EFFECTS OF SUPPLEMENTAL $NaHCO_3$, KCl, $CaCl_2$, NH_4Cl AND $CaSO_4$ ON ACID-BASE BALANCE, WEIGHT GAIN AND FEED INTAKE IN JAPANESE QUAILS EXPOSED TO CONSTANT CHRONIC HEAT STRESS

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ABSTRACT

The effects of dietary supplementation of potassium chloride (KCl) calcium chloride ($CaCl_2$), ammonium chloride (NH_4Cl), sodium bicarbonate ($NaHCO_3$) and calcium sulphate ($CaSO_4$) on acid-base balance, plasma electrolyte, weight gain and feed consumption in chronically thermostressed Japanese quails were investigated. Chronic thermostress lead to significant decrease in pCO_2, HCO_3, tCO_2, weight gain and feed consumption. The supplementation of NH_4Cl, $CaCl_2$, KCl and $CaSO_4$ at levels of 1 per cent to the basal diet restricted the increase in pH, while pH significantly increased in the groups received basal diet and dietary $NaHCO_3$ ($P<0.05$). NH_4Cl and KCl significantly increased weight gain and feed consuption ($P<0.05$) when compared with birds fed the basal diet. The results showed that particularly NH_4Cl and KCl supplementations alleviated the negative effects of chronic heat stress in Japanese quails.

INTRODUCTION

Departure from normal acid-base balance, affects normal growth and reproduction in mammals and hens (Bottje *et al.*, 1983; Lopez and Austic, 1993; Kutlu, 1996). Heat stress also reduces growth rate of broiler chicks (Teeter and Smith, 1986). McNaughton and Reece (1982) reported that maximal growth rate of the 3-7 week-old broiler chicks occurred at 20°C approximately.

Thermal polypnea associated with heat loss in chickens reduces blood carbondioxide partiel pressure (pCO_2) and hydrogen ions (H^+) concentration and results in acid-base imbalance called respiratory alkalosis (Bottje and Harrison, 1985a). According to Odom (1982), respiratory alkalosis develop within 60 min. after the onset of an acute thermal stress in hens. Blood alkalosis occurred by altering Na:Cl ratios reduces both feed consumption and growth rate of chicks (Hurwitz *et al.*, 1973). Similar to metabolic alkalosis, the negative effects in respiratory alkalosis induced thermal stress were determined in broiler chicks (Bottje and Harrison, 1985b; Teeter *et al.*, 1985; Teeter and Smith, 1986).

Because of the economic effects of reduced growth rate resulting from chronic heat stress and death losses induced acute heat stress, there is an interest in alleviating the effects of high temperature through chemical manipulation of the blood-acid-base balance. It was reported that decline in growth rate induced heat stress resulted directly from reduced feed intake (Bottje *et al.*, 1983; Branton *et al.*, 1986; Smith and Teeter, 1987; Kutlu, 1996). Smith and Teeter (1987) observed that K^+ excretion increased with heat stress in broilers and their needs increased during period of heat stress. They indicated that dietary levels of 1.5-2 per cent K^+ in the form of KCl improved weight gain in chicks under chronic heat stress. The use of 1 per cent dietary NH_4Cl as a potential blood acidifier and 0.5 per cent $NaHCO_3$ as a source of HCO_3 together alleviated the effects of chronic heat exposure in broiler chickens (Teeter *et al.*, 1985).

Bottje and Harrison (1985a) have shown that infusion of carbonated water into crops of cockerels produced a more favorable acid-base balance during acute heat stress than tap water by reducing blood pH change during thermal polypnea and the infusion of high levels of $NaHCO_3$ (2%) and $CaCl_2$ (3.5%) lead to abnormal acid-base equilibrium conditions during the heat stress induced respiratory alkalosis. Bottje and Harrison (1985b) obtained better growth rate and feed conversion by using carbonated water rather than tap water as a source for drinking water of broilers exposed to chronic heat stress.

Branton *et al.* (1986) reported that blood pH of birds was substantially lowered by consumption of water containing either NH_4Cl at 6.25 or 31 g/L while consumption of $NaHCO_3$ at 6.25 g/L did not significantly affect blood pH.

The study was planned to investigate the effects of supplementing sorted compounds, at the levels offered by early studies conducted in chickens, on blood acid-base balance, growth rate, weight gain and feed consumption of Japanese quails exposed constantly to chronic heat stress because of the restricted data about the effects of ration supplementation in heat stressed quail chicks.

