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Effect of Dietary Inclusion of Sodium Bicarbonate on Production Performance of Caged Layers During Summer

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ABSTRACT

Effect of dietary inclusion of sodium bicarbonate on production performance of caged layers during summer was studied. One hundred sixty commercial layers (24 weeks old) were purchased from a poultry farm and were reared in a group for one week (adaptation period). At the start of 25th week of age, these layers were divided into 20 experimental units/replicates (8 layers/ replicate), which were further allotted to five treatment groups (4 replicate/ treatment). Five diets (A, B, C, D and E) were prepared with or without addition of sodium bicarbonate. Diet A, was without sodium bicarbonate and served as control whereas, diets B, C, D, and E contained 0.5, 1.0, 1.5 and 2.0% sodium bicarbonate, respectively. All the diets were iso-nitrogenous (CP 17%) and iso-caloric (ME 2700 Kcal/Kg) and were fed to the experimental birds *ad libitum*, for 12 weeks (26-37 weeks of age). Data on feed consumption, number of eggs produced, egg weight and egg mass laid by the birds were recorded. These data were used for the calculation of feed conversion ratios on the basis of per dozen eggs and per kg egg mass produced. Five eggs from each replicate were checked weekly for their shell thickness, yolk index, albumen index, haugh unit score, yolk pH, albumen pH, specific gravity and yolk cholesterol. The results revealed that dietary inclusion of sodium bicarbonate significantly ($P<0.05$) improved feed consumption, water intake, weight gain, egg production and feed efficiency of the birds. Addition of sodium bicarbonate significantly ($P<0.05$) increased egg weight, egg shell thickness and specific gravity of eggs produced by the birds. Yolk cholesterol was found to be the lowest in the eggs produced by the birds fed diets containing 1% $NaHCO_3$. Whilst, pH of egg yolk and egg albumen were found to be significantly ($P<0.05$) higher in birds, which were fed diet containing 2% sodium bicarbonate Respiration rate and rectal temperature was found to be lowered ($P<0.05$) by addition of sodium bicarbonate in the diet of layers. No mortality was observed in any group throughout the experiment.

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Authors' Contribution
GA designed the study, executed the experiment and prepared the manuscript. SM supervised the research and provided the research materials. Being members of supervisory committee, AH and HN provided guidance during the execution of this project.

Key words
White leghorn, Heat stress, Sodium bicarbonate, Production performance, Egg quality, Body temperature

INTRODUCTION

Pakistan is situated in the subtropical zone of Northern Hemisphere of the world where temperature usually remains well beyond the higher side of thermoneutral zone (25-37°C) for the greater part of the year (Anjum, 2000). The environmental temperature of some parts in the region reaches up to 52°C (Vidal and Walsh, 2010). The optimum temperature for efficient performance is 19-22°C for laying birds, however, ambient temperature especially on higher side is very disruptive and may reduce survival rate and production (Charles, 2002). High environmental temperature (heat stress) during summer is a major problem in most parts of Pakistan, which has pronounced effects on production and reproductive performance of layers (Mashaly *et al*., 2004). Egg production declines drastically, thereby adversely affecting the economics of poultry production, which may lead to increase a sizeable number of layers as culled birds.

High temperature in laying house causes detrimental effects not only on egg production, egg size and egg quality (Farnell *et al*., 2001; Lin *et al*., 2004) but also adversely affects physiology of the birds (Sahota *et al*., 1990) resulting in high mortality. As ambient temperature goes higher than thermoneutral zone, respiratory rate of birds increases up to 10 times (Nillipour and Melog, 1999), resulting in more loss of carbon dioxide that brings about significant rise in blood pH and upsets acid-base level (Toyomizu *et al*., 2005). Any disturbance in this acid base level may produce acidosis or alkalosis, distracting the metabolic machinery worked for production to the homeostatic regulation (Carlson, 1997). Any change in level of CO_2 may cause disturbance in blood pH and deterioration in eggshell quality (Jones, 2006).

Different techniques have been used in poultry production to combat heat stress. These techniques include nutritional manipulations such as dietary addition of oils (Ghazalah *et al*., 2008), reduction in protein level of feed, supplementation of feed with limiting amino acids (Daghir,

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1995) and management practices like intermittent feeding, feeding the birds in cool h of the day, time limit feeding (Yalcin *et al*., 2001), sprinkling of water, evaporative cooling (Donald, 2000), improved ventilation (Nilipour, 2000) and supplementation of electrolytes (Ahmad *et al*., 2005). These techniques are considered helpful in reducing heat stress.

