Effect of Oral Administration of Diakur™ (a Glucose and Electrolytes Additive) on Growth and Some Physiological Responses in Broilers Reared in a High Temperature Environment

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ABSTRACT : An experiment was conducted to determine effects of oral administration of Diakur™ (an additive of glucose and electrolytes for young calves) on growth performance and some physiological responses in male broilers reared in a high temperature. A 2 by 3 factorial arrangement test of 2 temperatures (24 and 36°C) and 3 levels of oral administration of the glucose and electrolytes additive, Diakur™, (0, 150 and 300 mg/day/100 gBW) were applied in the experiment. Male broiler chicks (2 weeks of age) were assigned to six groups and received dietary and temperature treatments for 7 days. The additive of glucose and electrolytes was suspended with water and intubated into crop twice a day (08:00 and 17:00). Oral administration of the additive prevented decreases in food intake and growth rates in broilers due to exposure of the hot environment. Oral administration of the additive also improved a lowered electrolyte (Na^{+} + K^{+} - Cl^{-}) balance in plasma, low mitogenic response of blood mononuclear cell and an increase in glucose concentration due to exposure to the high environmental temperature. Oral administration of the additive increased rectal temperature regardless of environmental temperatures. On the other hand, blood pH, pCO_2 and HCO_3^- concentration and plasma creatine kinase activity were not affected by the oral administration. The results suggested that oral administration of the glucose and electrolytes additive, Diakur™ during heat stress did not only prevent decrease in growth performance, but also normalized some physiological and immunological responses in male broilers. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 9 : 1341-1347)***

Key Words : Plasma Electrolyte Balances, Glucose and Electrolytes Additive, Diakur™, Growth, Heat Stress, Immune Responses

INTRODUCTION

Enviromental temperature is a crucial factor in the growth performance of poultry. In a high temperature there is a decrease in feed intake and in body gain, and additions of certain nutrients to feed or drinking water can reduce these effects. Teeter (1997a,b) reported that electrolyte balance in feed had a significant influence on body weight gain and feed intake. Balnave and Gorman (1993) and Botje and Harrison (1985) showed that dietary sodium bicarbonate is a nutrient with the ability to improve the acid-base balance and the electrolyte balance in blood in high environmental temperature, and that it promoted an improvement in growth rate. Iwasaki et al. (1997, 1998) reported that in a high ambient temperature the addition of glucose to the drinking water prevented the decreases in feed intake and growth, and heat stroke, and expected that energy supply, especially from glucose, is then important for broiler production. Although the method of dose of some electrolytes and/or glucose to animals is crucial to improve growth performance, supply of these nutrients to chicks kept at high environmental temperature would be an important factor for improving growth performance. The high environmental temperature also affected some physiological functions, resulting in the decrease in broiler productivity (Etches et al., 1995). It is also known that the ambient temperature has a great impact on the immune function (Kelley, 1985). However, there is little information concerning changes in physiological functions by nutrient supplementation to diets of heat stressed broilers related to growth and reproduction performances. In this experiment, the effects of administration by intubation of glucose and electrolytes solubilized in water on growth, feed intake, blood composition, and immune function were examined in broiler chicks reared in a high environmental temperature.

MATERIALS AND METHODS

Seventy-two male broiler chickens (Ross breed) with similar body weights were selected at 2 weeks of age, and were divided into six groups. Three out of six groups were moved into a room kept at 24°C, and the remainder were kept at 36°C. Birds were assigned to 6 replicates per treatment with 2 chicks per cage. Chicks were given a

