Journal of Animal and Veterinary Advances 6 (8): 912-916, 2007
ISSN: 1680-5593
© Medwell Journals, 2007

The Effects of Dietary Electrolyte Balance on the Performance and Eggshell Quality in the Late Laying Period

A.R. Safameher and A. Nobakht
Department of Animal Science, Islamic Azad University,
Marageh Branch, P.O.Box 345. Maragheh, Iran

Abstract: This study was designed to evaluate the effects of Dietary Electrolyte Balance (DEB = $Na^+ + K^+ - Cl^-$) on the performance and eggshell quality of layers in their late laying period. Two hundred fifty six Hy-Line strain laying hens, 55-65 of age, were randomly assigned to 4 dietary treatments. The DEB levels were 0, 120, 240 and 360 mEq kg^{-1} and were obtained by addition of NaCl, $NaHCO_3$, $KHCO_3$ and NH_4CL as needed. Egg production, feed intake, egg mass and Feed Conversion Ratio (FCR) were not significantly affected by any of the treatments, whereas eggshell quality was significantly affected ($p<0.05$). The shell thickness were increased with increasing DEB from 120-360 mEq kg^{-1} relative to the control diet. It was concluded that high rate DEB (360 mEq kg^{-1}) can improve eggshell quality in the late laying period.

Key words: Electrolyte balance, eggshell, performance, laying hens

INTRODUCTION

"Electrolytes" are compounds, which are dissolved and dissociated into positively and negatively ions in a suitable medium. This term, commonly used in animal nutrition primarily refers to sodium (Na_+), potassium (K_+) and chloride (Cl_-) (Hooge, 1995). Dietary Electrolyte Balance (DEB) is often described by simple formulas expressed as mEq kg^{-1} of diet such [$Na^+ + K^+ - Cl^-$] (Cohen and Hurwitz, 1974). These monovalent electrolytes have important role in maintaining of body acid-base homoeostasis (NRC, 1994). These minerals are essential for synthesis of tissue proteins, maintenance of intracellular and extracellular homeostasis and electric potential cell membranes, enzymatic reactions, osmotic pressure and acid-base balance (Borges *et al*., 2003).

Eggshell quality is of major importance to the egg industry worldwide and may be affected by the DEB (Hughes, 1988). The proper dietary electrolyte balance should not only maintain acid-base homoeostasis, but also achieve optimal egg production and feed conversion ratio (Hughes, 1988). In metabolism of poultry, particular in layers, the Na and H_2CO_3 have a distinguished importance in egg productivity and shell formation.

The formation of the eggshell in poultry is affected by the acid-base balance in blood because the acid-base rate of the blood is a restrictive factor for the accumulation of $CaCO_3$ in eggshell (Mehner and Harlfiel, 1983). Mongin (1968) has noted that the first restrictive factor of the shell formation was the Ca and the second factor was the carbonate ions so the breakage, which was observed in eggshell in hot weather, had been caused by a certain decrease in blood CO_2 level depending on the increase in respiration speed.

According to Sauveur and Mongin (1978), no effect on shell weight or surface was obtained when electrolyte balance evaluated by [Na^+]+[K^+]-[Cl^-] was comprised between 160-360 mEq kg^{-1}. On the contrary, Hamilton and Thompson (1980) reported no significant alteration of eggshell quality when electrolyte balance was lower than 330 mEq kg^{-1} or higher than 620 mEq kg^{-1}, but they observed the reduction of the rate of lay and of feed intake. Furthermore, in their experiment, a low electrolyte balance depressed blood pH, HCO^-_3 concentrations and shell quality. Consequently, we postulate that laying hens need dietary supplementation by alkaline salts through continuous provision of $NaHCO_3$ or $KHCO_3$ into diets, for compensating lay induced metabolic acidosis and maintaining eggshell quality.

Although the effects of different Dietary Electrolyte Balance on eggshell quality and laying performance during the peak production period have been investigated intensively in layers, data on its impact during the late laying period are limited. The objective of this study, was to evaluate the effects of DEB various levels on egg production, egg quality parameters of hens during the late laying period.