Among the electrolytes, $NaHCO_3$ may be used to maintain a correct plasma acid-base balance to combat heat stress. Sodium bicarbonate is a cheap salt (electrolyte) and is also used as a buffering agent, source of carbon dioxide, an antacid and for the production of sodium carbonate (Whiting *et al*., 1991). It influences blood pH positively by providing bicarbonate ions and sodium (Ahmad *et al*., 2006). Many studies have reported beneficial effects of supplementing drinking water of broilers with sodium bicarbonate as sodium source (Hassan *et al*., 2011). However, scientific information regarding the use of $NaHCO_3$ in layer diet is still scarce. Keeping in view the information above, supplementation of $NaHCO_3$ may be a useful technique to combat heat stress, which still needs to be addressed in layers. Therefore, a study was planned to investigate the impact of dietary supplementation of $NaHCO_3$ on production performance of caged layers under the geonatical conditions of Pakistan during summer.

MATERIALS AND METHODS

Birds and housing

A total number of 160 commercial layer birds of age of 24 weeks were purchased from a local commercial poultry farm. These birds were divided into twenty experimental units having 08-layer birds in each unit/replicate. These units/replicates were further distributed to five treatment groups (4 replicate/ treatment). These experimental birds were kept up in individual cages in a thoroughly cleaned and disinfected Experimental Poultry House of the Department of Parasitology, Faculty of Veterinary Sciences, University of Agriculture, Faisalabad, Pakistan. These layer birds were kept under similar managemental conditions like relative humidity, light, temperature and floor space.

Initially these birds were reared in a group and were fed commercial layer ration during 25th week of age as an adaptation period. Thereafter, at the start of 26th week, all the birds were individually weighed, leg banded and transferred randomly to the individual cages using Completely Randomized Design. Each cage was supplied with a feeder and drinker line. The length, width and height of each cage were 41, 39 and 37cm, respectively. Daily, 17 h light was provided to the birds throughout the experiment. A dry bulb thermometer was installed in the center of the house to record daily ambient temperature. Whereas, daily records of relative humidity inside the poultry house were maintained by using a digital hygrometer.

Experimental diets, groups and their feeding plans

Five treatment/diet groups A, B, C, D and E were formulated with or without supplementation of $NaHCO_3$. Group A contained 0% sodium bicarbonate and dealt as control group whereas treatment group B contained 0.5% sodium bicarbonate, group C contained 1.0% sodium bicarbonate, group D with 1.5% sodium bicarbonate and group E with 2.0% sodium bicarbonate. All the treated diets were iso-caloric (ME 2700 kcal/kg) and iso-nitrogenous (CP 17%) and were fed to the experimental birds, for 12 weeks (26-37 weeks of age). A weighed amount of the experimental diets were fed twice a day (morning and evening). Proportions of ingredients used in the treated diets are given in Supplementary Table I. Before the start of experiment, all the diets were analyzed for their proximate chemical composition, as shown in Supplementary Table II, according to the technique described by AOAC (2010), in the Analytical Laboratory of the Institute of Animal Sciences, Faculty of Animal Husbandry, University of Agriculture, Faisalabad (Pakistan).

Live performance

Body weight of the birds was recorded at the start of the experiment and thereafter at the end of each subsequent week. Feed consumption and number of eggs laid by the birds were recorded daily for each replicate, separately. From these observations, egg production (%), feed intake/bird/day, and FCR on the basis of per dozen eggs and per kg egg mass produced was calculated. A measured quantity of water was offered to each group *ad libitum,* in the morning and evening time. At each time, the residual water was again measured and recorded. Daily water intake of each replicate was summed up to calculate water consumption/group. A complete record of mortality, if any, in each replicate was maintained.

Egg characteristics

At the last day of each week of the experiment, a total number of 120 eggs (6 eggs from each replicate) were taken to determine egg characteristics. Egg weight was taken using a digital balance and shell thickness was measured with the help of an electronic digital Vernier caliper. The thick albumen height and yolk height was measured using Tripod Micrometer (TSS, England). Egg yolk cholesterol was calculated by the method described by Roeschlau *et al*. (1974). Haugh units (HU) was calculated as described by Haugh (1937). Specific gravity of eggs was determined the NaCl solutions of varying concentrations according to the methodology described by Hamilton (1982).