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commercial starter diet (20.5% crude protein content, 3,050 kcal/kg diet of metabolizable energy) which consisted mainly of corn, soybean meal, and fish meal, and water *ad libitum* throughout the experimental periods. All other essential nutrients except crude protein and energy met or exceeded the Japanese Feeding Standard (1997) for young chicks. A commercial glucose and minerals additive (Diakur™, Boehringer Ingelheim Agrovet, Hellerup, Denmark, DK-2700) was suspended in water and intubated into the crop twice a day (8:00 and 17:00). The control groups were intubated with water alone. Dietary and temperature treatments were given over 7 days. Diakur™ consists of 27.5% dried citrus pulp, 10% lecithin, 33.4% glucose, 8% sodium chloride, 8% sodium bicarbonate, 5% glycine, 2.8% potassium chloride, 4% silicon dioxide, 1% xanthan gum, and 0.3% flavoring agents. The temperature of water for suspending the additive was the same as the room temperature. The relative humidity in each environmental room was controlled to the ranges of 50-70%.

Body weight gain and feed intake for 7 days were measured. Sodium, potassium and chloride ion concentration in plasma, and blood lymphocyte proliferation to pokeweed mitogen and concanavalin A, and pH, pCO_2 and HCO_3^- concentration, hemoglobin concentration and plasma creatine kinase activity were determined at the end of the experiment. Blood samples were taken just before and 3 hours after final intubation of Diakur™; they were collected into heparinized syringes from the wing vein and stored on ice. Blood pH, pCO_2, HCO_3^- concentration, and hemoglobin concentration were determined within 2 min using an automated blood gas and acid-base balance analyzer (Denmark radiometer, model ABL-2, Copenhagen, Denmark). Blood lymphocyte proliferation to pokeweed mitogen and concanavalin A were determined by the methods of Takahashi et al. (1998). The remaining blood samples were centrifuged and plasma samples were obtained. Sodium, potassium and chloride ion concentration in plasma were determined using an ion concentration meter (Touwa Denpa Industry, model IM-40s). Plasma glucose and protein concentration and creatine kinase activity were determined with commercial assay kits (Wako Pure Chemical Co. Ltd. Osaka, Japan 540-8605). A 2×3 factorial arrangement of 2 temperature (24 and 36°C) and 3 levels of Diakur™ (0, 150 and 300 mg/day/100 g BW) were used in order to analyze data using GLM procedure of SAS (SAS Institute, Cary, NC, USA) with mean separation by Duncan's multiple range test. The analyses for feed intake and feed efficiency were based on cage replication. For the analyses of the other parameters, individual chicks were considered as an experimental unit in the experiment. For the analyses for immune response, a 2 by 2 factorial arrangement of 2 temperature regimens (24 and 36°C) and 2 levels of Diakur™ (0 and 300 mg/day/100 g BW) were applied in order to analyze data with mean separation by Duncan's multiple range test.

RESULTS

Table 1 shows effect of heat stress and oral administration of Diakur™ on growth performance in male broiler chicks. Feed intake, body weight gain and feed efficiency were decreased by the high temperature exposure. Oral administration of Diakur™ tended to improve body weight gain and feed efficiency in 24°C environment. The growth performance decreased in 36°C conditions and was recovered partially by oral administration of Diakur™.

Table 2 shows effect of heat stress and oral administration of Diakur™ on rectal temperature, blood pH and hemoglobin concentration, pCO_2 and HCO_3^- concentration in male broiler chickens before oral administration of Diakur™ at the final day of the experiment. Body temperature in chicks reared in 36°C was higher than that in chicks reared in 24°C and oral administration of Diakur™ also enhanced the rectal temperature under the 24°C condition. The high environmental temperature (36°C) decreased pCO_2, HCO_3^- and hemoglobin concentration. Oral administration of Diakur™ did not influence these parameters. Blood pH was not affected by environmental temperature and oral

Table 1. Effect of heat stress and oral administration of Diakur™ on body weight gain, feed intake, and feed efficiency in male broiler chickens

