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Research Article
Performance and Physiological Responses of Broiler Chickens Supplemented with Potassium Chloride in Drinking Water Under Environmental Heat Stress

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Abstract

Background and Objective: Broiler reared above the condition of thermoneutral zone will be vulnerable to environmental heat stress and exhibit behavioural and physiological changes. This study is to evaluate the effects of supplementation of potassium chloride (KCl) in drinking water on broiler performance and physiological responses under conditions of environmental heat stress. **Methodology:** A total of 200 days old broiler chicks were evaluated in this study. They were randomly divided into 20 plots and reared for 5 weeks. A completely randomized design with 5 treatments and 4 replications were assigned in this study. The treatments were symbolized as R0, R1, R2, R3 and R4, which is respectively supplemented with KCl as much as 0, 0.25, 0.50, 0.75 and 1.00% (w/v) in drinking water. Variables observed were feed and water intake, body weight gain, feed conversion ratio, the amount of potassium, sodium and chloride absorbed, mortality, the panting percentage, cloacal temperature, numbers of leukocytes and blood pH. **Results:** The results indicated that the supplementation of KCl in drinking water did not significantly ($p>0.05$) affect the panting percentage, however, significantly ($p<0.05$) affected the feed and water intake, body weight gain, feed conversion ratio, the amount of potassium, sodium and chloride absorbed, cloacal temperature, numbers of leukocytes and blood pH. **Conclusion:** It was concluded that the supplementation of 0.50% KCl in drinking water was the optimal level for improving performance and physiological response of broiler chickens under environmental heat stress condition.

Key words: Broiler, drinking water, heat stress, physiological responses, potassium chloride

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Broiler needs the ambient temperature in a range that is appropriate to live in comfortable conditions, which is known as thermoneutral zone. The appropriate range of the environmental temperature for chicken after 3 weeks of age is 20-25°C, while air humidity is 50% or less[1]. If broiler was reared above the condition of thermoneutral zone, it will be vulnerable to environmental heat stress[2] and exhibit behavioural and physiological changes[3]. Nutritional manipulation of heat stress has been suggested[4-7]. In conditions of heat stress, aldosterone is secreted excessively. Consequently, the excretion of K^+ in urine increased and finally reduced the plasma K^+ level[8]. Basically, the anion is needed for maintaining the acid-base balance[9]. The main anion needed is chloride. The needs of potassium and chloride on broiler chicken are varied. Typically, broilers need about 4-6 g of potassium and chloride of 3-4 g kg^{-1} of feed[10]. Nevertheless, under heat stress K is essential and supply the requirements must be assured. This is due to potassium is more excreted from the body than the normal condition[8,11]. In this way, it can be known for certain amount of potassium requirement for broiler chickens reared under conditions of environmental heat stress. It is considered that the provision of electrolyte through the drinking water was more efficient than through the diet, especially when exposed to heat stress[12]. Hence, this study aims to investigate the effect of different concentrations of potassium chloride (KCl) in drinking water on the performance and physiological responses of broiler under heat stress condition.

MATERIALS AND METHODS

Birds, feed and housing: A total of 200 days old chicks (DOCs) of Cobb strain were allocated into 5 treatments of experimental drinking water and reared for 5 weeks. All the chicks were reared in a conventional open-sided house and placed in 20 plots (l×w×h, 100×100×75 cm) with containing 10 chicks per plot. Each plot was placed sawdust as litter. The birds were reared under continuous thermostress environment, which is above the thermoneutral zone. The ambient temperatures and humidity were recorded daily as shown in Table 1. Based on Table 1, the daily ambient temperature and air humidity along this experiment were above thermoneutral zone for broiler (T = 26.95-36.71°C, RH = 85.24-93.95%). During the experiment, 60 watt bulb lamp was provided on each plot and switched on for 24 h as a heater. Moreover, the house was also equipped with thermohygrometer to record ambient temperature and air humidity inside of the housing. The birds were fed a commercial starter diet (crumble) from 1-21 day of age and commercial finisher diet (pellet) from 22-35 day of age. The Metabolizable Energy (ME) and crude protein in the starter diet (0-3 weeks) were 3,000 kcal kg^{-1} and 21% and in the finisher diet (3-5 weeks) were 3,100 kcal kg^{-1} and 19%, respectively as indicated in Table 2. Potassium chloride was used in a mesh form. Based on calculations, in 1 g KCl contained 527.8 mg K and 472.2 mg Cl.

