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Assessment the Impacts of Dietary Electrolyte Balance Levels on Laying Performance of Commercial White Layers

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Abstract: Two experiments were conducted to test whether egg performance and egg shell quality during peak egg production are affected by the diets supplemented with $NaHCO_3$ or K_2CO_3. In experiment 1 four diets were formulated using different inclusions of NaCl, $NaHCO_3$ and K_2CO_3 to give the dietary electrolyte balances (DEB) as 176, 204, 225 and 242 mEq/kg, and fed to laying hens from 22 weeks to 30 weeks of age. In experiment 2, two diets were formulated to obtain DEB of 186 and 208, and fed to the same strain from 31 to 39 weeks of age. Egg production, egg shell quality, feed intake, egg mass and feed conversion ratio were not significantly affected by the diets of various DEB ($P>0.05$). In conclusion, the results suggested that there was no need for the supplementation of sodium bicarbonate and or potassium carbonate into practical laying hen diets during peak egg production.

Key words: Electrolyte balance, sodium bicarbonate, potassium carbonate, layers

Introduction

Egg shell quality has been a prominent property not only for table eggs but also for hatching eggs due to its economical importance in poultry industry. Therefore, a number of studies have been done in an attempt to improve egg shell quality. Some studies focused on the relationship between the dietary electrolyte balance (DEB) and egg shell quality (Mongin, 1968; Sauveur and Mongin, 1978; El Hadi and Sykes, 1982; Vogt and Harnisch, 1983; Harms *et al.*, 1996; Balnave and Muhereeza, 1997). Electrolyte balance has been reported to be an important factor affecting egg shell quality. Decline in laying performance and egg shell quality are the primary responses of laying hens subjected to acute heat stress. Therefore, incorporating the layer diets with available anions or cations has been suggested to prevent the dietary electrolyte imbalance. This can be achieved by a careful balancing of $Na^+ + K^+ - Cl^-$ levels using Sodium bicarbonate ($NaHCO_3$), potassium carbonate (K_2CO_3) and ammonium chloride (NH_4Cl) in the diet. An electrolyte balance of 250 mEq/kg has been proposed for an optimum performance in broilers with minimal undesirable side effects such as tibial dyschondroplasia or abnormal amino acid metabolism (Mongin, 1980; Leeson and Summers, 2001). Thus, this level of electrolyte balance (250 mEq/kg) seems to be appropriate for broilers as they are usually fed with high levels of soybean meal (25-35%) in soy-maize based diets considering the high electrolyte balance content of soybean meal (675 mEq/kg).

With respect to laying hens, however, not many suggestions have been found in the scientific literature. Greater than 1.5 (Na+K)/Cl ratio was suggested to prevent decrease in blood pH during shell formation fed with semi-purified diets (Cohen and Hurwitz, 1974). A weak relationship between acid-base balance and shell strength was reported (Hamilton and Thompson, 1980). In this study, feed efficiency and egg production were adversely affected when (Na+K)/Cl ratio was lower than 1.91 or higher than 2.83. This research group found that (Na+K)/Cl ratio between 1.92 and 2.83 resulted in the highest shell weight, which is considered to be important shell quality criteria, among the lowest (0.40) and highest ratios (7.69).

Finally, in a review conducted by Hughes (Hughes, 1988), it was concluded that, the discrepancies in scientific literature was attributed to extremely deficient sodium and chlorine or potassium levels which fall below the practical recommendations. Other possible reasons have been reported to be the differences in breed, age and health of the hens, environmental conditions and particularly the degree of heat stress. On the other hand, a practical ratio of $NaHCO_3$ supplementation to obtain a dietary electrolyte level between 230 and 250 mEq/kg which is also very close to the value suggested for broilers have long been using regardless of heat stress or aging for the laying hens, and even for the diets of young laying hens. This application might increase the feed cost as well.