Corresponding Author: A.R. Safameher, Department of Animal Science, Islamic Azad University, Marageh Branch, P.O.Box 345. Maragheh, Iran

MATERIALS AND METHODS

Hens and dietary treatments: Two hundred and fifty six 55 weeks old Hy-Line W36 laying hens obtained from a Company, were used in this study. These 256 hens were divided into 16 groups (each group containing 16 laying hens) in completely random design. Treatments were in a completely randomized design. The rations (Table 1) prepared for different experimental groups (n=64) are summarized below:

Group 1: Basal diet containing dietary electrolyte balance 0 mEq kg^{-1}.

Group 2: Basal diet containing dietary electrolyte balance 120 mEq kg^{-1}.

Group 3: Basal diet containing dietary electrolyte balance 240 mEq kg^{-1}.

Group 4: Basal diet containing dietary electrolyte balance 360 mEq kg^{-1}.

All diets were in the meal form and based on corn and soybean meal. The diets were formulated to be isonitrogenous (15.25%) and isocaloric (2860 Kcal kg^{-1}) According the NRC (1994) as fed basis. Treatment groups were formed according to Dietary Electrolyte Balance (DEB). Dietary Electrolyte Balance was calculated in mEq according to mongin's formula: DEB = $[Na^+]+[K^+]-[Cl^-]$. The dietary electrolyte balance differents were obtained with the inclusion of NaCl, $NaHCO_3$ and NH_4Cl. Respective amounts of dietary electrolytes were first blended thoroughly with small amount of dicalcium phosphate then was mixed with a larger amount of the basal diet until the total amount of the respective diets were homogeneously mixed.

Experimental feeds were supplied to the birds after the 55 wk old to 65 wk of age. They were reared in cages under conditions with access to feed and water ad libitum and with a constant 16 h lighting daily.

Chemical analysis and measurements of hens performance and eggshell quality: Prior feeding, laboratory assays were conducted in each diets for sodium, potassiumand chloride. The sodium and potassium were determined by Flame spectrophotometer. The chloride in feed was determined by titration (Lacroix *et al*., 1970). Assay of these elements determined required values of NaCl, $NaHCO_3$, $KHCO_3$ and NH_4CL. Quantities were adjusted to provide the wanted DEB according to assay groups. Analyses of the drinking water revealed very low quantities of sodium, potassium and chloride. Therefore, the intake of these elements via drinking water was not considered in the calculations.

Table 1: Composition of laying hen diets (as fed basis)

	DEB			
	0	120	240	360
Ingredient composition(kg t^{-1})				
† Corn grain	410.4	410.4	410.4	4104
Wheat grain	200	200	200	200
Soybean meal	212.5	212.5	212.5	2125
Oil	42.3	42.3	42.3	42.3
Oyster shell	95.4	95.4	95.4	95.4
Dicalcium phosphate	13.4	13.4	13.4	13.4
Salt	2.8	2.8	2.8	2.8
Vitamin premix	2.5	2.5	2.5	2.5
Mineral premix	2.5	2.5	2.5	2.5
DL- Methionine (990 g kg^{-1})	1.5	1.5	1.5	1.5
L-Lysine	0.3	0.3	0.3	0.3
Inert	7.7	10.9	8.1	0
NH4Cl	8.7	3.6	0.9	0
KHCO3	0	0	0	3.4
NaHCO3	0	1.9	7.4	13
Chemical composition (g kg^{-1})				
Metabolizableenergy (kcal kg^{-1})	2860	2860	2860	2860
Crude protein	152.5	152.5	152.5	1525
Calcium	40	40	40	40
Avail. Phosphorus	3.7	3.7	3.7	3.7
Potassium	6.4	6.4	6.4	7.9
Chloride	8.1	4.6	2.7	2.1
Sodium	1.5	2	3.5	5
Lysine	7.6	7.6	7.6	7.6
Methionine + cystine	6.4	6.4	6.4	6.4
Tryptophan	2.1	2.1	2.1	2.1