Method: Potassium chloride was added into drinking water based on weight/volume (w/v) and given every day from 1-35 days of age. The treatments tested on broiler chickens were symbolized R0, R1, R2, R3 and R4. R0 was the treatment without added potassium chloride in the drinking water (control), while the R1, R2, R3 and R4 were treatment plus potassium chloride in the drinking water with the amount of 0.25, 0.50, 0.75 and 1.00%, respectively. Feed and drinking water were offered *ad libitum*. At day 4 of age, birds were vaccinated with ND1 vaccine through eye drops, followed by ND2 vaccines through drinking water at 21 day of age.

Measurement of performances: Feed and water consumption were calculated per experimental unit, divided by the number of birds in the unit and by the number of experimental days. The average body weight gain was calculated as the weight gain of the experimental unit divided by the number of birds in each unit. Feed conversion ratio was calculated as the ratio of gain to feed. The amount of potassium, chloride and sodium absorbed by the body is

Table 1: Means of ambient temperatures and air humidity

Time measurement (h)	Ambient temperatures (°C)	Air humidity (%)
05:00-06:00	26.95±0.18	93.95±0.61
12:00-13:00	36.71±0.40	85.24±0.45
16:00-17:00	33.48±0.22	89.43±0.54
20:00-21:00	29.48±0.35	91.10±0.52

Table 2: Nutrient composition of the diets for a period of starter and finisher

Nutrients (%)	Starter diets (1-21 days)	Finisher diets (22-35 days)
Metabolizable energy (kcal kg^{-1})	3,000.00	3,100.00
Crude protein	21.00	19.00
Crude fat	4.00	4.00
Crude fiber	5.00	5.50
Ash	6.00	6.00
Calcium	0.90	0.90
Available phosphorus	0.70	0.70
*Sodium	0.68	0.68
*Potassium	1.50	1.50
*Chloride	0.33	0.30

*Analyzed value

obtained by subtracting the amount of potassium, chloride and sodium consumed from the diet and drinking water with the amount of potassium, chloride and sodium in excreta. Mortality was recorded daily throughout the experimental period.

Measurement of physiological status: The rectal temperature was monitored 3 times a week after 14 days of age[13]. As many as 2 birds per pen were randomly selected to record rectal temperature in the morning and afternoon at 05.00 am and 12.00 pm, respectively. The rectal temperature was measured using a digital thermometer with an accuracy of ±0.1, by inserting the thermistor probe in the cloaca to a depth of 1-2 cm and held till the thermometer beeped. Before the measurements, the fecal materials have been forced out from cloaca. Panting is characterized by rapid breathing activity with beak open[14]. Panting expressed in a percentage that is by comparing the number of chickens that panting and whole chickens in each experimental unit and then multiplied by 100%. The observation was carried out every day at 12.00 pm, when the ambient temperature was 36.71±0.40°C.

Blood analysis: At the end of the experiment (35 days of age) as many 3 mL of venous blood samples, which is 2 birds per pen were collected during panting by puncture of the brachial vein with using sterilized syringes then inserted into tubes containing heparin as an anticoagulant. The syringes were then capped and taken to the laboratory for counting the number of leukocytes. The whole blood pH analysis were performed within 30 min after the blood collection by using a pH meter[9].

Statistical analysis: The data were subjected to analysis of variance (ANOVA) using SPSS Programme version 17. If there was a difference between treatments, it would be further tested using Duncan's multiple range test at 5%. Data are presented as Mean±Standard Error of Mean (SEM) of measurements on treatments from 4 replicates.

RESULTS AND DISCUSSION

Performance responses: Based on this study, the results showed that the treatments significantly ($p<0.05$) affected the feed intake, water intake, body weight gain, feed conversion and the amount of potassium, sodium and chloride absorbed (Table 3). Feed intake of broiler supplemented KCl in drinking water was significantly ($p<0.05$) higher than those not supplemented with KCl (R0). However, the average feed intake of broilers significantly ($p<0.05$) decreased when added KCl over 0.25% (R2, R3 and R4) (Table 3). Furthermore, the water intake of broilers significantly ($p<0.05$) decreased as the amount of KCl added through drinking water exceeds 0.75%. Body weight gain significantly ($p<0.05$) increased in the treatment with the addition of 0.25-0.50% KCl. Conversely, the body weight gain of broilers significantly ($p<0.05$) becomes declining when supplemented more than 0.50% KCl. Broilers supplemented with 0.50% KCl had the lowest feed conversion of 1.52 among other treatments. It is shown that broiler chickens treated with various levels of KCl in drinking water did not occur death during the study.