Rectal temperature and respiration rate

On the last day of each experimental week, rectal temperature and respiration rate of three birds from each replicate were recorded thrice *i.e.*at 6:00 am, 12:00 noon and 6:00 pm. Thereafter average values of these observations were calculated to be used in the statistical analysis.

Statistical analysis

The statistical analysis was conducted for interpretation of results using completely randomized design (CRD) and group differences were compared by the Least Significance Differences (Steel *et al*., 1997) test.

RESULTS

The results of this research work showed that dietary supplementation of sodium bicarbonate highly ($P<0.05$) improved weight gain, feed consumption, egg production, egg weight and egg mass of the birds (Table I). The birds of experimental Group C which were fed treated diet containing 1% $NaHCO_3$ exhibited better weight gain, feed consumption, egg production, egg weight, egg mass than those of its counterparts. Layers performance in terms of feed conversion ratio on the basis of per dozen eggs produced and FCR on the basis of per kg egg mass produced was also significantly improved due the supplementation of sodium bicarbonate in their diets. The birds using diet containing 1% sodium bicarbonate utilized their diet more efficiently than those of other treatment groups.

Egg quality characteristics of the layers such as specific gravity, albumen height, Haugh unit score, yolk height and yolk diameter, were also significantly ($P<0.05$) improved due to the dietary inclusion of sodium bicarbonate (Table II). Eggs produced by the birds of experimental group C, which were fed treated diet containing 1% sodium bicarbonate, exhibited maximum values for specific gravity, albumen height, Haugh unit score, yolk height and yolk diameter when compared to the eggs produced by the birds of other treatment groups. Differences in shell thickness of eggs produced by the birds among treated group were also found to be significant. Birds of experimental group D, which were fed diet containing 2% sodium bicarbonate, revealed maximum shell thickness when compared to the eggs produced by the birds of other treatment groups. Yolk cholesterol was found to be the lowest in the eggs produced by the birds, which were fed diet containing 1% $NaHCO_3$. Whilst, pH values in yolk and albumen of the eggs were found to be the highest in the birds of group E which were fed diet containing 2% $NaHCO_3$. However, yolk index of eggs produced by birds remained unaffected due to dietary supplementation of sodium bicarbonate.

Mean values of rectal temperature, respiration rate and water consumption of the experimental birds have been shown in Table III. Rectal temperature and respiration rate of the birds kept under treated groups was significantly influenced due to addition of sodium bicarbonate in their diets. Statistical analysis of the data revealed that birds using diets containing sodium bicarbonate exhibited significantly ($P<0.05$) lower rectal temperature and respiration rate when compared to those of control group. The lowest rectal temperature and respiration rate was observed in the birds which were fed diet containing 1% sodium bicarbonate among those of treated groups. Water consumption of the layers was significantly influenced due to dietary inclusion of sodium bicarbonate in their diets. Statistical analysis of the data showed that birds using diets containing sodium bicarbonate consumed significantly ($P<0.05$) more water as compared to those of control group. There was a linear increase in water consumption of the birds with increase in the level of sodium bicarbonate in their diets. Birds of group E, which were fed diet containing (2%) sodium bicarbonate, exhibited maximum water consumption as compared to the birds of other treated groups. Incidence of mortality was zero in all groups.

DISCUSSION

Heat-stress causes incidence of respiratory alkalosis in the poultry birds (Diabartola, 1992; Carlson, 1997) due to excessive excretion of carbon dioxide. However, dietary supplementation of certain minerals salts such as $NaHCO_3$ appears to be helpful in alleviating the effects of heat stress (Barbosa *et al*., 2014). $NaHCO_3$ may be used as a supplemental source of Na^+ as well as HCO_3^- ions thus helps to replace CO_2 losses which may occur due to panting. Its use in poultry birds diet can improve their feed consumption and water intake which ultimately may improve performance of the layer birds.