Therefore, the purpose of the present study was to assess the impacts of DEB levels using $NaHCO_3$ and K_2CO_3 on laying performance and shell quality of white commercial laying hens fed with the commercially practiced diets during peak egg production.

Materials and Methods

Bird husbandry: Two experiments were carried out to examine the impacts of DEB levels using $NaHCO_3$ and K_2CO_3 on laying performance and shell quality. In experiment 1, 288 laying hens of Bovans White at the

Table 1: The ingredients and chemical composition of experimental diets (as fed)

Ingredients, g/kg diet	Experiment 1				Experiment 2	
Electrolyte balance, mEq/kg	176	204	225	242	186	208
Salt	2.8	1.1	1.1	1.1	3.1	1.7
$NaHCO_3$	-	2.4	2.4	2.4	-	2.0
K_2CO_3	-	-	1.5	3.0	-	-
Wheat	-	-	-	-	200	200
Corn	611.9	610.3	607.0	603.8	377.3	376.0
Full fat soybean (37% CP)	97.3	100.0	105.3	110.6	-	-
Soybean meal (48% CP)	65.5	63.7	60.2	56.6	162.6	162.8
Sunflower meal (38% CP)	65	65	65	65	80	80
Corn gluten meal	30	30	30	30	20	20
Fish meal	20	20	20	20	10	10
Limestone	93.1	93.1	93.1	93.1	92.8	92.8
Monocalcium phosphate	7.8	7.8	7.7	7.7	-	-
Dicalcium phosphate	-	-	-	-	11.2	11.2
Vitamin + mineral mix*	5	5	5	5	5	5
DL-Methionine	0.8	0.8	0.8	0.8	1.0	1.0
L-lysine HCl	0.6	0.6	0.6	0.6	0.6	0.6
Phytase	0.2	0.2	0.2	0.2	0.2	0.2
Total	1000	1000	1000	1000	1000	1000
Calculated nutrients, g/kg						
Dry matter	905.9	905.9	905.9	905.9	903.2	903.2
ME, Kcal/kg	2800	2800	2800	2800	2800	2800
Crude protein	175	175	175	175	175	175
Crude fiber	37.4	37.4	37.4	37.4	37.6	37.6
Ether extract	52.5	52.9	53.9	54.8	63.2	63.6
Lysine	8.8	8.8	8.8	8.8	8.8	8.8
Meth + Cys	7.2	7.2	7.2	7.2	7.3	7.3
Methionine	4.2	4.2	4.2	4.2	4.2	4.2
Calcium	38.5	38.5	38.5	38.5	39.4	39.4
Available phosphorus	3.9	3.9	3.9	3.9	3.9	3.9
Sodium	1.6	1.6	1.6	1.6	1.6	1.6
Chlorine	2.4	1.4	1.4	1.4	2.5	1.7
Potassium	6.8	6.8	7.6	8.3	7.3	7.3

*Provides per kg of diet: vitamin A, 8000 IU; vitamin D_3, 2500 IU; vitamin E, 30 mg; vitamin K_3, 2.5 mg; vitamin B_1, 2 mg; vitamin B_2, 5 mg; vitamin B_6, 2 mg; vitamin B_{12}, 0.01 mg; niacin, 30 mg; calcium-D-pantothenate, 8 mg; folic acid, 0.5 mg; D-biotin, 0.045 mg; choline chloride 300mg, vitamin C, 50 mg; Mn, 70 mg; Fe, 35 mg; Zn, 70 mg; Cu, 8 mg; I, 1 mg; Co, 0.2 mg; Se, 0.25 mg

age of 17 wks were provided from a local parent stock supplier, and randomly confined in the commercial compact type wire cages (50x44x46 cm) equipped with nipple drinkers and trough feeders Laying pullets were fed on pre-laying diet (18%CP; 2800 ME Kcal/kg; and 2.5% calcium) and a lighting regimen was adjusted to increase day light by 1h each wk until 16h is reached. Pre-layer feed was fed until the commencement of egg production (5%).

