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Effects of Dietary Sodium Bicarbonate and Rearing System on Laying Hens Performance, Egg Quality and Plasma Cations Reared Under Chronic Heat Stress (42°C)

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Abstract: This study was conducted to determine the effects of dietary $NaHCO_3$ supplementation on laying hen's performance under heat stress. Ninety six Leghorn hens (Hy-Line), were used in a 2×4 factorial arrangement with two rearing system (cage and floor) and 4 levels of dietary $NaHCO_3$ (0, 0.5, 1 and 1.5%) in a completely randomized design with 8 treatments and 3 replicates and 4 birds per replicate. All diet was isoenergetic and isonitrogenous. Feed Intake (FI), Egg Production (EP), Egg Weight (EW), Shell Thickness (ST), Shell Weight (SW), Shell Strength (SS), Albumen Index (AI), Yolk Index (YI) and Haugh Unit (HU) were measured weekly. In the end of experiment, 10 mL blood of hens per treatment were collected by venipuncture from the brachial vein into vacuum tubes and held on ice until all were centrifuged for plasma cations assay. The result of this experiment indicated that SW was not significantly affected by addition of dietary $NaHCO_3$. ST was significantly decrease and EW, EP, FI and plasma potassium were increase with $NaHCO_3$ levels in 0-1.5 percentage ($p<0.05$). The rearing system had no significant effect on ST ($p>0.05$). However, all factor in cage system is higher than floor system. SW, EP, SS and EW were significantly increased in cage system, but FI was increased in floor system ($p<0.05$). Haugh unit, yolk index, plasma sodium and calcium were not affected ($p>0.05$) by dietary $NaHCO_3$ supplementation and system of rearing.

Key words: Sodium bicarbonate, plasma cations, egg quality, heat stress

INTRODUCTION

Heat stress is a problem in large parts of the world, including many parts of Iran. Summertime temperatures often cause laying hens to produce thin and soft-shelled eggs. Due to this phenomenon, extreme losses in income from marketable eggs can occur (Koelkebeck *et al.*, 1992). Both heat exposure per se and reduced appetite affect the laying performance and eggshell quality of hens exposed to high ambient temperatures (Balnave and Muheereza, 1997). Whereas egg production and egg weight are influenced to a major extent by the reduction in feed consumption, eggshell quality is influenced primarily by high temperature (Balnave and Muheereza, 1997; Sauveur and Picard, 1987). Birds are 'heat stressed' if they have difficulty achieving a balance between body heat production and body heat loss. This can occur at all ages and in all types of poultry. Poor egg shell quality from hens housed at high temperatures continues to be a major source of economic loss to egg producers (Balnave and Muheereza, 1997). Efforts to improve laying performance at high temperatures have been relatively successful. Methods include the feeding of high nutrient density diets and the use of self-selection feeding (Balnave and Abdoellah, 1990). However, problems associated with eggshell quality have proved difficult to resolve.

The formation of the eggshell in poultry is affected by the blood acid-base balance (Nobakht *et al.*, 2006). Ca is the first restrictive factor of the egg shell formation and the carbonate ions is second factor. In hot weathers, the respiratory speed was increased and respiratory alkalosis that occurs. In this time, carbon dioxide from the blood and bicarbonate from the blood and body fluids were losses (Mongin, 1968; Nobakht *et al.*, 2006; Balnave and Muheereza, 1997). This loss of carbon dioxide is accentuated by the need for blood bicarbonate to buffer the hydrogen ions produced during eggshell formation (Lorcher and Hodges, 1969; Makled and Charles, 1987). Poultry are very sensitive animals to blood acid-base disorders and thus, the blood pH should be close to physiological limits of 7.35-7.45 (Dibartola, 1992; Carlson, 1997). A reduced bicarbonate concentration in the lumen

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of the shell gland adversely affects eggshell quality (Balnave *et al*., 1989). Therefore, it is possible that at high temperatures, hens have a nutritional requirement for bicarbonate. Attempts to improve eggshell quality through supplementation of the diet or drinking water with sodium bicarbonate have been equivocal. Although, positive responses have been observed by some (Makled and Charles, 1987) others have reported no benefits (Ernst *et al*., 1975; Grizzle *et al*., 1992).

This study was therefore, designed to evaluate the effect of dietary sodium bicarbonate supplementation on many layer factors include laying performance, egg quality, egg shell quality and main plasma cations in south west of Iran during the very hot period (42°C) of the year.

MATERIALS AND METHODS

Diets, birds and their management: The experiment was conducted at the poultry station of Ramin Agricultural and Natural Resources University in southwest of Iran. Ninety six leghorns (HyLine-W36) layers in 50 weeks of age were used for the study, which was conducted during the hot months (August-September) of the year. Four isoenergetic and isonitrogenous diets were formulated (Table 1). Feed and water were *ad libitum* and the hens in this Experiment were acclimatized a 16 h daily photoperiod. The temperature is reached to 36-42°C in experiment period. Half of the layers were housed on the floor and the other in battery cages located in a closed poultry house.