Birds using diets supplemented with sodium bicarbonate showed more feed consumption as compared to those of untreated group (control). Increase in feed consumption of the treated groups may be due to more sodium ions concentration in the rations containing sodium bicarbonate (Puron *et al*., 1997). Similar effect of increased sodium ions concentration in broilers has been observed by Ahmad *et al*. (2006), Balnave and Gorman (1993), Puron *et al*. (1997), Gongruttananun and Ratana (2005) and Yoruk *et al*. (2004).

Table I. Effect of dietary inclusion of sodium bicarbonate on production performance of caged layers.

Variables	Control	Treatment			
		0.5%$NaHCO_3$	1%$NaHCO_3$	1.5%$NaHCO_3$	2%$NaHCO_3$
Initial body weight (g)	1328±14.3	1310 ±7.0	1318 ±16.4	1324 ±11.0	1312 ±12.1
Final body weight (g)	1494±60.9	1497±53.4	1517±36.7	1501±24.6	1481±61.0
Weight gain (g)	166±11.4^{c}	187±6.4^{ab}	199±15.1^{a}	177±9.3^{bc}	169±13.5^{c}
Feed consumption (g)	743±12.90^{d}	770±10.45^{b}	780±14.84^{a}	766±10.51^{b}	755±12.16^{c}
Egg prod. (no)	5.33±0.20^{d}	5.63±0.21^{b}	5.86±0.36^{a}	5.51±.12^{c}	5.42±0.51^{c}
Egg weight (g)	50.9±4.0^{d}	54.0±3.5^{c}	58.2±1.50^{a}	56.0±1.1^{b}	55.2±1.6^{b}
Egg mass produced (g)	267±10.8^{c}	303±13.0^{b}	339±12.6^{a}	307±11.2^{b}	299±17.5^{b}
FCR/ dozen eggs	1.70±0.05^{a}	1.64±0.05^{c}	1.60±0.05^{d}	1.67±0.02^{b}	1.67±0.02^{b}

Values within the same row having different superscripts are significantly ($P<0.05$) different.

Table II. Effect of dietary inclusion of sodium bicarbonate on egg quality characteristics of caged layers.

Variables	Control	Treatment			
		0.5%$NaHCO_3$	1%$NaHCO_3$	1.5%$NaHCO_3$	2%$NaHCO_3$
Specific gravity	1.077±0.030^{c}	1.081±0.012^{b}	1.086±0.020^{a}	1.086±0.020^{a}	1.079±.028^{bc}
Shell thickness (mm)	0.307±0.013^{c}	0.335±0.010^{b}	0.334±0.012^{ab}	0.336±.011^{ab}	0.34±0.011^{a}
Albumen height (mm)	4.39±0.107^{d}	4.71±0.101^{b}	4.97±0.123^{a}	4.6±0.150^{bc}	4.46±0.130^{cd}
Haugh unit	66.9±1.25^{c}	68.7±0.73^{ab}	70.2±0.97^{a}	68±1.29^{bc}	67.2±1.15^{bc}
Yolk diameter (mm)	33.4±1.00^{b}	34.5±1.14^{b}	36.6±1.55^{a}	33.9±1.20^{b}	33.4±1.02^{b}
Yolk height (mm)	13.3±0.37^{c}	14.2±0.26^{a}	14.5±0.28^{a}	13.8±0.20^{b}	13.49±0.14^{bc}
Yolk index	0.404±0.014^{a}	0.401±0.014^{a}	0.393±0.014^{a}	0.408±0.011^{a}	0.401±0.010^{a}
Yolk cholesterol (mg/egg)	243±5.9^{a}	214±13.7^{b}	193±15.0^{c}	191±17.0^{c}	185±6.4^{c}
Yolk pH	6.8±0.22^{b}	6.8±0.56^{b}	7.1±0.18^{ab}	7.3±0.16^{a}	7.4±0.17^{a}
Albumen pH	6.9±0.32^{c}	7.3±0.29^{bc}	7.7±0.26^{ab}	7.6±0.24^{ab}	7.8±0.21^{a}

Values within the same row which have different superscripts are significantly different ($P<0.05$).

Table III. Effect of dietary inclusion of sodium bicarbonate on rectal temperature, respiration rate and water consumption of caged layers.