[1]Dry matter content 900 g kg^{-1}. [2]DEB 0 (Dietary Electrolyte Balance=0), DEB120 (dietary electrolyte balance=120), DEB 240 (dietary electrolyte balance = 240), DEB360 (Dietary Electrolyte Balance=360). [3]Premix supplied per kg of diet: 9000 IU vitamin A, 1.78 mg vitamin B_1, 6.6 mg vitamin B_2, 30 mg niacin, 10 mg pantothenic acid, 3 mg vitamin B_6, 0.15 mg biotin, 1500 mg choline, 0.015 mg vitamin B_{12}, 2000 IU vitamin D, 18 IU vitamin E, 2 mg vitamin K_3. [4]Premix supplied per kg of diet: 10 mg Cu, 0.99 mg I, 50 mg Fe, 100 mg Mn. 0.08 mg Se, 100 mg Zn. [5]All values were calculated from NRC values (1994)

The birds were weighted at the commencement (55 week of age) and the end (65 wk of age) of the trial.

Egg production (%hen–day) and egg weight (g) were recorded daily. Daily production was determined on a shelled egg weight basis. Feed intake (g/hen/day) was recorded weekly. Feed Conversion Ratio (FCR) was calculated as gram feed consumption per day per hen divided by gram egg mass per day per hen.

Every 25 d, 4 eggs per replicate (16 eggs per treatment) were individually weighed and the egg specific gravity (g mL^{-1}) was also evaluated. During the 25 day periods, eggs from each treatment group (16 eggs) were taken to determine eggshell quality parameters.

Eggshell weight and shell thickness were determined by randomly collecting 4 eggs from each replicate. After the eggs were broken the shells were washed and dried in room temperature for the determination of shell weight. The shell thickness was measured with a micrometer

gauge (Measure, 24 21/1 type) on three part of shell from the eqator of each egg. These measurements were pooled.

The shell weigh/area also recorded and shell ash was determined after draying at room temperature for 3 days.

Statistical analysis: Data were analyzed by the General Linear models procedure of SAS Institute (1985). Means for treatments showing significant differences in the analysis of variance were compared using Duncan's multiple range tests. All statements of significance are based on the probability level of 0.05.

RESULTS AND DISCUSSION

For the total experiment period, hen day egg production, feed intake, egg weight, egg mass and feed conversion ratio were not statistically different between groups (Table 2).

The results of eggshell quality parameters presented in Table 3 shows that the specific gravity and eggshell weight were unaffected in various treatments during the experiment. By contrast, eggshell thickness (Table 3) were reduced in group 2 (DEB=120 mEq kg^{-1}) ($p<0.05$) but differences between group 1 and 2 (DEB=0 and DEB=120 mEq kg^{-1}, respectively) were not statistically significant for the total experimental period. No variation of eggshell ash and shell weight/surface area were noticed according to dietary electrolyte balance in total experiment period (Table 3).

Egg production rate decreases and egg weight increases as age advances (Bustan and Elwinger, 1987; Summers and Lesson, 1983). Egg quality and composition also change in accordance with level of production and age of layer. As age advances, proportion of yolk increases, where as proportions of albumen and shell thickness decrease (Akbar *et al*., 1983; Fletcher *et al*., 1983).

The results of this experiment showed that the different level of DEB in diet do not statistically affected on the productivity characteristics in layer.

The addition of choloride ammonium to the experimental diets due to decrease of DEB to 0 and 120 mEq kg^{-1} of diet have not significant effect on egg production. The percentage of egg production in 1 to 4 different treatments were 75/0, 72/1, 69.6 and 72.8, respectively. Furthermore, feed intake and feed conversion ratio were not significantly different between groups. The average of feed intake were 111.8-119.2 in different treatment. Nizamettin *et al*. (2005) formulated different Dietary Electrolyte Balances (DEB, 176, 204, 225 and 242 mEq kg^{-1}) and fed to laying hens from 22 weeks to 30 weeks of age. They reported that egg production, egg shell quality, feed intake, egg mass and feed conversion ratio were not significantly affected by the diets of various DEB.