Table 1: Composition of experimental diet

	Diet			
Composition	1	2	3	4
Ingredients (%)				
Corn	60.70	60.57	60.62	61.48
SBM	21.33	21.35	21.61	22.10
Wheat	3.00	3.00	2.20	0.10
$NaHCO_3$	0.00	0.50	1.00	1.50
Bran	0.20	0.15	0.00	0.00
Veg. oil	2.95	3.00	3.19	3.42
DCP[2]	0.99	0.99	0.99	1.00
Dl-met	0.11	0.11	0.11	0.11
L-lysine	0.05	0.05	0.05	0.05
Salt	0.35	0.05	0.00	0.00
Oyster	8.53	3.53	0.53	0.00
Limestone	1.10	6.10	9.10	9.63
Min.Vit. premix[1]	0.50	0.50	0.50	0.50
Vit D_3	0.10	0.10	0.10	0.10
Vit E	0.05	0.05	0.05	0.05
Calculated analysis				
ME (kcal kg^{-1})	2870.00	2870.00	2870.00	2870.00
CP (%)	15.00	15.00	15.00	15.00
Ca (%)	3.95	3.95	3.95	3.95
AP (%)	0.30	0.30	0.30	0.30
Na+K-Cl (mEq kg^{-1})	164.60	219.60	273.10	329.60

[1]Supplied/kg of diet: vitamin A, 10000 IU; vitamin D3, 9790 IU; vitamin E, 121 IU; B12 , 20 µg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 µg; thiamin, 4 mg; zinc sulfate, 60 mg; manganese oxide, 60 mg; [2]Di calcium phosphate

Experimental design and data collection: The experimental Design Was Completely Randomized (CRD) using a 2×4 factorial arrangement with 2 rearing system (cage and floor) and 4 level of sodium bicarbonate supplementation (0, 0.5, 1 and 1.5%). Each treatment had 4 replicates and each replicate was allotted 3 birds. Daily egg collection was in the morning (11:00 am). The number of eggs laid by birds in each replicate was recorded daily. Feed Intake (FI), Egg Production (EP), Egg Weight (EW), Shell Thickness (ST), Shell Weight (SW), Shell Strength (SS), Albumen Index (AI), Yolk Index (YI) and Haugh Unit (HU) were measured weekly.

Yolk index was calculated as yolk diameter/yolk height and Haugh unit was determined using following equation:

$$\text{Haugh unit} = 100\log\left[H - \frac{\sqrt{G(30W^{0.37} - 100)}}{100} + 1.9\right]$$

where:

G = 32.2
H = Albumin height in mm
W = The weight of whole egg in grams

For plasma cations assays, 10 mL of blood were collected by venipuncture from the brachial vein into vacuum tubes and held on ice until all were centrifuged.

Data analysis: All collected data were subjected to analysis of variance using General Linear Models (GLM) procedure of SAS (ver. 9.1) and Duncan's multiple range test were used to determine treatments difference.

RESULTS AND DISCUSSION

The result of this experiment showed that feed intake was increased with $NaHCO_3$ levels (Table 2). Hen's diet supplemented with 1.5% $NaHCO_3$consumed greatest amount of feed. It is suggested that increasing of $NaHCO_3$ can overcome, adverse effect of heat stress on hens feed intake. These results agree with other findings. Yörük *et al.* (2004) reported feed intake affected by addition of dietary $NaHCO_3$. Contrasting with the current study, other studies (Balnave and Muheereza, 1997; Grizzle *et al*., 1992; Ergin, 1999) reported that 1% $NaHCO_3$ supplementation did not change feed intake in peak producing layers. Hens that rearing in floor system fed more than hens in cage system.

Table 2: Effect of $NaHCO_3$ supplementation of diet and rearing system on egg quality characteristics (mean±Standard error of mean)

	Level of $NaHCO_3$ supplementation (%)				Rearing system	
Parameters	0	0.5	1	1.5	Floor	Cage
Egg production (%)	52.91 ± 1.50^{ac}	55.50 ± 1.30^{ab}	51.04 ± 1.30^{c}	58.20 ± 1.30^{a}	52.67 ± 1.50^{b}	55.76 ± 0.20^{a}
Egg weight (g)	49.83 ± 0.70^{b}	51.13 ± 0.50^{b}	53.10 ± 0.40^{a}	54.16 ± 1.10^{a}	51.09 ± 0.40^{b}	52.87 ± 0.60^{a}
Feed intake (g)	99.42 ± 0.20^{b}	99.66 ± 0.20^{ab}	99.63 ± 0.2^{ab}	99.92 ± 0.60^{a}	99.99 ± 0.00^{a}	99.41 ± 0.10^{b}
Shell thickness (mm)	0.349 ± 0.5^{a}	0.342 ± 0.5^{ab}	0.338 ± 0.5^{b}	0.336 ± 0.5^{b}	0.338 ± 0.3^{a}	0.334±0.4
Shell weight (g)	7.4±0.1	7.5±0.10	7.4±0.1	7.3±0.1	7.3 ± 0.1^{b}	7.53 ± 0.10^{a}
Eggshell strength	17.4±0.6	17.6±0.60	16.2±0.7	16.1±0.7	15.9 ± 0.5^{b}	17.6 ± 0.5^{a}
Albumin height (mm)	6.2±0.1	6.3±0.10	6.6±0.1	6.5±0.2	6.3±0.1	6.5±0.1
Albumen index	9.2±0.2	9.1±0.21	9.7±0.2	9.5±0.4	9.5±0.2	9.3±0.2
Haugh unit	54.3±1.6	54.9±1.70	58.9±1.6	55.1±2.3	55.3±1.3	56.3±1.3
Yolk diameter (mm)	36.6±0.2	36.9±0.20	36.7±0.2	36.7±0.2	36.7±0.1	36.7±0.1
Yolk height (mm)	16.7±0.1	16.5±0.10	16.4±0.2	16.5±0.2	16.5±0.1	16.6±0.1
Yolk index	45.6±0.3	44.7±0.40	44.9±0.4	44.9±0.4	45.0±0.3	45.1±0.3

