.0
Canola meal	20.0	20.0	20.0	20.0	20.0
Wheat	150.0	150.0	150.0	150.0	150.0
DDGS	50.0	50.0	50.0	50.0	50.0
Limestone	87.0	87.0	87.0	87.0	87.0
Oyster shells	10.0	10.0	10.0	10.0	10.0
Molasses	5.0	5.0	5.0	5.0	5.0
Tallow	5.0	5.0	5.0	5.0	5.0
Dicalcium phosphate	7.0	7.0	7.0	7.0	7.0
NaCl	2.0	2.0	2.0	2.0	2.0
Vitamin-mineral premix[1]	1.5	1.5	1.5	1.5	1.5
Zeolite[2]	4.0	3.0	2.0	1.0	-
Fe-soy proteinate[3]	0.5	0.5	0.5	0.5	0.5
MgO	-	1.0	2.0	3.0	4.0
Total	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0
Nutrient content[4]					
Me_n (kcal kg^{-1})	2,749.0	2,749.0	2,749.0	2,749.0	2,749.0
Crude protein (g kg^{-1})	165.0	165.0	165.0	165.0	165.0
Lysine (g kg^{-1})	9.0	9.0	9.0	9.0	9.0
Methionine (g kg^{-1})	4.5	4.5	4.5	4.5	4.5
Ca (g kg^{-1})	39.0	39.0	39.0	39.0	39.0
Available P (g kg^{-1})	3.3	3.3	3.3	3.3	3.3
Mg (g kg^{-1})[5]	1.7	2.3	3.0	3.5	4.2

[1]Provided per kilogram of the complete diet: Vitamin A (as vitamin A acetate), 12,500 IU; vitamin D_3, 2,500 IU; vitamin E (as DL-α-tocopheryl acetate), 20 IU; vitamin K_3, 2 mg; vitamin B_1, 2 mg; g vitamin B_2, 5 mg; vitamin B_6, 3 mg; vitamin B_{12}, 18 µg; calcium pantothenate, 8 mg; folic acid, 1 mg; biotin, 50 µg; niacin, 24 mg; Zn (as ZnO) , 60 mg; Mn (as $MnSO_2 \cdot H_2O$), 50 mg; Fe (as $FeSO_4 \cdot 7H_2O$), 50 mg; Cu (as $CuSO_4 \cdot 5H_2O$), 6 mg; Co (as $CoCO_3$), 250 µg; I (as $Ca(IO_3)_2 \cdot H_2O$), 1 mg; Se (as Na_2SeO_3), 150 µg; [2]Zeolite (Handu Co., Ltd., South Korea); [3]Fe-soy proteinate contains approximately 200 g kg^{-1} Fe; [4]Nutrient contents except Mg content in all diets were calculated; [5]Analyzed value

3.0, 3.5 and 4.2 g kg^{-1} Mg, respectively. The experimental periods were 6 weeks. During the experiment, hens were provided with feed and water *ad libitum* and were exposed to a 16 L: 8D lighting schedule. The temperature and humidity of laying house was maintained at 18±3°C and 65~70%, respectively during the experiment. The protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at Chung-Ang University.

Chemical analysis and data collection: Hen-day egg production (%), egg weight (g) and shell-less egg production rate (%) was recorded daily whereas feed intake and feed conversion ratio was recorded weekly from 46-51 weeks of age. Feed conversion ratio was expressed as g of feed intake per g of egg produced. Twenty eggs per replicate were randomly collected every week to measure individual weight and then the external (eggshell strength, eggshell thickness and eggshell color) and internal (eggyolk color and Haugh unit) quality was determined. Eggshell strength was measured by the compression test cell with Texture Systems (Model T2100C, Food Technology Co., Ltd., Rockville, MD, USA) and was expressed as unit of compression force exposed to unit eggshell surface area (kg/cm^2).