Experiment 1: In experiment 1, to assess the impacts of DEB (Na+K-Cl) levels as mEq/kg, four layer diets were formulated to contain various (DEB) of, 176, 204, 225, 242 mEq/kg, using 1) corn-soya basal diet (BD), 2) BD+2.4 g/kg $NaHCO_3$, 3) BD+ 2.4 g/kg $NaHCO_3$ + 1.5 g/kg K_2CO_3 and 4) BD + 2.4 g/kg $NaHCO_3$ + 3.0 g/kg K_2CO_3 , respectively (see Table 1). Experimental diets were isocaloric and isonitrogenous according to the NRC (1994) recommendations as shown in Table 1 and fed in mash form ad libitum. Experimental diets were prepared in the feed mixing unit at the Department of Animal Science. The feed ingredients were ground by a hammer mill to pass 3 mm sieve and mixed through a horizontal mixer (200 kg capacity) and fed to the laying pullets between 19 to 22 wk of age to get the birds accustomed to the test diets. Each of the four experimental diets was randomly assigned to 18 cage replicates, each with 4 hens, to result in totally 72 hens per treatment. Laying hens were kept in the experimental house with windows and received an additional artificial lighting to adjust daily 16 h light and 8 h dark.

The birds were weighted at the commencement (22 wk

Table 2: Effects of electrolyte balance on laying performance (trial 1, 22-30 wk of age)

Treatments	Egg production (%)	Feed intake (g/hen/day)	Egg weight (g/egg)	Egg mass (g/hen/day)	FCR (g feed/g egg)
DEB (mEq/kg)					
176	91.7	98.3	55.3	50.9	1.95
204	89.4	98.2	55.0	49.4	2.01
225	89.6	96.5	55.2	49.7	1.97
242	91.1	96.9	54.7	50.0	1.96
Pooled SEM	1.7	1.3	0.4	1.2	0.04
p-level	0.961	0.953	0.975	0.980	0.939

Means in the same column did not differ significantly (P > 0.05). SEM: Standard error of the mean; DEB: Dietary electrolyte balance

Table 3: Effects of electrolyte balance on laying performance (trial 2, 31-39 wk of age)

Treatments	Egg production (%)	Feed intake (g/hen/day)	Egg weight (g/egg)	Egg mass (g/hen/day)	FCR (g feed/g egg)
DEB, mEq/kg					
186 (control)	98.3	112.2	61.2	61.1	1.87
208 (test)	97.6	110.9	61.4	59.9	1.85
Pooled SEM	0.2	0.7	0.2	0.2	0.01
p-level	0.189	0.330	0.538	0.682	0.542

Means in the same column did not differ significantly (P > 0.05). SEM: Standard error of the mean; DEB: Dietary electrolyte balance

of age) and at the end (30 wk of age) of the trial. Laying pullets received feed and water ad libitum throughout the 8 wks of experiment. Feed intakes of hens were recorded weekly. Egg production and cracked eggs were recorded daily, whereas egg weight was determined each week by weighing all the collected eggs. Egg shell 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. Shell thickness was measured at the two ends and one from the middle using a micrometer (Mauser, 2421/1 type). These measurements were pooled. Cracked eggs were determined each week on the same day by examining all the eggs collected from the cages and they were subjected to a bulb control in the dark to identify the cracked eggs. The rate of cracked eggs was calculated as percentage of the total collected eggs on the same day. Feed conversion ratio, FCR, was calculated as gram feed consumption per day per hen divided by gram egg mass per day per hen.

Experiment 2: Exp 2 was conducted to confirm the results of experiment 1 and to examine if $NaHCO_3$ is necessary for laying performance and egg shell quality at this stage of production. Therefore, a similar basal diet consisted of maize, wheat, soybean and sunflower were formulated to form a control diet, 1) containing 3.1 g/kg, salt, and 2) a test diet containing 1.7 g/kg salt + 2.0 g/kg $NaHCO_3$ (Table 1). Experiment 2 was designed according to completely randomized design. Each of the two dietary treatments was allocated to 36 replicate cages, each with 4 hens. The experiment 2 started at the age of 31 weeks using the same flock of layers, and was terminated at the end of 39 wk of age.