Variables	Treatment				
	A Control	B 0.5%$NaHCO_3$	C 1%$NaHCO_3$	D 1.5%$NaHCO_3$	E2%$NaHCO_3$
Rectal temperature (^{0}F)	106.75±5.81^{a}	106.39±4.43^{b}	106.20±4.2^{b}	106.41±3.14^{b}	106.38±2.10^{b}
Respiration rate (per min)	57.04±1.7^{a}	53.46±3.18^{b}	47.74±3.9^{d}	51.30±4.2^{bc}	50.5±4.1^{c}
Water intake (ml/day)	333±9.51^{d}	380±14.6^{c}	427±9.7^{b}	446±10^{ab}	467±8.7^{a}

Values within the same row which have different superscripts are significantly different ($P<0.05$).

However, Balnave and Muheereza (1997) and Waldroup *et al*. (2005) have observed a non-significant ($P<0.05$) difference in feed consumption of birds using rations with or without supplemented sodium bicarbonate. Similar results have also been reported by Senkoylu *et al*. (2005) who investigated the effect of inclusion of different levels of NaCl, $NaHCO_3$ and K_2CO_3 in poultry diets, on feed consumption of layers during peak production period and did not observe any effect due to the dietary inclusion of these compounds on feed intake of the birds. Contrary to the findings of present study, Fuentes *et al*. (1998) found no effect of adding different levels of sodium bicarbonate (0.6, 1.2, 1.8 and 2.4%) in the diets on feed consumption in guinea fowl reared at high ambient temperature.

Body weight gain of the layer birds using diets containing sodium bicarbonate was found to be increased due to the supplementation of $NaHCO_3$ in their diets. A possible reason of increased body weight of the birds in treated groups may be the higher feed intake of the birds using sodium bicarbonate. Similar results have been observed by Balnave and Gorman (1993) and Genedi (2000) who reported that adding anti-stressors like $NaHCO_3$ in to drinking water offered to Matrouh and Leghorn hens increased their weight gain under heat stress condition. Another possible explanation of these results may be the response to dietary inclusion of sodium bicarbonate, which depends upon presence or absence of factors influencing acid-base status of the birds. Presence of metabolizable anions (Na^+) in poultry diets has shown to exhibit a significant improvement in the body weight gain of broilers (Ruiz-Lopez and Austic, 1993). Contrary to the findings of this study, Junqueira*et al*. (2003), Osman *et al.* (2015), Hayat *et al*. (1999) and Wideman *et al*. (2003), found no effect on body weight by adding different concentrations of sodium bicarbonate in the diets.

Egg production of the layers using diets containing sodium bicarbonate was found to significantly higher than those of untreated group (control). The increase in egg production may be due either to more feed consumption or increased sodium ions concentration, in the rations containing sodium bicarbonate (Puron *et al*., 1997), or both. Results of the study are in line with the findings of Okan (1999), Ghorbani and Fayazi (2009), Hassan *et al*. (2011), Balnave and Muheereza (1997), Ghorbani and Fayazi (2009) and Yoruk *et al*. (2004) who have reported improved egg production due to the supplementation of sodium bicarbonate (1%) in layer diets.

Birds using diets containing sodium bicarbonate exhibited more egg weight as compared to those of untreated group. Increase in egg weight of the birds of supplemented groups may apparently be due to better utilization of digested proteins, amino acids, monosaccharide and energy due to metabolic effect of sodium present in sodium bicarbonate containing rations as has been reported by Murkami *et al*. (2001). Another possible reason of better egg weight in treated groups may be higher feed intake of the layer birds as observed in the findings of present research work. The results of this study are in line with the findings of Balnave and Muheereza (1997) and Ghorbani and Fayazi (2009) who fed diet supplemented with sodium bicarbonate to birds.

The birds using diets containing sodium bicarbonate utilized their diets more efficiently than the birds of untreated group (control). A probable clarification of better FCR calculated on the basis of per dozen eggs produced by the birds of treated groups may be more synthesis of tissue proteins (Borges *et al*., 2003) as a result of higher feed consumption. Similar results regarding efficiency of feed utilization have also been reported by Barton (1996) due to the addition of $NaHCO_3$ in turkey feeds. Another probable explanation of better efficiency of feed utilization in the birds using sodium bicarbonate may be the improved electrolyte balance in the diets, which might have created some favorable conditions for improvement in the feed efficiency (Drinah *et al*., 1990). Better FCR may also be attributed to better digestion and absorption of nutrients due to incorporation of sodium carbonate, which ultimately may have resulted in improved egg production; a vital factor involved in the calculation of feed efficiency.