There were not significant different in eggshell weight, specific gravity, shell weight/area and eggshell ash During the experiment. Our finding agreed with the results obtained by Sauveur and Mongin (1978) where no effect of DEB over the range 160-360 mEq kg^{-1} on shell weight/surface area was observed. Hughes (1988) using young hens (32 wk of age), observed curvilinear increase in shell thickness as DEB increased from about 150mEq kg^{-1}. Likewise, Austic and Keshavarz (1988) also reported a weak relationship (R^2 = 0/2) between DEB and shell thickness. However, some other researchers, Hughes (1988) and Cohen and Hurwitz (1974), reported positive results by increasing DEB using old hens at 70wk of age. Similarly, Hamilton and Thompson (1980) reported a lack of response to DEB in term of shell quality in hens of 68 weeks of age. They only found that the rate of lay and feed intake significantly depressed by 330 and 620 mEq kg^{-1} which were found to be extreme DEB values and not commonly practiced with the commercial diets. Dietary

Table 2: Effects of electrolyte balance on laying performance

FCR (g feed g^{-1} egg)	Egg mass (g/hen/day)	Egg weight (g/egg)	Feed intake (g/hen/day)	Egg production (%)	Treatments DEB(mEq kg^{-1})
2.61[a]	46.8[a]	62.5[a]	111.8[a]	75.0[a]	0
2.71[a]	45.5[a]	63.1[a]	119.2[a]	72.1[a]	120
2.8[a]	43.8[a]	62.9[a]	118.8[a]	69.6[b]	240
2.51[a]	45.1[a]	62.1[a]	112.6[a]	72.8[a]	360

Means within each column with same superscripts are not significantly different ($p<0.05$) [a]

Table 3: Effects of electrolyte balance on eggshell quality

Shell weight/surface area (mg cm^{-2})	Egg shell ash (%)	Eggshell thickness (mm)	Eggshell weight (g)	Specific gravity	Treatments DEB(mEq kg^{-1})
79[a]	91.8[a]	.341[ab]	5.88[a]	1.08[a]	0
75.7[a]	92.3[a]	.337[b]	5.65[a]	1.078[a]	120
78.1[a]	93[a]	.350[a]	5.85[a]	1.081[a]	240
75.7[a]	88.4[a]	.352[a]	5.75[a]	1.082[a]	360

Means within each column with different superscripts are significantly different ($p<0.05$) [a-b]

electrolyte balance has been reported to influence egg shell quality (Mongin, 1968). Chen and Balnave (2001) reported an optimal activity of carbonic anhydrase that plays an important role in eggshell formation in slightly alkaline medium. Moreover an excessive Chloride intake limited calcium transports to shell gland lumen. Consequently, our finding's show that high DEB positively affected the eggshell quality, are consistent with these observations. In contrast with Yoruk *et al.* (2004) for increase DEB used $NaHCO_3$ (0, 0.1, 0.2, 0.4) during the late laying period and reported that increasing sodium bicarbonate level positively affected laying performance, but did not improve shell quality. Nobakht *et al.* (2006) reported that increase of DEB to 360 mEq kg^{-1} in diets of laying hens (late period of production) under heat stress (30-35°C) can improve egg quality (shell weight/surface area, shell weight, shell thickness and egg specific gravity were significantly affected by DEB ($p<0.01$)). High (above 25°C) environmental or shed temperatures may affect the feed (and therefore calcium) intake of the bird, thus resulting in a decreased availability of calcium for shell deposition. As well as decreasing feed intake, laying hens will try to overcome heat stress by panting. However, this causes a decrease in the amount of Carbon dioxide (CO_2) in the hens blood, a condition known as respiratory alkalosis (Jones *et al.*, 1990). As egg shells are made up of 95% Calcium Carbonate ($CaCO_3$), this decrease in blood CO_2 levels, combined with an increase in blood pH and a subsequent decrease in Ca^{2+} ions for shell formation leads to an increase in the number of thin or soft shelled eggs produced. Arima *et al.* (1976) found that the egg quality of older hens was more severely affected by increased temperature than younger hens.

CONCLUSION

In conclusion, our study has confirmed that a high dietary electrolyte balance (240-360 mEq kg^{-1}) improved egg shell quality (thickness and ash). Consequently, during establishments of laying hens in late period of production, should be adjusted dietary electrolyte balance.