Physiological responses: The results showed that the administration of KCl in drinking water did not significantly affect ($p>0.05$) the panting percentage, however, significantly ($p<0.05$) affected the rectal temperature, numbers of leukocytes and blood pH (Table 4). The rectal temperature of broilers treated with the addition of KCl was significantly ($p<0.05$) lower than that without the addition of KCl. The addition of 0.25-0.5% KCl significantly ($p<0.05$) resulted in blood pH lower than non-supplemented Kcl.

Feed and water intake: The feed intake of broilers supplemented with KCl in drinking water were significantly ($p<0.05$) higher than those not supplemented with KCl (R0).

Table 3: Performance of broiler chicken aged 5 weeks supplemented with different levels of potassium chloride (KCl) in drinking water (Mean±SE)

	Treatments				
Parameters	R0	R1	R2	R3	R4
Feed intake (g bird^{-1})	2.900±14.14^{a}	2.920±6.81^{a}	2.807±24.57^{b}	2.719±19.49^{b}	2.485±24.47^{c}
water intake (mL bird^{-1})	8.102±56.72^{a}	8.994±51.80^{bc}	9.122±11.36^{c}	9.148±6.61^{c}	8.893±45.30^{b}
Body weight gain (g bird^{-1})	1.627±77.64^{b}	1.787±69.30^{c}	1.855±71.58^{c}	1.524±39.29^{b}	1.071±79.87^{a}
Feed conversion	1.790±0.09^{b}	1.640±0.13^{ab}	1.510±0.07^{a}	1.800±0.05^{b}	2.330±0.21^{c}
Potassium absorbed (g bird^{-1})	3.060±1.36^{a}	21.030±0.85^{b}	36.070±0.87^{c}	34.860±2.32^{c}	34.390±1.15^{c}
Sodium absorbed (g bird^{-1})	12.610±0.39^{c}	14.380±0.39^{d}	14.430±0.28^{d}	11.110±0.48^{b}	8.170±1.07^{a}
Chloride absorbed (g bird^{-1})	6.540±0.34^{a}	13.010±0.23^{b}	18.600±0.14^{c}	23.130±0.16^{d}	26.850±0.50^{e}

Mean in the same column with different superscript differ significantly ($p<0.05$), R0: Drinking water without added KCl (control), while R1, R2, R3 and R4: Drinking water added 0.25, 0.5, 0.75 and 1.00% of KCl, respectively

Table 4: Physiological statue of broiler chicken aged 5 weeks supplemented with different levels of potassium chloride (KCl) in drinking water

	Treatments				
Variables	R0	R1	R2	R3	R4
Rectal temperature (°C)	41.180±0.03^{c}	41.160±0.05^{bc}	41.100±0.02^{b}	41.010±0.02^{a}	41.110±0.05^{b}
Panting (%)	92.620±2.11	91.190±1.96	90.480±2.33	90.950±2.27	91.430±2.80
Blood pH	7.350±0.06^{c}	7.230±0.05^{b}	7.130±0.05^{a}	7.180±0.05^{ab}	7.330±0.05^{c}
Leukocyte (mm^{-3})	20.325±0.005^{a}	25.375±0.003^{b}	28.425±0.003^{d}	26.475±0.004^{c}	26.450±0.003^{c}

Mean in the same column with different superscript differ significantly (p<0.05), R0: Drinking water without added KCl (control), while R1, R2, R3 and R4: Drinking water added 0.25, 0.5, 0.75 and 1.00% of KCl, respectively