Efficiency of feed utilization of the layers, calculated on the basis of per dozen eggs produced was also found to be affected as result of addition of different concentrations of sodium bicarbonate (0.5-2.0%) in layer diets. A probable explanation of better utilization of feed containing various concentrations of sodium bicarbonate may be due to better feed consumption, improved egg production and production of heavier eggs by the birds of treated groups. These results are in line with the findings of Yoruk *et al*. (2004) who reported that dietary addition of various concentrations of sodium bicarbonate improved feed conversion ratio of the birds, calculated on the basis of one dozen eggs produced.

The results regarding efficiency of feed utilization calculated on the basis of per kg egg mass produced, revealed that the birds using diets containing sodium bicarbonate utilized their feeds more efficiently than those birds fed diet without inclusion of $NaHCO_3$ (control). Better FCR/kg eggs mass produced in the treated groups may probably be due to their higher feed consumption, resulting in increased availability of nutrients after fulfilling the maintenance requirements of the birds and ultimately leading to more egg production and heavier eggs. Improvement in efficiency of feed utilization in the birds using sodium bicarbonate may also be due to the improved electrolyte balance, better digestion and absorption of nutrients, enzymatic reactions and synthesis of tissue proteins in the diet by creating favorable conditions for an improvement in feed efficiency (Drinah *et al*., 1990; Borges *et al*., 2003). The results of the present study are in line with the findings of Keskin and Durgan (1997) who have reported an improved FCR in quails fed diet supplemented with $NaHCO_3$, KCl, $CaCl_2$, NH_4Cl and $CaSO_4$ and Those of Yoruk *et al*. (2004) who reported that inclusion of different levels of sodium bicarbonate in laying hens diets improved their feed conversion ratio.

Inclusion of sodium bicarbonate in feed has also shown potential benefits on egg quality characteristics (Balnave and Muheereza, 1997; Kaya *et al*., 2004) in heat stressed layers. Layer birds exposed to high environmental temperature (control) produced eggs with poor shell thickness. Decreased shell thickness of eggs produced by control birds might be because of low feed intake (Balnave and Muheereza, 1997; Anjum, 2000) of these birds, which probably caused reduction in calcium intake, an important element required for shell formation (Karimian *et al*., 2004). Another probable reason advocated regarding this aspect is decrease in serum calcium level in control layers as a result of heat stress (Hassan *et al*., 2011). However, addition of sodium bicarbonate in the diet caused an increase in feed intake which resulted in better shell thickness of eggs produced by these layers.

Increase in specific gravity of the eggs produced by the birds of different dietary treated groups may be result of better utilization of calcium because of metabolic effect of sodium and/or bicarbonate ions, present in sodium bicarbonate containing diets (Keskin and Durgan, 1997), leading to the production of thick shelled eggs.

Eggs produced by the birds using diets containing sodium bicarbonate exhibited more albumen height and haugh unit score as compared to those of control group, which again be due to higher feed intake and better absorption of nutrients by these birds. Moreover, birds using dietary sodium bicarbonate also showed significant serum albumen concentration as compared to the birds of control group. Therefore, more albumen height of the eggs produced by the birds using treated ration may also be due to more serum albumen concentration. The albumen height is an essential constituent for calculation of Haugh units and is known to be affected by the temperature during storage. The quality of albumen and yolk deteriorates with increase in storage time and temperature of egg (North and Bell, 1990). However, in the present study the eggs used for the determination of albumen height, were fresh. Therefore, probably albumen quality of the eggs produced by the birds of control group was deteriorated only because of high environmental temperature.

In the present study, no bird died from any group (treated or untreated) during the experimental period. High environmental temperature have shown to increase mortality rate in fowls as has been observed by Zakia *et al*. (1995) and Mandal *et al*. (2010). There exists a significant difference in livability of heat resistant and susceptible lines of poultry birds. It was further reported that the birds reared in cold environment exhibited significantly higher mortality under subsequent heat stress than those reared in the hot environment (Bohren *et al*., 1982). Dietary addition of anti-stress compounds, like sodium bicarbonate have been proved to be beneficial in controlling mortality of birds during heat stress (Mushtaq *et al*., 2005).