Temperature Diakur™	(°C) (mg/100 g BW/day)	24			36			Analysis of variance		
		0	150	300	0	150	300	Temperature	Diakur™	Interaction
Body weight gain[1]	(g/7days)	359±13[a]	366±9[a]	375±8[a]	108±9[c]	156±11[b]	177±10[b]	p<0.01	p<0.01	p<0.05
Feed intake[2]	(g/7days)	575±12[a]	554±16[a]	557±9[a]	261±13[c]	281±4[bc]	301±7[b]	P<0.01	NS	p<0.05
Feed efficiency		0.65±0.02[a]	0.66±0.01[a]	0.67±0.06[a]	0.41±0.03[c]	0.56±0.04[b]	0.59±0.03[b]	P<0.01	p<0.01	p<0.05

[1] Mean±SE (n=12).
[2] Mean±SE (n=6).
NS: p>0.05.

Table 2. Effect of heat stress and oral administration of Diakur™ on rectal temperature, blood pH and hemoglobin concentration, pCO_2 and HCO_3 concentration in male broiler chickens before oral administration of Diakur™ at the final day of the experiments[1)]

Temperature Diakur™	(°C) (mg/100 g BW/day)	24			36			Analysis of variance		
		0	150	300	0	150	300	Temperature	Diakur™	Interaction
Rectal temperature	(°C)	40.5 ±0.02[c]	41.4 ±0.1[b]	41.5 ±0.1[b]	42.6 ±0.2[a]	43.0 ±0.2[a]	42.7 ±0.1[a]	p<0.01	p<0.01	p<0.01
Blood										
pH		7.4 ±0.01	7.38 ±0.01	7.37 ±0.03	7.35 ±0.03	7.41 ±0.02	7.41 ±0.01	NS	NS	NS
Hemoglobin	(g%)	9.6 ±0.3[a]	9.2 ±0.3[a]	9.2 ±0.4[a]	6.4 ±0.3[b]	6.0 ±0.2[b]	6.6 ±0.4[b]	p<0.01	NS	NS
pCO_2	(mmHg)	43.4 ±1.2[a]	41.5 ±1.5[a]	44.3 ±2.0[a]	37.7 ±2.2[ab]	32.4 ±1.9[b]	32.9 ±0.6[b]	p<0.01	NS	NS
HCO_3^-	(meq/l)	26.2 ±0.3[a]	24.1 ±0.4[a]	25.0 ±1.0[a]	20.3 ±0.6[b]	21.3 ±1.2[b]	21.5 ±0.6[b]	p<0.01	NS	NS

[1)] Mean±SE (n=12).
NS: p>0.05.

administration of Diakur™.

Table 3 shows effect of heat stress and oral administration of Diakur™ on rectal temperature, blood pH and hemoglobin concentration, pCO_2 and HCO_3^- concentration in male broiler chickens three hours after oral administration of Diakur™ at the final day of the experiment. Rectal temperature was higher in chicks kept at 36°C than that in chicks kept at 24°C. Oral administration of Diakur™ increased rectal temperature in 24°C condition, but not in 36°C condition. Blood pCO_2 and $HCO3^-$ concentration and hemoglobin concentration decreased under the high environmental temperature. The oral administration of Diakur™ decreased pCO_2 in the blood in chicks kept at 36°C. The influence of the temperature treatment and oral administration of Diakur™ was not seen on blood pH at three hours after oral administration of Diakur™. Interaction of the ambient temperature and oral administration of Diakur™ was found in concentration of the hemoglobin in the blood.

Table 4 shows effect of heat stress and oral administration of Diakur™ on plasma sodium, potassium and chloride ion concentrations in male broiler chicks. The concentration of the plasma chloride ion increased under the high environmental temperature exposure, while plasma sodium ion concentrations decreased. Consequently, a balance of the plasma electrolytes concentrations of plasma was decreased by the high temperature exposure. Oral administration of Diakur™ increased concentration of plasma sodium ion under the high environmental temperature, with the result that chicks intubated with Diakur™