MATERIALS AND METHODS

Seventy, male 3 weeks old Japanese quail chicks were used in the study. The birds were randomly assigned into 7 groups including ten chicks in each. All groups were housed in seperate wire cages within temperature controlled chamber under continuous lighting. One of these groups was used as thermoneutral group (20-22°C). Remaining groups were exposed to chronic heat stress. The heat exposure was performed by stepwise increase of chamber temperature from 20-22 to 33-34°C and lasted ten days at this temperature. The thermostressed groups (from II to VII) received basal diet (group II) and basal diet containing KCl (group III), $CaCl_2$ (group IV), $NaHCO_3$ (group V), NH_4Cl (group VI) and $CaSO_4$ (group VII) at level of 1 per cent during the chronic heat stress period, respectively, whereas thermoneutral group (group I) received basal diet (Table 1).

Table 1: Composition of the basal ration used in the experiment

Ingredients	Percent
Ground corn grain	55.0
Soybean meal	36.0
Meat and bone meal	6.2
Dicalcium phosphate	1.0
Calcium carbonate	0.9
Vitamin mix	0.5
Salt (Sodium chloride)	0.3
Trace mineral	0.1

Prior to experiment, one week was utilized to adopt all birds to basal diet and environment. For each trial, feed and water were continuously available.

At the end of the 10th day, all chicks were weighed, then venous blood samples were drawn into heparinized (lithium heparin) syringe for determination of pH, HCO_3, pCO_2, tCO_2, BE, Na^+, K^+, Ca^{++} and PCV by blood gases analyser (Ciba-Corning, 288 blood gas system). Also weight gain, feed consumption were calculated in all groups. The pH, HCO_3, pCO_2, tCO_2, BE, Na^+, K^+, Ca^{++} and PCV were determined.

Data were analysed statistically by student's t test to obtain significance of differences between group means and correlation coefficient between pH, weight gain and feed consumption (Steel and Torrie, 1982).

RESULTS AND DISCUSSION

At the end of the chronic heat stress period, blood pH in groups fed the basal diet and the diet with $NaHCO_3$ significantly increased ($P<0.05$) compared to thermoneutral group and the other groups. Supplementing the basal diet with KCl, $CaSO_4$, $CaCl_2$ and NH_4Cl restricted the increase in pH. It was dtermined that pH in groups fed the diets with KCl, $CaCl_2$ and NH_4Cl did not differ from that in thermoneutral group (Table 2).

Parker and Boone (1971) observed that pH in the male turkey decreased when exposed to thermal stress, whereas Kohen and Jones (1975) observed that chronic heat stress leads to decrease in egg production, egg shell thickness and egg weight in turkeys, but had no effect on blood acid-base balance.

A study conducted in quails (Altan and Oguz, 1996) demonstrated that although chronic heat stress (2 hours at 35-36°C/day for one week) caused a significant decrease in blood pCO_2 and shell thickness and a significant increase in blood pO_2, there was no significant difference in blood pH, egg production and egg weight. On the other hand, acute heat stress resulted in significant increase in blood pH and significant decrease in pCO_2 and HCO_3 levels of quails (Durgun *et al.*, 1996).

The chronic heat stress significantly decreased pCO_2, HCO_3 and tCO_2 levels ($P<0.05$) in all thermostressed groups (Table 2) similar to results reported for hens (Bottje and Harrison, 1985a; Teeter *et al.*, 1985) and quails (Altan and Oguz, 1996; Durgun and Keskin, 1996) unlikely turkey (Kohne and Jones, 1975; Parker and Boone, 1971). The levels of pCO_2 in the groups fed the diets with $CaCl_2$ and NH_4Cl and HCO_3^- in the groups fed the diets with $CaCl_2$, NH_4Cl and $CaSO_4$ were significantly lower than those in the group received $NaHCO_3$ ($P<0.05$). On the other hand tCO_2 level in the group received $NaHCO_3$ was significantly higher than in other themostressed groups. These are similar to results of previous studies (Bottje and Harrison, 1985a; Teeter *et al.*, 1985). Despite of the decrease in pCO_2, HCO_3 and tCO_2 levels of the groups received acidogenic supplements, limitation of the increase in pH of these groups reflects a compensation of alkalosis occured by hyperventilation (Bottje and Harrison, 1985a; Boulahsen *et al.*, 1989; Lopez and Austic, 1993).