[a, b]Mean in the same row for each main factor bearing different superscript, differ ($p<0.05$)

Table 3: Effect of $NaHCO_3$ supplementation of diet and rearing system on plasma cations (mean±standard error of mean)

	Level of $NaHCO_3$ (g kg^{-1})				Rearing system	
Plasma cations	0	5	10	15	Floor	Cage
Sodium (meq L^{-1})	140.43±1.090	136.43±3.01	141.00±1.360	142.71±3.06	141.33±2.42	139.25±1.00
Potassium (mg dL^{-1})	5.29 ± 0.80^{bc}	4.47 ± 0.63^{c}	5.81 ± 0.57^{ab}	7.07 ± 0.51^{a}	6.83 ± 0.32^{b}	4.78 ± 0.46^{a}
Calcium (mg dL^{-1})	14.63±0.670	15.06±0.59	13.76±0.700	13.74±0.70	14.01±0.60	14.51±0.38

[a, b, c] Mean in the same row for each main factor bearing different superscript, differ ($p<0.05$)

Egg weight and egg production (Table 2) were significantly increase with $NaHCO_3$ levels in 0-1.5 percentage ($p<0.05$). Increasing egg production with inclusion of $NaHCO_3$ agree with finding of El-Gammal and Makled (1977). They showed that replacing NaCl (0.67%) with $NaHCO_3$ (1%) increased egg production by 6%, whereas increasing $NaHCO_3$ from 1-2% decreased egg production by 9%. Choi and Han (1983) reported that Na provided as $NaHCO_3$ (1.5%) caused higher egg production in comparing with Na provided as NaCl (1.4%). However, no change in egg production was also reported in hens supplemented with 1% $NaHCO_3$ during peak period (Balnave and Muheereza, 1997; Grizzle *et al*., 1992). Egg weight was increased with dietary $NaHCO_3$ that agree with Yörük *et al.* (2004) finding. Sauvar and Picard (1987) indicated that in heat stress the egg weight and egg production affected by decreasing of feed intake and egg shell quality influenced by above temperature. Egg production and egg weight were significantly increased in cage system ($p<0.05$).

Eggshell thickness (Table 2) and plasma potassium (Table 3) were significantly ($p<0.05$) affected by treatments. Eggshell thickness was decreased from 0.349-0.336 mm by increasing $NaHCO_3$ from 0-1.5% of diets. This is contradict with some researcher which suggest that the use of sodium bicarbonate may aid in promoting better egg shell calcification by alteration of acid-base balance, especially in heat stress situations (Makled and Charles, 1987; Balnave and Muheereza, 1997). Researcher such as Yörük *et al.* (2004) and Ergin (1999), reported that use of $NaHCO_3$ had no significant effect on egg shell, whereas Emery *et al.* (1990) reported that use of $NaHCO_3$ increase egg shell thickness. The rearing system had no significant effect on Shell thickness.

The result of this experiment indicated that Haugh unit, albumen index, yolk index shell strength, Shell weight, plasma sodium and calcium were not significantly affected (Table 2 and 3) by addition of dietary $NaHCO_3$ ($p>0.05$). In this study, the eggshell strength, eggshell weight and thickness were reduced numerically by dietary $NaHCO_3$ supplementation. So may be there is another phenomenon like physiological adaptation to long time heat stress and this adaptation can decrease the effect of dietary $NaHCO_3$ supplementation.

There was positive correlation between adding $NaHCO_3$ supplementation and increased plasma potassium. Eggshell strength and weight were affected by rearing system but not by diet. Caged hen showed greater eggshell weight and more strength eggshell than hen reared on floor. In this experiment, 4 birds placed in a battery cage (60×40 cm) and probably have better ventilation and better nutrient utilization efficiency. Maybe this reason of better cage hen performance. There was significant interactions between rearing system and dietary $NaHCO_3$ on many of the traits ($p<0.05$).

CONCLUSION

Inclusion of sodium bicarbonate positively affected laying hen's performance and altered inner egg quality, but did not improve shell quality, during the heat stress.

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