Table 3. Effect of heat stress and oral administration of Diakur™ on rectum temperature, blood pH and hemoglobin, pCO_2 and HCO_3 concentrations at three hours after oral administration of Diakur™ at the final day of the experiments in male broiler chickens[1)]

Temperature Diakur™	(°C) (mg/100 g BW/day)	24			36			Analysis of variance		
		0	150	300	0	150	300	Temperature	Diakur™	Interaction
Rectal temperature	(°C)	41.0 ±0.2[c]	41.8 ±0.1[b]	41.6 ±0.1[b]	42.6 ±0.2[a]	42.8 ±0.1[a]	42.8 ±0.1[a]	p<0.05	NS	p<0.05
Blood										
pH		7.41 ±0.01	7.42 ±0.02	7.34 ±0.02	7.37 ±0.02	7.42 ±0.02	7.41 ±0.02	NS	NS	NS
Hemoglobin	(g%)	9.1 ±0.5[a]	8.9 ±0.3[a]	8.4 ±0.3[a]	6.5 ±0.4[b]	5.6 ±0.2[c]	6.8 ±0.3[b]	p<0.01	NS	p<0.05
pCO_2 pressure	(mmHg)	42.0 ±1.0[a]	37.7 ±1.4[ab]	43.6 ±2.3[a]	37.9 ±1.8[bc]	31.5 ±1.0[d]	36.5 ±1.1[c]	p<0.01	p<0.01	NS
HCO_3^-	(meq/l)	25.9 ±0.7[a]	24.2 ±1.1[ab]	22.7 ±0.8[abc]	21.5 ±1.4[bc]	20.1 ±1.1[c]	22.6 ±0.8[abc]	p<0.05	NS	NS

[1)] Mean±SE (n=12).
NS: p>0.05.

Table 4. Effect of heat stress and oral administration of Diakur™ on plasma sodium, potassium and chloride ion concentrations in male broiler chicks[1)]

Temperature	(°C)	24			36			Analysis of variance		
Diakur™	(mg/100 g BW/day)	0	150	300	0	150	300	Temperature	Diakur™	Interaction
Plasma sodium (Na^+)	(meq/l)	176±2[a]	168±2[b]	164±2[b]	154±2[c]	167±3[ab]	173±3[a]	p<0.05	NS	p<0.01
Plasma potassium (K^-)	(meq/l)	12±2	14±1	12±1	11±1	11±1	9±1	p<0.05	NS	NS
Plasma chloride (Cl^-)	(meq/l)	142±3[b]	136±2[b]	137±2[b]	150±3[a]	142±2[b]	152±3[a]	p<0.01	p<0.05	NS
Electrolyte balance Na^++K^+-Cl^-	(meq/l)	49±3	46±3	39±3	5±5	35±2	30±7	p<0.01	p<0.05	p<0.01

[1)] Mean±SE (n=12).
NS: p>0.05.

reared in 36°C recovered a similar concentration of plasma electrolyte to that of the chickens reared in 24°C.

Table 5 shows the effect of heat stress and oral administration of Diakur™ on plasma concentrations of glucose and protein, and plasma creatine kinase activity in male broiler chickens. Neither the environmental temperature nor the oral administration of Diakur™ influenced plasma total protein concentration. Plasma glucose concentration and the creatinine kinase activity rose in the high temperature environment. A higher level (300 mg/kg body weight) of oral administration of Diakur™ partially reduced a plasma glucose concentration increased by the high environmental temperature.

Table 6 shows effect of heat stress and oral administration of Diakur™ on blood lymphocyte proliferation to concanavalin A and pokeweed mitogen three hours after intubating on the final day of the experiment in male broiler chicks. The high environmental temperature decreased the proliferative response of blood lymphocyte to mitogens. On the other hand, the oral administration of Diakur™ increased the proliferative response regardless of the ambient temperature.

