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EFFECTS OF DRINKING WATER TEMPERATURE ON THE GROWTH, MEAT QUALITY, AND SERUM BIOCHEMICAL INDICES OF BROILER CHICKENS UNDER HOT-HUMID CONDITIONS IN SUMMER

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Abstract

This study evaluated the effects of drinking water temperature during the summer period on growth performance, meat quality, and serum biochemical traits in growing broilers. A total of 360 Cobb 500 broilers with uniform body weight aged 21 days were assigned to 3 treatments and 8 replicates of 15 birds each. Three groups were treated with drinking water, including ordinary room temperature tap water, and two fixed temperature water of 15.4°C and 24.3°C. The duration of the trial ranged from 22 to 35 days. Before the commencement of the study, all the broilers (400-day-old chicks) were fed commercial pre-starter (3050 kcal/kg ME, 22.50% CP) and starter (3100 kcal/kg ME, 20.50% CP) diet for the first 7 days and the next 14 days. The finisher diet containing 3200 kcal/kg of ME and 18.5% CP was fed up during the trial period. Results showed that the body weight gain (BWG) and feed intake (FI) were influenced ($P < 0.01$) by the drinking water temperature of 15.4°C and 24.3°C as compared to ordinary tap water. The highest body weight and feed intake were observed in the 15.4°C drinking water temperature group. But no consistent difference in BWG between the 15.4°C and 24.3°C water temperature group was observed. The treatments did not alter the color of the meat except for yellowness and other meat quality parameters. Moreover, no differences were found in the fatty acid composition of breast and thigh meat. Significantly ($P < 0.05$) lower glucose and higher alanine aminotransferase concentration in serum were found in the group treated with 15.4°C water. These results indicated that drinking water temperature below the ambient level during summer can effectively improve the growth performance, meat quality and maintaining homeostasis balance.

Keywords: Broiler; Water temperature; Meat quality; Serum; Summer season

Introduction

The high ambient temperature in the summer season globally is one of the environmental stressors challenging the poultry industry. Heat stress is frequently known in tropical and subtropical countries as a significant impediment to poultry production, especially in growing birds (Imik et al., 2012). Extreme heat stress has detrimental effects on feed intake, growth rate, feed efficiency, carcass quality, and immune status of broilers. It also increases mortality resulting in enormous economic losses for the poultry industry. Several studies have demonstrated that high air temperature and humidity have deleterious effects on poultry performance (Guterrez et al., 2009; Quinteiro-Filho et al., 2011). When the environmental temperature is raised to 32°C, the feed intake of normal broilers is reduced by 24%, adversely affecting the immune response to broilers (Niu et al., 2009). Heat stress not only adversely affected performance but also inhibited immune function (Mashaly et al., 2004) and ultimate result in death (Han *et al*., 2010). Extreme heat stress due to high temperature and humidity led to panting and open mouth respiration to maintain homeostasis. Chronic heat exposure during the growth period of broilers increased lactic acid production, decreased meat pH value by accelerating meat glycolysis, and deteriorated the meat quality (Zhang et al., 2012). Another study speculated that heat stress accelerated the production of free radicals in the body due to the disruption of homeostasis and led to a higher rate of lipid peroxidation, which reduced growth performance and meat quality (Babinszky et al., 2011). The normal body

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temperature of an adult fowl is 41-42°C; however, the thermally comfortable environment temperature is around 25°C (Cooper and Washburn, 1998).

Water is an essential nutrient component to the health and well-being of all animals. It has many beneficial effects on the metabolism of poultry by regulating body temperature, feed digestion and absorption, nutrient transport, and elimination of waste products from the body. In the summer, drinking water temperature is one of the stressor factors because the temperature of water usually rises with increasing environmental temperature, which adversely impacts poultry health and performance. In addition, water loss from the body due to the extreme weather conditions in summer disrupts acid-base balance and optimum performance. Under normal environmental temperatures usually, birds consume approximately 1.6 to 2.0 times more water as a feed on a weight basis (Beker and Teeter, 1994). Generally, it is hypothesized that a drinking water temperature below the ambient temperature of the bird's body has positively influenced growth performance and maintenance of physiological thermoregulatory mechanisms. A previous study regarding the drinking water temperature suggested that broilers at high temperatures exposed to cold water resulted in increased weight gain (Abioja et al., 2011) and improved the gain-to-feed ratio (Beker and Teeter, 1994). Another study demonstrated that dietary modification of nutrients and the inverse lighting system with cold water under heat wave conditions improved body weight gain, feed intake, and feed efficiency (Park et al., 2015). Most of previous pieces of literature reported that cold drinking water during high environmental conditions in summer enhanced the growth performance of broilers. However, the effects of drinking water temperature on meat quality and serum biochemical characteristics have not yet been reported. Therefore, the study aimed to elucidate the effects of drinking water temperature on growth performance, meat quality and serum biochemical traits of broilers during the summer.