Birds using diets containing sodium bicarbonate showed critical ($P<0.05$) lower rectal temperature when compared to the birds of untreated group. A possible reason of lower rectal temperature may be due to increased sodium ions concentration in their diets, which might have resulted in increased water consumption (Ahmad, 1997; Ahmad *et al*., 2006; Belay and Teeter, 1993). Results of the study are in line with the findings of Ahmad *et al*. (2005) who reported significant ($P<0.05$) reduction in body temperature and lower the respiratory rate of the birds given diets supplemented with sodium bicarbonate. Angiletta *et al*. (2010) have also reported decreased respiration rate of the birds fed diets containing sodium bicarbonate.

An increase in water intake helps in lowering the body temperature of broilers exposed to higher ambient temperature (Ahmad *et al*., 2005; Borges *et al*., 2003; Balnave and Gorman, 1993; Sayed and Scott, 2008).

CONCLUSION

Heat stress in caged layers was successfully alleviated with dietary inclusion of different levels of sodium bicarbonate. Use of 1% sodium bicarbonate in the diet of layer was the most effective in reducing the effects of heat stress in the poultry birds. Quality of eggs produced by the birds using dietary sodium bicarbonate was also improved. Use of Sodium bicarbonate could be a better choice to be included in the diets of poultry birds to reduce the effect of heat stress because it is cheap and can be handled easily.

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Supplementary material

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Statement of conflict of interest

The authors have declared no conflict of interest.

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Supplementary Material

Effect of Dietary Inclusion of Sodium Bicarbonate on Production Performance of Caged Layers During Summer

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Supplementary Table I. Proportion of the ingredients used in the experimental diets.

Ingredients (%)	A basal diet	B 0.5% $NaHCO_3$	C 1% $NaHCO_3$	D 1.5% $NaHCO_3$	E 2% $NaHCO_3$
Maize	31.50	28.00	29.00	30.60	30.60
Rice broken	30.20	30.00	30.00	30.00	30.00
Fish meal	3.60	5.50	7.00	7.00	7.00
Soybean meal	17.00	1.50	0.00	2.00	4.40
Canola meal	4.50	14.00	13.60	11.60	8.40
Rapeseed meal	3.10	3.00	3.00	3.00	3.00
Guar meal	0.00	2.50	3.00	3.00	3.00
Corngluten 60%	0.00	2.00	2.00	2.00	2.00
Rice polishing	0.00	2.20	2.00	0.00	0.00
Dicalcium phosphate	0.50	0.00	0.00	0.00	0.00
Limestone	9.00	9.00	8.70	8.70	8.70
Mineraland vitamin premix	0.30	0.30	0.30	0.30	0.30
DL-methionine	0.13	0.08	0.07	0.07	0.09
Lys. sulphate 65%	0.00	0.15	0.14	0.13	0.12
Salt	0.23	0.00	0.17	0.17	0.18
Sodium bicarbonate	0.00	0.50	1.00	1.50	2.00
Allzyme	0.015	0.015	0.015	0.015	0.015
Lincomix	0.02	0.02	0.02	0.02	0.02

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Supplementary Table II. Chemical composition of the experimental diets.

Nutrients	A basal diet	B 0.5% $NaHCO_3$	C 1% $NaHCO_3$	D 1.5% $NaHCO_3$	E 2% $NaHCO_3$
ME Kcal/Kg	2700	2700	2700	2700	2700
Crude protein (%)	17.00	17.00	17.00	17.00	17.00
Crude fiber (%)	3.29	3.8	3.74	3.44	3.39
Crude fat (%)	3.27	3.9	3.9	3.67	3.65
Crude ash (%)	11.97	11.9	12.01	11.85	11.89
Calcium (%)	3.9	3.9	3.9	3.9	3.9
Av. Phosphorus (%)	0.37	0.37	0.38	0.38	0.39
Sodium (%)	0.17	0.23	0.43	0.57	0.7
Potassium (%)	0.70	0.53	0.51	0.52	0.52
Chloride (%)	0.22	0.15	0.20	0.20	0.20
Digestible Lys (%)	0.80	0.80	0.80	0.80	0.80
Digest. Met (%)	0.44	0.41	0.42	0.42	0.47
Digest. Thr (%)	0.55	0.56	0.56	0.57	0.57
Digest. Trp (%)	0.16	0.16	0.16	0.16	0.16
Dietary electolyte balance (DEB)	210	210	261.73	324.9	387.69