DISCUSSION

In this experiment, a high environmental temperature suppressed growth performances in male broiler chicks (Table 1) as previously reported (Balnave and Gorman, 1993; Bottje and Harrison, 1985; Iwasaki et al., 1997, 1998; Teeter et al., 1985). The oral administration of glucose and electrolytes additive (Diakur™) partly prevented reduction of food intake and growth rate in broilers kept at a high temperature (Table 1). The oral administration of glucose and electrolytes additive to chicks increased rectal temperature regardless of temperature regimens (Tables 2 and 3). Since it has been known that heat acclimatization is an effective way for preventing heat stress (Deaton et al., 1986; Sykes and Fataftan, 1986; Reece et al., 1972; Zou and Yamamoto, 1997), improvement of growth performance in chicks kept at 36°C by intubating with oral administration of the glucose and electrolytes additive may, in part, be due to proper increment of body temperature.

It has been reported that supplying sodium, potassium and glucose to drinking water or diets prevents the decrease in growth and feed intake under a high environmental temperature (Balnave and Gorman, 1993; Bottje and Harrison, 1985; Iwasaki et al., 1997, 1998; Teeter et al.,

Table 5. Effect of heat stress and oral administration of Diakur™ on plasma concentrations of glucose and protein, and plasma creatine kinase activity in male broiler chickens[1)]

Temperature	(°C)	24			36			Analysis of variance		
Diakur™	(mg/100 g BW/day)	0	150	300	0	150	300	Temperature	Diakur™	Interaction
Plasma protein	(mg/100 ml)	3.1±0.1	3.1±0.2	3.5±0.3	3.2±0.3	2.9±0.1	3.1±0.2	NS	NS	NS
Plasma glucose	(mg/100 ml)	255±6[de]	241±8[e]	265±11[cd]	367±21[a]	354±37[ab]	294±5[bc]	p<0.001	NS	p<0.05
Plasma creatine kinase	(IU/l)	341±29[b]	ND	344±36[b]	448±5[a]	429±13[a]	441±20[a]	p<0.001	NS	NS

[1)] Mean±SE (n=12).
NS: p>0.05.
ND: Not determined.

Table 6. Effect of hot environment and oral administration of Diakur™ on blood lymphocyte proliferation to concanavalin (Con A) and pokeweed mitogen (PWM) in male broiler chickens[1)]

Temperature Diakur™	(°C) (mg/100 g BW/day)	24		36		Analysis of variance		
		0	300	0	300	Temperature	Diakur™	Interaction
Stimulation								
Non	(absorbance)	0.213±0.003	0.206±0.006	237±0.022	0.215±0.012	NS	NS	NS
Con A	(absorbance)	0.282±0.017	0.336±0.024	277±0.017	0.301±0.021	NS	NS	NS
PWM	(absorbance)	0.278±0.019[b]	0.402±0.038[a]	170±0.005[c]	0.245±0.010[b]	$p<0.01$	$p<0.05$	NS
Increased ratio by mitogens								
Con A		1.32±0.08[b]	1.63±0.1[a]	1.17±0.07[b]	1.41±0.1[b]	$p<0.05$	$p<0.05$	NS
PWM		1.31±0.09[b]	1.94±0.2[a]	0.72±0.02[c]	1.15±0.05[c]	$p<0.01$	$p<0.01$	NS

[1)] Mean±SE (n=6).
NS: $p>0.05$.

1985). Heat stressed broilers reduced serum sodium and potassium concentration, resulting in the low electrolyte balances (Ait-Boulahsen et al., 1989; Arad et al., 1983; Siegel et al., 1974; Teeter 1997a,b; Teeter et al., 1986). In this experiment, exposure of chicks into the high temperature lowered the Na^{-} + K^{+} - Cl^{-} concentrations in plasma, while higher level of the supplement alleviated the reductions (Table 4). Reductions in blood sodium and potassium concentrations caused by heat stress are accompanied by reduced potassium balance in heat stressed broilers (Etches et al., 1995; Teeter, 1997a). However, the results of the present experiment suggested that changes in sodium and chloride ion concentrations might contribute to normalization of electrolytes balance. The results of the present experiment suggested that some electrolytes in Diakur™ were, at least in part, associated with the improvement of the Na^{+} + K^{+} - Cl^{-} concentrations in plasma, which were related with prevention of decreased growth performances of chicks kept at the high environmental temperature.