Dietary $NaHCO_3$ significantly increased ($P<0.05$) Na^+ level in this group compared with the other groups

Table 2: Effects of dietary supplements on blood acid-base state in thermostressed quails

Treatments	pH	pCO_2 (mmHg)	HCO_3 (mEq/L)	tCO_2 (mEq/L)	BE (mEq/L)
Thermoneutral group (Control)	7.36±0.03cd	30.30±1.34a	19.20±1.01a	23.4±1.26a	-3.1±0.51a
Basal diet	7.59±0.02a	15.40±1.48bc	10.80±0.76bc	11.5±0.81c	-8.2±0.98b
1 % KCl	7.43±0.02bc	14.80±1.42bc	10.30±0.81bc	11.30±0.66c	-10.40±084bcd
1 % $CaCL_2$	7.41±0.02bc	13.3±1.76c	9.40±0.73c	11.90±0.79c	-11.90±0.91d
1 % $NaHCO_3$	7.61±0.02a	18.70±1.21b	12.6±0.78b	14.7±0.68b	-9.50±0.59bc
1 % NH_4Cl	7.34±0.02d	11.50±1.54c	9.10±0.59c	9.8±0.71c	-12.4±0.68d
1 % $CaSO_4$	7.45±0.03b	14.60±1.56c	9.40±0.57c	11.20±0.63c	-10.90±0.49cd

Treatment means with different letters in a column differ significantly.

Table 3: Effects of dietary supplements on some electrolytes, PCV, body weight gain and feed consumption in thermostressed quails

Treatments	Na^+ (mEq/L)	K^+ (mEq/L)	Ca^{++} (mEq/L)	PCV (%)	WG (g/day)	FC (g/day)
Thermoneutral group (Control)	140.70±0.79b	5.09±0.19ab	2.16±0.07bc	34.80±1.81a	9.10±0.61a	27.70±1.72a
Basal diet	143.10±0.86b	4.84±0.15b	2.11±0.06c	32.40±1.72ab	4.60±0.32d	14.30±1.11c
1 % KCl	142.40±1.14b	5.48±0.18a	1.99±0.12c	31.90±2.04ab	5.50±0.25bc	18.20±0.95b
1 % $CaCL_2$	142.60±0.94b	5.18±0.13ab	2.37±0.09ab	30.90±1.16ab	5.30±0.36bcd	17.1±1.63bc
1 % $NaHCO_3$	146.50±1.20a	4.96±0.11b	2.06±0.07c	30.10±1.14b	4.90±0.29cd	15.60±0.76c
1 % NH_4Cl	141.20±0.96b	5.27±0.14ab	2.13±0.10bc	31.30±1.32ab	6.0±0.38b	20.20±1.22b
1 % $CaSO_4$	142.80±1.18b	5.15±0.12ab	2.41±0.08a	32.40±1.35ab	5.20±0.35bcd	16.50±1.18bc

Treatment means with different letters in a column differ significantly.

whereas K^+ level was found to be significantly ($P<0.05$) higher in the group received KCl than the Dietary $NaHCO_3$ significantly increased ($P<0.05$) Na^+ level in this group compared with the other groups whereas K^+ level was found to be significantly ($P<0.05$) higher in the group received KCl than the finding has been explained by either a K^+ shift between muscle and extracellular fluid (acute hyperventilation), an increase K^+ excretion (chronic heat stress) or by an increase in K^+ uptake of erythrocytes and/or skin (acute heat stress) (Smith and Teeter, 1987; Boulahsen *et al.*, 1989). Also Laiken and Fanestil (1985) reported that respiratory alkalosis in mammals reduced competition between H^+ and K^+ for urinary excretion and thereby increased urinary K^+ loss.

PCV in thermostressed groups was generally lower than those in the thermoneutral group, decreased hematocrit in response to heat stress alone has been determined in the birds treated with $NaHCO_3$ ($P<0.05$) compared with the thermoneutral group (Table 3). The reason of the significantly decline in PCV for the group received $NaHCO_3$ may be due to increased water consumption adding to peripheral vasodilation which reflects an influx of extracellular fluid into the vascular space (Darre and Harrison, 1986; Boulahsen *et al.*, (1989). It was demonstrated that dietary $NaHCO_3$ increased water consumption relative to the other dietary supplements such as $CaCl_2$, NH_4Cl, KCl (Morgan and Schultz, 1986; Branton *et al.*, 1986; Davison and Wideman, 1992). Hence, voluntary intake of water inclines with the increase in ambient temperature (Ogunji *et al.*, 1983).