REFERENCES

Akbar, M.K., J.S. Gavora, G.W. Friars and R.S. Gowe, 1983. Composition of eggs by commercial size categories effects of genetic group, age and diet. Poult. Sci., 62: 925-933.

Al Bustany, Z. and K. Elwinger, 1987. Shell and interior quality and chemical composition of ages from different dietary lysine levels. Acta. Agric. Scand., 37: 175-187.

Arima, Y., F.B. Mather and M.M. Ahmad, 1976. Response of egg production and shell quality, to increases in environmental temperature in two age groups of hens. Poult. Sci., 55: 818-820.

Austic, R.E. and K. Keshavarz, 1988. Interaction of dietary calcium and chloride and the influence of monovalent minerals on eggshell quality. Poult. Sci., 67: 750-759.

Borges, S.A., D.A. Fischer, A.V. Silva, J. Ariki and D.M. Hooge, 2003. Dietary electrolyte balance for broiler chickens exposed to thermoneutral or heat-stress environments. Poult. Sci., 82: 428-435.

Chen, J. and D. Balnave, 2001. The influence of drinking water containing sodium chloride on performance and eggshell quality of a modern colored layer strain. Poult. Sci., 80: 91-94.

Cohen, I. and S. Hurwitz, 1974. The response of blood ionic constituents and acid-base balance to dietary sodium, potassium and chloride in laying fowls, Poult. Sci., 53: 378-383.

Fletcher, D.L., W.M. Britton, G.M. Pesti and S.I. Savage, 1983. The relationship of later flock age and egg weight on egg component yields and solid content. Poult. Sci., 62: 1800-1805.

Hamilton, R.M.G. and B.K. Thompson, 1980. Effects of sodium plus potassium to chloride ratio in practical type diets on blood gas levels in three strains of white leghorn hens and the relationship between acid-base balance and egg shell strength. Poult. Sci., 59: 1294-1303.

Hooge, D.M., 1995. Dietary electrolytes influence metabolic processes of poultry. Feedstuffs,12: 14-21.

Hughes, R.I., 1988. Inter-relationships between eggshell quality, blood acid-base balance and dietary electrolytes. Worlds Poult. Sci. J., 44: 30-40.

Jones, J.E., J. Solis, B. L. Hughes, D.J. Castaldo and J.E. Toler, 1990. Production and egg quality responses of White Leghorn layers to anticoccidial agents. Poult. Sci., 69: 378-387.

Lacroix, R., D.R. Keeney and L.M. Welsh, 1970. Potentiometric titration of chloride in plant tissue extracts using the chloride ion electrode. Commum. Soil Sci. Plant Anal., 1: 1-6.

Mehner, M.N. and W. Hartfiel, 1983. Hanbuch der gefiugerphsiologie. Teil. I., 519: 333-337.

Mongin, P., 1968. Role of acid-base balance in the physiology of egg shell formation. Worlds Poult. Sci. J., 24: 200-230.

National Research Council (NRC), 1994. Nutrient Requirements of Poultry. (9th Rev. Edn.) National Academy Press, Washington, DC.

Nizamettin, S. H., Akyurek. H. Ersin and A. Agma., 2005. Assessment the impacts of dietary electrolyte balance levels on laying performance of commercial white layers. Pak. J., Nut., 4: 423-427.

Nobakht, A.M. Shivazad, M. C h amany and A.R. Safameher, 2006. The Effects of Dietary Electrolyte Balance on Performance of Laying Hens Exposed to Heat-Stress Environment in Late Laying Period. Int. J. Poult. Sci., 5: 948-951.

SAS Institute, 1985. SAS User's guide: Statistics, Version 5. SAS (Statistical Analysis System) Institute Inc., California, USA.

Sauveur, B. and P. Mongin, 1978. Interrelationship between dietary concentrations of sodium, potassium and chloride in laying hens. Br. Poult. Sci., 19: 475-485.

Summers, J.D. and S. Leeson, 1983. Factors influencing early egg size. Poult. Sci., 62: 1155-1159.

Yoruk, M.A., M. Gul, A. Hayirli and M. Karaoglu, 2004. Laying performance and egg quality of hens supplemented with sodium bicarbonate during the late laying period. Int. J. Poult. Sci., 3: 272-278.