In the present study, analysis of venous blood was preferred to that of arterial blood to minimize invasive procedures and disturbance to the animals. This is acceptable when analyses are confined to the blood pH and pCO_2 pressure (Ilkiw et al., 1989; Elborn et al., 1991) and has frequently been employed in previous studies with poultry (Ait-Boulahsen et al., 1989; Deyhim and Teeter, 1991; Hocking et al., 1994). Slight changes in blood pH, pCO_2 and HCO_3^- among the treatments were observed in this experiment. Electrolytes concentration or balance is closely associated with blood pH, gas pressure and bicarbonate concentration (Darre et al., 1980; Mather et al., 1980; Teeter 1997a,b; Teeter et al., 1986). The occurrence of respiratory alkalosis in response to thermal stress has not been consistently observed in all studies in poultry. Siegel et al. (1974) were unable to detect any significant change in blood pH in broiler reared under continuos heat (35°C), whereas Raup and Bottje (1990) reported that blood pH in cockerels and broilers was increased at higher ambient temperature. Why changes in plasma electrolyte balances were not associated with those in blood pH, pCO_2 and HCO_3^- may be due to variations in the degree of thermal stress, the length of thermal stress period and the degree to which the birds had been acclimatized to the condition cited by Teeter (1985) in the present experiment.

Plasma creatine kinase activity has been employed as an index of stress in growing birds and the activity was enhanced by muscle injury in response to thermal loads and transportation in chicks (Mitchell et al., 1992). Hocking et al. (1994) observed that feeding condition (restricted feeding) did not affect the activity under a hot climate. In the present experiment, chicks exposed in a hot environmental temperature increased plasma creatine kinase activity, whereas the oral administration of glucose and electrolytes additive did not affect the activity in the present experiment (Table 5). Thus muscle injury in chicks kept at 36°C could not be not prevented by oral administration of the glucose and electrolytes additive. An increased glucose concentration in plasma of chicks exposed in 36°C was lowered by the oral administration of glucose and electrolytes additive in the present experiment (Table 5). Iwasaki et al. (1998) observed that glucose supplement from drinking water prevented an increase in plasma glucose concentration of chicks due to a hot climate. These observations suggested that giving glucose from the oral administration of glucose and electrolytes additive might normalize glucose metabolism under a hot environmental temperature.

Hot or cold temperature environment has great impact on humoral and cell mediated immune functions in mammals (Kelley, 1985; Regnier and Kelly, 1981) and chicks (Siegel et al., 1974; Subba Rao and Glick, 1970;

Thaxton. 1974). In the present experiment. lymphocyte proliferation in blood of chicks exposed in 36°C was lower than that in chicks kept at 24°C, and the oral administration of glucose and electrolytes additive increased the proliferation regardless of environmental temperature and type of mitogens. Glucose requirement markedly increased in immune related cells under oxidative stress (Spolarics and Spitzer et al.. 1993). It has been also shown that proper supply of sodium is important to normalize cell mediated immune function in chicks (Latshaw. 1991). Thus both of glucose and some electrolytes have a great impact on immune responses. although it seems that the other nutrients of Diakur™ would affect immune functions.

In conclusion. the oral administration of glucose and electrolytes additive, Diakur™ during heat stress did not only prevent decrease in growth performance by high environmental temperature. but also normalized physiological and immunological functions in male broilers. However. it is not clear which component(s) of Diakur™ used in the present experiment is a predominant factor(s) to normalize physiological functions of chicks kept at a high environmental temperature. although glucose and/or some electrolytes of Diakur™ may have contributed to a certain extent.

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