Eggshell thickness (without inner and outer shell membrane) was determined by measuring the thickness mean values taken at 3 locations on the eggshell (air cell, equator and sharp end) by using a using a dial pipe gauge (Model 7360, Mitutoyo Co., Ltd., Kawasaki, Japan). The Hunter color values for lightness (L*), redness (a*) and yellowness (b*) in the eggshell were measured using the Minolta Chroma Meter CR-400 (Minolta, Osaka, Japan). Eggyolk color was also evaluated by the Roche color fan (Hoffman-La Roche Ltd., Basel, Switzerland; 1 = Light pale and 15 = Dark orange). Haugh units were determined by using micrometer (Model S-8400, Ames, Waltham, MA, USA) and calculated from the values for albumen height and egg weight using the following equation:

$$\text{Haugh units} = 100 \log_{10} (H\text{-}1.7\ W^{0.37} + 7.56)$$

Where:

H = Height of the albumen

W = Egg weight (Eisen *et al*., 1962)

The concentrations of Mg in diets and eggshells were determined by the Inductively Coupled Plasma spectrometry (ICP; Optima 5300 DV, Perkin Elmer Co., Ltd., New York, USA) following nitric/perchloric acid wet-ash digestion (AOAC, 1995). The data for laying performance and eggshell characteristics were pooled and summarized for overall means during the 6 weeks experimental period.

Statistical analysis: All data were analyzed by ANOVA according to completely randomized design using the Proc Mixed procedure of SAS (SAS Inst., Inc., Cary, NC). Outlier data were identified by the UNIVARIATE procedure of SAS but no outliers were found. The experimental unit for all data was the replicate. Dietary treatment was a fixed effect in the model. The LSMEANS procedure was used to calculate mean values. The orthogonal polynomial contrast test was performed to determine linear and quadratic effects of increasing concentrations of Mg in diets on laying performance and eggshell characteristics. Significance for statistical tests were set at $p<0.05$.

RESULTS AND DISCUSSION

During 6 weeks of the feeding trial, hen-day egg production, feed intake, feed conversion ratio, egg weight and broken and shell-less egg production were not influenced by increasing concentrations of Mg from

Table 2: Effects of Mg concentrations in diets on productive performance of laying hens[1]

Items	Mg concentrations in diets ($g\ kg^{-1}$)[2]					SEM	p-value[3]	
	1.7	2.3	3.0	3.5	4.2		Linear	Quadratic
Laying performance								
Hen-day egg production (%)	87.20	87.30	88.00	87.30	87.30	0.30	0.41	0.57
Feed intake (g/d/hen)	127.80	123.80	125.30	125.80	126.30	1.53	0.82	0.17
Feed conversion ratio (g/g)	2.27	2.18	2.21	2.22	2.22	0.03	0.49	0.17
Egg weight (g)	64.60	65.10	65.10	65.80	65.60	0.32	0.46	0.80
Broken and shell-less eggs (%)	0.02	0.05	0.03	0.09	0.07	0.02	0.10	0.93
Eggshell quality								
Eggshell Mg (mg/g of DM)	2.54	2.76	2.82	2.86	2.93	0.03	<0.01	0.03
Eggshell strength ($kg\ cm^{-2}$)	3.41	3.90	3.83	3.68	3.72	0.11	0.26	0.03
Eggshell thickness (μm)	373.00	384.00	388.00	376.00	401.00	4.28	0.02	0.45
Eggshell color[4]								
L*	54.50	54.30	54.60	54.30	53.30	0.52	0.07	0.14
a*	14.90	14.70	14.30	13.20	13.60	0.30	<0.01	0.58
b*	20.50	20.40	20.70	20.20	20.20	0.14	0.12	0.22
Eggyolk color	8.90	9.00	8.80	9.10	9.00	0.10	0.50	0.68
Haugh units	81.80	83.60	81.70	82.70	81.30	0.84	0.50	0.27

[1]Data are least square means of 4 replicates per treatment; [2]Magnesium oxide (600 g Mg kg^{-1}) was supplemented at the level of 0.0, 1.0, 2.0, 3.0 or 4.0 g kg^{-1} of the basal diet, respectively; [3]p-values for linear and quadratic effects of increasing concentrations of Mg in diets; [4]Hunter values for lightness (L*), redness (a*) and yellowness (b*)

1.7-4.2 g kg^{-1} in diets (Table 2). This result agrees with previous experiments reporting that 2.0-6.6 g kg^{-1} Mg from either $MgCO_3$ or MgO in diets had no effects on laying performance (Hossain and Bertechini, 1998; Seo *et al*., 2010; Kim *et al*., 2013). Therefore, it is likely that surplus amounts of Mg up to 4.2 g kg^{-1} in diets may apply to laying hens' diet with no negative impacts on laying performance.