This is assumed that the supply of potassium and chloride have been fulfilled. Murakami *et al.*[15] reported that the feed intake in broilers were increased when the supply of potassium and chloride from outside the body fulfilled, so that optimum growth could be achieved. Furthermore, the feed intake of broilers significantly (p<0.05) started decreasing when added KCl over 0.25% (Table 3). It indicated that the KCl consumed had exceeded the requirements. The exceeding of potassium can disturb the transport systems of amino acids, resulting in a higher concentration of amino acids in the blood stream, which lead to inhibition of the hunger centre in the hypothalamus and finally, reduce the feed intake[11]. A significantly (p<0.05) increase in water consumption is due to KCl can cause thirst when consumed. Basically, water intake is a main parameter that effective to monitor the efficiency of salt supplementation[12]. The thirst would appear when the concentration of potassium in the body of broilers increased. Guyton and Hall[16] stated that the high level of potassium in the body resulted in the increase of body fluid osmolarity, then it would stimulate thirst centers located in the hypothalamus to consume more water so that the concentration of body fluids remained normal. Furthermore, the water consumption of broilers significantly (p<0.05) decreases as the amount of KCl added exceeds 0.75%. The decline in water consumption could be due to the too salty taste of drinking water, therefore the chickens were less interested. Whittow[17] and El-Deek *et al.*[18,19] reported that the chickens did not like drinking water that was too salty.

Body weight gain: The body weight gain significantly (p<0.05) increased with the addition of KCl up to 0.50%. An increase of body weight gain is due to the role of potassium in helping the absorption of nutrients. Jeukendrup *et al.*[20] and Barbosa Lima *et al.*[12] reported that saline solutions could stimulate nutrient absorption (co-transport) into the body, such as glucose and amino acids. It is also as expressed by Pilliang[21] that the availability of potassium in the body was very important that aimed to increase the uptake of amino acids into the cell. Inside the cell, amino acids combine to make a protein called tissue proteins, which are useful to spur growth process that is characterized by weight gain. Amino acids affected by the mineral potassium are arginine and lysine[11]. Moreover, the body weight gain of broilers begins declining significantly when supplemented more than 0.50% KCl in drinking water. It is considered to have exceeded the body needs, resulting in excessive mineral and must be removed from the body. Costa *et al.*[11] and Vieites *et al.*[22] reported that if there was an excess of K^+, the body started to eliminate K^+ to regulate the acid-base balance in order to maintain the organic homeostasis. The spending the excess minerals from the body needs energy. As a result, the energy needed for growth was reduced besides the decrease in energy intake under heat stress[4-7]. The process of growth, eventually, become stunted and weight gain was decreased[18,19].

Amount of potassium, sodium and chloride absorbed: The absorption pattern of electrolytes into the body, both sodium and potassium was almost the same. Both are equally increased when given KCl up to 0.50% and decreased when supplemented above 0.75% in drinking water. This is because the sodium and potassium are two types of electrolytes that amount should always be balanced in the body so that the osmotic pressure of body fluids remain stable[18,19]. Guyton and Hall[16] stated that if the amount of the mineral potassium and sodium in the body was in equilibrium, the osmotic pressure of body fluids would run normally. However, both mineral absorption patterns are slightly different than the absorption of chloride, wherein chloride was absorbed growing up with the addition of 1% KCl, while the absorption of potassium and sodium start to decline when added KCl over 0.75. This because chloride is one of the anions, which is important to maintain the acid-base balance of body fluids[9]. Thus, the more potassium and sodium absorbed into the body, the more chloride that will be consumed, so that acid-base conditions of body fluids remain balanced[18,19].

Feed conversion and mortality: Broilers supplemented 0.5% KCl was the most efficient in the use of ration. It could be observed from the lowest feed conversion in such treatment.

The lower the feed conversion value, the more efficient utilization of feed by livestock. During the study, broilers treated by administration of KCl in drinking water did not indicate a death. It means that the administration of KCl to the extent of 1.00% in drinking water is still safe and well tolerated. Pilliang[21] stated that any excess potassium and chloride in the body would always be excreted through urine so rarely caused poisoning.