The feed intake and body weight gain were restricted in all thermostressed group (Table 3) compared with thermoneutral group ($P<0.05$) as demonstrated by earlier studies (Hurwitz *et al.*, 1973; Bottje and Harrison, 1985b; Teeter *et al.*, 1985; Kutlu, 1986). The highest weight gain and feed consumption were obtained in the group supplemented with NH_4Cl (Table 3). Dietary NH_4Cl significantly increased weight gain relative to the basal diet and the diet with $NaHCO_3$, while dietary KCl increased the weight gain alone relative to the basal diet. On the other hand, either dietary NH_4Cl and KCl significantly ($P<0.05$) increased the feed intake compared with the basal diet and the diet with $NaHCO_3$. It is also noteworthy that the other supplements except NH_4Cl and KCl caused at least partially growth improvement compared with the basal diet unless difference in the study. These data agree with results of the other investigations conducted in hens (Bottje and Harrison, 1985b; Teeter *et al.*, 1985; Branton *et al.*, 1986; Smith and Teeter, 1987; Lopez and Austic, 1993).

The beneficial effects of dietary NH_4Cl supplementation may be due to both H^+ and Cl^- dissociation and also reducing Na:Cl ratio (Teeter *et* *al.*, 1985). The positive effects of $CaCl_2$ and KCl on weight gain and feed consumption relative to unsupplemented diet in the study may be attributed to the reduction of Na:Cl ratio in which any decrease lowers the blood pH (Hurwitz *et al.*, 1973). Hence, Teeter *et al.* (1985) reported that the reason of the improving effects of KCl on weight gain and feed consumption was to meet the K^+ requirement occurred by respiratory alkalosis in related to heat stress.

Despite $CaSO_4$ supplementation slightly increased weight gain and feed intake when compared with the basal diet, this finding indicated that SO_4 (sulfate) was less acidogenic than chloride. The lower acidogenicity of sulfate as compared with chloride in the study is consistent with results of other studies (Lopez and Austic, 1993; Durgun *et al.*, 1996).

Any beneficial effects of $NaHCO_3$ on weight gain in the study would likely be due to the HCO_3 anion, independent of pH, as pH was not favorably affected in aggrement with the reports of Teeter *et al.* (1985) who suggest that reduced blood HCO_3 level precipitated by chronic thermostress create a dietary as well as physiological requirement for this anion.

In the study, negative correlation between feed consumption and blood pH was dtermined in the groups treated basal diet, dietary $NaHCO_3$ and NH_4Cl (r = -0.759, -0.930, -0.781, respectively) while blood pH was inversely related with weight gain in the groups treated with basal diet dietary $CaCl_2$, $NaHCO_3$ and NH_4Cl (r = -0.806, -0.755, -0.714, -0.810, respectively).

Consequently, by resisting these data, lowered feed intake and thereby growth rate resulting from respiratory alkalosis in thermostressed quail chicks can be improved dietarily by supplements such as NH_4Cl, KCl that affect favorably the acid-base status during the heat stress.

REFERENCES

Altan, O. and I. Oguz, 1996. Effects of heat stress on some egg characteristics on acid-base balance in two lines of Japanese quail, unselected and selected for four week body weight. Tr. J. Vet. Anim. Sci., 20-3: 211-214.

Bottje, W.G. and P.C. Harrison, 1985a. The effects of tap water, carbonated water, sodium bicarbonate and calcium chloride on blood acid-base balance in cockerels subjected to heat stress. Poultry Sci., 64: 107-113.

Bottje, W.G. and P.C. Harrison, 1985b. Effects of carbonated water on growth performance of cockerels subjected to constant and cyclic heat stress temperatures. Poultry Sci., 64: 1285-1292.

Bottje, W.G., P.C. Harrison, D.W. Boehm, F.E. Staten and T.W. Odom, 1983. Influence of carbonated water treatment on growth performance of heat-stressed and nonheat-stressed cockerels. Poultry Sci., 63: 1384 (Abstract).