The concentrations of Mg in eggshells were increased with Mg concentrations in diets (linear and quadratic, $p<0.05$). Increasing concentrations of Mg in diets increased eggshell strength (quadratic, $p<0.05$) and eggshell thickness (linear, $p<0.05$). Similar improvements by feeding surplus amounts of Mg above requirements to laying hens were observed in earlier experiments (Mehring and Johnson, 1965; West *et al*., 1980; Seo *et al*., 2010; Kim *et al*., 2013). The reason for this improvement has been associated with increased concentrations of Mg in eggshells because eggshell hardness is positively correlated with Mg concentrations in eggshells (Brooks and Hale, 1955; Stafford and Edwards, 1973). In the earlier experiments, however aged laying hens (72 weeks old) has a linear improvement in eggshell strength as the Mg concentrations in diets increased from 1.6-4.2 g kg^{-1} whereas in this experiment eggshell strength was the highest for laying hens fed the diets containing 2.3 g kg^{-1} Mg and then gradually decreased with Mg concentrations. This result indicates that optimal Mg concentrations in diets for eggshell strength may depend on the age of hens.

For the eggshell hunter values for redness (a*) was decreased (linear, $p<0.01$) as Mg concentrations in diets increased. Although, the significance was not detected, the hunter L* and b* values were also numerically decreased with Mg concentrations in diets. The earlier experiments also reported that laying hens fed the diets containing surplus amounts of Mg decreased hunter L*, a* and b* values for eggshells (Seo *et al*., 2010; Kim *et al*., 2013). The possible reason for this observation is an increase in Mg concentrations in eggshells and its white elemental color (Kim *et al*., 2013). However, the overall hunter values for eggshells as observed in this experiment were within the range of normal eggshell colors. The eggyolk color and Haugh units were not affected by Mg concentrations in diets which indicate that surplus amounts of Mg in diets may have no effects on eggyolk pigmentation and freshness of eggs.

CONCLUSION

In this study, the results show that surplus amounts of Mg up to 4.2 g kg^{-1} Mg in diets improve eggshell strength and eggshell thickness but have no detrimental effects on performance of laying hens.

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REFERENCES

AOAC, 1995. Official Method of Analysis. 16th Edn., Association of Official Analytical Chemists, Washington, DC., USA.

Brooks, J. and H.P. Hale, 1955. Strength of the shell of the hen's egg. Nature, 175: 848-849.

Eisen, E.J., B.B. Bohren and H.E. Mckean, 1962. The Haugh unit as a measure of egg albumen quality. Poult. Sci., 41: 1461-1468.

Gaal, K.K., O. Safar, L. Gulyas and P. Stadler, 2004. Magnesium in animal nutrition. J. Am. College Nutr., 23: 754S-757S.

Hossain, S.M. and A.G. Bertechini, 1998. Effects of varying levels of magnesium and available phosphorus on performance of layers. Anim. Feed Sci. Technol., 71: 363-368.

Kim, C.H., I.K. Paik and D.0Y. Kil, 2013. Effects of increasing supplementation of magnesium in diet on productive performance and eggshell quality of aged laying hens. Biol. Trace Elem. Res., 151: 38-42.

McWard, G.W., 1967. Magnesium tolerance of the growing and laying chicken. Br. Poult. Sci., 8: 91-99.

Mehring, A.L. and D. Johnson, 1965. Magnesium in limestones for laying chickens. Poult. Sci., 44: 853-860.

NRC, 1994. Nutrient Requirements of Poultry. 9th Edn., National Academy Press, Washington, DC., USA., ISBN-13: 9780309048927, Pages: 155.

Romanoff, A.L. and A.J. Romanoff, 1949. The Avian Egg. John Wiley and Sons Inc., New York, pp: 353-354.

Seo, Y.M., K.S. Shin, A.R. Rhee, Y.S. Chi, J. Han and I.K. Paik, 2010. Effects of dietary Fe-soy proteinate and MgO on egg production and quality of eggshell in laying hens. Asian Aust. J. Anim. Sci., 23: 1043-1048.

Stafford, J.E.H. and N.A. Edwards, 1973. Magnesium metabolism in the laying fowl. Br. Poult. Sci., 14: 137-148.

West, B.L., P.L. Williams, C.F. Nockels and H.L. Enos, 1980. Calcium, magnesium and phosphorus for ageing hens. Poult. Sci., 59: 1672-1672.