Rectal temperature: The cloacal temperature of broilers treated with the addition of KCl was significantly ($p<0.05$) lower than that without the addition of KCl (Table 4). This is due to broilers supplemented with KCl consume more water than those not supplemented with KCl as indicated in Table 3. Water, one of the nutrients has an important role in the absorption of heat in the body[23]. In line with Furlan *et al.*[24], this study reported that water had a significant role in bird's temperature regulation through heat exchange systems and the maintenance of hydric balance. The increase in water consumption could reduce the rise in body temperature. Therefore, the more water enters the body, the more heat can be absorbed to be removed from the body via urine. The results indicated, overall, that the body temperature of broiler chickens in this study were still in the normal range at 41.01-41.18°C. As reported by Aengwanich and Simaraks[25] and Attia *et al.*[6,7] that the normal body temperature range in chickens was 41-42°C with a variation of about 1.5°C.

Panting percentage: The treatments with the addition of KCl in drinking water did not significantly ($p<0.05$) affect the percentage of panting (Table 4). This is presumably because the air temperature inside the house was too high (average = 36.71°C) (Table 1), so that the effect of KCl in the drinking water was not significant. Whittow[17] reported that if the ambient temperature was above 32°C, the heat dissipation by radiation, conduction and convection were ineffective, therefore, the main way was by evaporation through panting. According to the results, respiratory rate of broilers in this study was almost 2 times more than the normal respiratory rate, which was 90-110 breaths/min. Under normal conditions, bands of respiratory rate in chickens are approximately 42 breaths/min[26]. Chicken respiratory rate reported by Nascimento *et al.*[26] and Santos *et al.*[27] were lower compared to this study, namely 61-82 breaths/min and 73-93 breaths/min, respectively.

Blood pH: The blood pH of broilers supplemented KCl up to 0.5% was significantly ($p<0.05$) lower than that non-supplemented KCl. This is closely related to evaporative heat loss during high temperature stress. Compared to the treatment without adding KCl, it seemed that the rectal temperature and the panting percentage with the addition of KCl up to 0.50% were lower. Hassan and Reddy[28] reported that during heat stress, poultry would be panting that allowed them to increase their evaporative heat loss. This increased respiratory rate causes disturbance to the gas exchange and acid-base equilibrium, which is characterized by a dramatic lowering blood CO_2 and H^+concentrations[18,19,29]. The effect of these reactions, finally, is a high level of blood pH. In line with this, Toyomizu *et al.*[29] reported that chickens that exposed to high ambient temperatures increased blood pH. Besides that, it is also assumed relating to the aldosterone secretion in the body. Costanzo[30] stated that the aldosterone could increase the secretion of H^+ ions and caused alkalosis in the blood. Based on the panting percentage, it indicated that broilers supplemented with KCl up to 0.50% had lower stress levels compared to broilers without adding KCl. It is assumed that the amount of the aldosterone produced in the broiler's body without adding KCl was lower than that by adding KCl. As a consequence, the concentration of H^+ ions were higher and blood pH eventually was increased.

Numbers of leukocyte: The number of leukocytes in broilers supplemented with KCl were significantly ($p<0.05$) higher than without supplementing KCl. The KCl can reduce stress levels during heat stress condition. This can be noticed from a lower percentage of panting and rectal temperature in broilers that can be used as indicators in determining the level of heat stress[4-7]. Heat stress is a major factor that can inhibit the formation of antibody[7,31]. The more severe heat stress suffered, the less immune cells produced[32,33]. The decline in the number of leukocytes is also expected due to the influence of glucocorticoid hormones produced in the body[6,7]. Padgett and Glaser[34] reported that glucocorticoid would inhibit immune cell proliferation and the formation of several types of cytokines and their receptors. Eventually, the function and the production of immune cells in the body decreased.

CONCLUSION

The supplementation of 0.50% KCl in drinking water is the optimal level to improve the performance and physiological status of broilers under environmental heat stress conditions, namely the feed and water intake, body weight gain, feed conversion ratio, the amount of potassium, sodium and chloride absorbed, cloacal temperature, numbers of leukocytes and blood pH.

SIGNIFICANT STATEMENT

This study mainly focuses on supplementation of potassium chloride in drinking water which aims to improve the performance and physiological status of broiler chickens reared under conditions of environmental heat stress. Under heat stress condition, physiological processes occurred in the body of broilers will be changed, including the need for electrolytes such as potassium which is increasing. To meet the needs of potassium, it is necessary supplementation from outside in the form of potassium chloride. Through this study, it would be obtained detailed information about the amount of potassium needed by broilers under heat stress conditions. Furthermore, it could be observed that changes in physiological status as well as improved performance in broiler chickens.

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