Statistics: The collected data was recorded on a weekly basis and statistically analyzed by ANOVA using GLM (General Linear Model) in a windows-based statistical package program, SAS (1985). The differences between the means of groups were separated by Duncan's Multiple Range Test. Significant level used in the group comparison was set at P < 0.05.

Results

The results of both experiments indicated that DEB levels did not significantly (P > 0.05) affect egg production. Layers in the control group, fed with only salt produced 69.8 eggs per 100 hens at 23 wk and this increased to a production of 97.3 eggs per 100 hens at 30 wk of age. Proportionally similar increase in egg production was seen with the other experimental groups. Adding sodium bicarbonate ($NaHCO_3$) or potassium carbonate (K_2CO_3) into layer diets to increase dietary electrolyte balance from 176 to 242 did not affect the egg production. The overall egg production results between 22 to 30 wk of age demonstrated that there were no significant (P > 0.05) differences between the dietary treatments: 91.7, 89.4, 89.6 and 91.1%, respectively (Table 2). Modification of dietary electrolyte balance during this period did not significantly (P > 0.05) affected feed intake, egg weight, egg mass and FCR either. Average feed intake from the 22 to 30 weeks of age ranged from 96.5 to 98.3 per bird per day. Average egg weight or egg mass was not significantly (P > 0.05) affected by electrolyte balance. No significant differences in FCR values between the dietary treatments were observed: the corresponding FCR values were 1.95,

Table 4: Effects of electrolyte balance on laying performance (trial 1, 22-30 wk of age)

Treatments	Egg weight (g/egg)	Egg Shell Weight (g)	Egg Shell Thickness μ	Cracked Eggs(%)	Mortality (number of hens)
DEB (mEq/kg)					
176	55.3	6.7	290	0.1	1
204	55.0	6.7	290	0.1	0
225	55.2	6.7	288	0.1	1
242	54.7	6.5	288	0.1	0
Pooled SEM	0.440	0.086	2.194	0.012	-
p-level	0.975	0.880	0.960	0.862	-

Means in the same column did not differ significantly ($P > 0.05$). SEM: Standard error of the mean; DEB: Dietary electrolyte balance

Table 5: Effects of electrolyte balance on laying performance (trial 2, 31-39 wk of age)

Treatments	Egg weight (g/egg)	Egg shell weight (g)	Egg shell thickness μ	Cracked eggs (%)	Mortality (hens)
DEB (mEq/kg)					
186	61.2	6.8	294	0.05	1
208	61.4	7.0	301	0.02	0
Pooled SEM	0.2	0.1	2.5	0.01	-
p-level	0.538	0.161	0.219	0.224	-

Means in the same column did not differ significantly ($P > 0.05$). SEM: Standard error of the mean; DEB: Dietary electrolyte balance

2.01, 1.97, and 1.96, respectively.

The results of exp 2 on the effects of electrolyte balance in practical layer diets on the post peak production confirmed the results of exp 1. Layers fed with a diet supplemented with only salt to attain DEB at 186 mEq/kg (control) did not significantly ($P > 0.05$) differ from the layer groups fed with DEB of 208 mEq/kg (test group) in terms of egg production, feed intake, egg mass and FCR. During the 8 wk trial period, egg production of control and test groups was 98.3 and 97.6%, respectively. Feed intakes of both control and test groups were 112 and 111 gram feed per bird per day and egg mass were 61 and 60 g/hen/day, respectively. There was no significant ($P > 0.05$) difference between the dietary treatments in FCR values as determined 1.87 for the control and 1.85 for the test group (Table 3).