Boulahsen, A., J.D. Garlich and F.W. Edens, 1989. Effect of fasting and acute heat stress on body temperature, blood acid-base and electrolyte status in chickens. Comp. Biochem. Physiol., 94: 683-687.

Branton, S.L., F.N. Reece and J.W. deaton, 1986. Use of ammonium chloride and sodium bicarbonate in acute heat exposure of broilers. Poultry Sci., 65: 1659-1663.

Darre, M.J. and P.C. Harrison, 1986. Heart rate, blood pressure, cardiac output and total peripheral resistance of single comb white leghorn hens during an acute exposure to 35°C ambient temperature. Poultry Sci., 66: 541-547.

Davison, S. and R.F. Wideman, 1992. Excess sodium bicarbonate in the diet and its effect on leghorn chickens. British Poultry Sci., 33: 859-870.

Durgun, Z. and E. Keskin, 1996. The changes associated with fasting and acute heat stress in body temperature, blood acid-base balance and some parameters of Japanese quail. Published by University of Selcuk, Faculty of Vet. Sci., 12 (2): 173-176.

Durgun, Z., E. Keskin, M. Kocabatmaz and T. Kececi, 1996. Effect of sorted anions on the acid-base balance and growing in Japanese quails. Tr. J. Vet. & Anim. Sci., 20 (4): 241-244.

Hurwitz, S., I. Cohen, A. Bar and S. Bornstein, 1973. Sodium and chloride requirements of the chick: relationship to acid-base balance. Poultry Sci., 52: 903-909.

Kohne, H.J. and J.E. Jones, 1975. Acid-base balance, plasma electrolytes and production performance of adult turkey hens under conditions of increasing ambient temperature. Poultry Sci., 54: 2038-2045.

Kutlu, H.R., 1996. Effect of feeding on performance of broiler chicks exposed to heat stress. Farmavet Bull., 3 (12): 1-8.

Laiken, N.D. and D.D. Fanestil, 1985. Potassium balance and the regulation of potassium excretion. In: Best and Taylor's Physiological Basis of Medical Practical. 11th ed. John B. West, ed. Williams and Wilkins, Baltimore, MD., pp:532-536.

Lopez, B. and R.E. Austic, 1993. The effect of selected minerals on the acid-base balance of growing chicks. Poultry Sci., 72: 1054-1062.

McNaughton, J.L. and F.N. Reece, 1982. Dietary energy requirements of broilers reared in low an moderate environmental temperatures. 1. Adjusting dietary energy to compensate for abnormal environmental temperatures. Poultry. Sci., 61: 1879-1884.

Morgan, G.W. and C.D. Schultz, 1986. Body temperatures of fasted broilers incubated with sucrose solutions. Poultry Sci., 65 (Suppl. 1): 183 (Abstr.)

Odom, T.W., 1982. The effects of high environmental temperature induced acid-base disturbance on the utilization of calcium in the domestic hen. Ph.D. Thesis, Univ. Illinois, Urbana, IL.

Ogunji, P.A., R.N. Brewer, D.A. Roland, Sr. and D. Caldwell, 1983. Effect of dietary sodium chloride, protein and strain difference upon water consumption and fecal moisture content of broiler breeder males. Poultry Sci., 62: 2497-2500.

Parker, J.T. and M.A. Boone, 1971. Thermal stress effects on certain blood characteristics of adult male turkeys. Poultry Sci., 50: 1287-1295.

Smith, M.O. and R.G. Teeter, 1987. Potassium balance of the 5 to 8-week-old broiler exposed to constant heat or cycling high temperature stress and the effects of supplemental KCl on body weight gain and feed efficiency. Poultry Sci., 66: 487-492.

Steel, R.G.D. and J.H. Torrie, 1982. Principles and Procedures of Statistics. 2nd Ed. McGraw-Hill International Book Company. Tokyo, Japan.

Teeter, R.G. and M.O. Smith, 1986. High chronic ambient temperature stress effects on broiler acid-base balance on their response to supplemental ammonium chloride, potassium chloride and potassium carbonate. Poultry Sci., 65: 1777-1781.

Teeter, R.G., M.O. Smith, F.N. Owenss, C.Arp, S.Sangiah and J.E. Breazile, 1985. Chronic heat stress and respiratory alkalosis: occurrence and treatment in broiler chicks. Poultry Sci., 64: 1060-1064.