The results of two experiments concerning the effects of electrolyte balance on shell quality indicated that egg weight, egg shell weight, shell thickness, % of cracked eggs and mortality were not significantly affected by dietary treatments (Table 4, 5).

Average egg weights were from 55 to 61g in both experiments. Egg shell weight ranged from 6.5 to 6.7g at exp 1 and from 6.8 to 7.0g in exp 2 whereas egg shell thickness ranged from 288 to 290 micron in exp 1 and from 294 to 301 micron in experiment 2. Cracked eggs and mortality variables were not affected by dietary electrolyte balance either. Percentage of cracked eggs was rather low as being 0.1% in exp 1, and between 0.2 to 0.5% in exp 2. No statistical comparison was made for mortality as it was not evenly distributed across the treatments.

The results of the present study suggest that laying pullets fed with practical diets, kept in conventional house where indoors temperature does not exceed 30°C, do not require any adjustment in their diets for electrolyte balance during peak egg production. The temperature in experimental unit ranged from 20.3 to 30.0°C in exp 1 and from 18.0 to 24.0 in exp 2, suggesting that even during exp 1 no evidence was observed to alter DEB (from 176 to 242 mEq/kg diet) due to the fact that there was no difference in the laying performance and the parameters related to egg shell quality between the experimental groups. Increasing DEB from 176 to 242 mEq/kg in experiment 1, and from 186 to 208 in experiment 2 did not affect laying performance in terms of egg production, feed intake, egg mass and FCR. No responses of hens in both two experiments to DEB could be associated with the relatively young age and the laying stage (peak production) of the birds used in the present study. The response of laying pullets to the modifications of DEB was tested for 8 weeks (from 22 to 30 weeks of age in exp 1 and 31 to 39 weeks of age in exp 2) during which overall egg weight ranged from 55 to 61 gram, implying that layers received sufficiently enough quantity of HCO^-_3 anions for an optimal formation of egg shell. It was clearly established that when the egg weight increased as the hen age increased, egg shell quality deterioration may occur and egg shell may become thinner [8]. This phenomenon was attributed to renal acidosis in which the same source of HCO_3^- anions were used to buffer the kidneys which are the competitor to shell gland where the similar acidosis could occur after the liberation of H^+ during the unification of Ca^{++} with HCO_3^- in the shell forming cells. As a result, lesser quantity of HCO_3^- anions remains for the formation of egg shell. Another possible explanation could be the lack of conditions, for example heat stress, which induce respiratory alkalosis. This phenomenon was reported by El Hadi and Sykes (1982) who described the usual pattern of respiratory alkalosis as it is developed in laying hens.

Discussion

Our findings agreed with the results obtained by Sauveur and Mongin (1978) where no effect of DEB over the range 160-360 mEq/kg on shell weight/surface area was observed. Similarly, Hamilton and Thompson (1980) reported a lack of response to DEB in terms 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 which were found to be extreme DEB values and not commonly practiced with the commercial diets. Dietary electrolyte balance has been reported to influence egg shell quality (Mongin, 1968).

Likewise, Austic and Keshavarz (1984) 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 70 wk of age. Moreover, Harms *et al.* (1996) found that shell quality can be improved by turning the lights on at midnight and operating the feeders for 45 min. This improvement was attributed to the hens laying the eggs in the morning hours when there is more time during the calcification period. Using young hens (32 wk of age), Hughes (1988) observed curvilinear increase in shell thickness as DEB increased from about 150 mEq/kg.

Although no heat stress conditions and no continuous lighting were applied in the present experiments, increasing the dietary electrolyte balance from 176 to 242 mEq/kg did not result in the improved laying performance and egg shell quality parameters in layer hens during peak production.

Conclusions: Increasing DEB from 176 to 242 mEq/kg did not improve egg laying performance and egg quality. Inclusion of sodium bicarbonate and or potassium bicarbonate into practical young laying hen diets at peak egg production stage is not necessary.

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