Materials and Methods

This study was performed during the hot weather conditions in summer (June-July, 2020) at a poultry research farm. The design and conduct of the study were reviewed and approved by the Institutional Animal Care and Use Committee of the Jeonbuk National University, Republic of Korea.

Bird management and experimental design

Before the commencement of the experiment, 400 broiler chicks (Cobb 500) were collected from a commercial hatchery on the day of hatching, and the average body weight of chicks (15 chicks) was 43.5 ± 0.10 g. These chicks were brooded for three weeks with rice husk spread on the floor to about 3.5 cm depth (0.65 sq. ft floor space per bird). The brooding temperature was maintained by setting the floor temperature in the control panel. The temperature was set to 33°C for the first week and gradually decreased by 2°C each week for three weeks, and the heating panel was turned off on day 22. Subsequently, a total of 360 broilers with uniform body weight (avg. wt 945.59 ± 0.15 g) were transferred and randomly distributed into three treatment groups in 24 pens of 15 birds each (1.3 m × 1.1m × 0.55 m) in a completely randomized design (CRD). The birds were reared under environmental temperature throughout the experimental period of 35 days. The three treatment groups subsisted on ordinary tap water (T1); and two set water temperatures of 15.4°C (T2) and 24.3°C (T3), respectively. Water was supplied in nipple drinker lines connected to three different water reservoirs: one for ordinary room temperature tap water, and the other two maintained separately by setting the temperature in the cooling panel system (Fig 1).

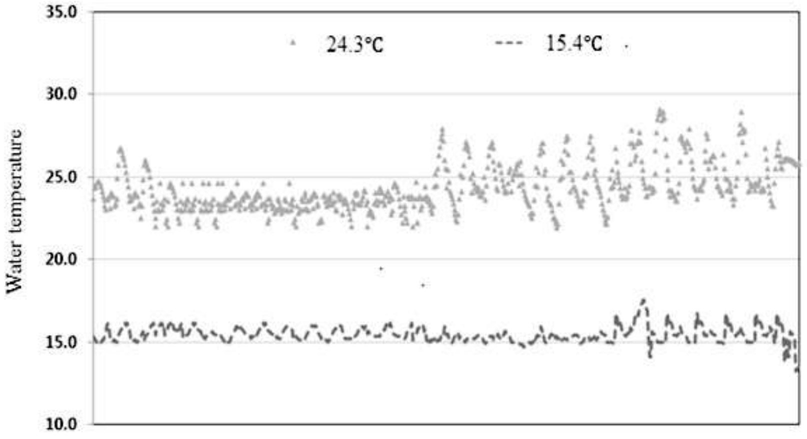

Figure 1. Cooling panel system controlling drinking water temperature

The ambient temperature and relative humidity were recorded three times inside the experimental room daily (9.0 am, 12.0 noon, and 3.0 pm) using an electronic thermometer. The average air temperature was measured over the trial period at 37.5 ± 1.0°C from days 22 to 35, and the minimum and maximum recorded temperatures were 23.4°C and 41.8°C, respectively. The mean relative humidity was 68% (38% to 92%). The light was provided continuously throughout the rearing period. The birds were fed a commercial pre-starter diet (22.50% CP and 3050 kcal/kg ME) for the first seven days, a starter diet (20.50% CP and 3100 kcal/kg ME) for the next two weeks, and a finisher diet (18.5% CP and 3200 kcal/kg ME) from days 22 to 35 by NRC for poultry (NRC, 1994). All diets were offered to birds in mash form.

Growth performance

Body weight gain (BWG) and feed intake (FI) were calculated over a 14-day period from days 22 to 35 of age. The feed intake of each pen was measured at the end of the experiment by subtracting the remaining feed weight from the initial feed weight. The feed conversion ratio (FCR) was calculated as the feed-to-gain ratio.

Meat quality

At the end of the experiment, six birds from each treatment were randomly selected and sacrificed through cervical dislocation. The right breast muscles were excised to evaluate pH, drip loss, cooking loss, shear force, and meat color. The breast muscle pH was measured at a depth of around 3.0 cm below the surface within one hour after sacrifice using a combined glass-penetrating electrode pH meter (Mettler Toledo AG 8603, Schwerzenbanch, Switzerland). The meat color was measured on breast muscle samples at 50 minutes after cooling at normal freezing temperature by Chroma meter CR-410 (Minolta, Suita-shi, Japan) using CLE-LAB trichromatic systems as L* (lightness), a* (redness) and b* (yellowness). Before measuring the color, the device was calibrated, and a fresh vertical cut was made in the middle of the breast muscles. Deboned breast muscle samples were cooked in a water bath at 80°C in zipper bags (size: 14× 16 cm) until the internal temperature of 70°C was reached. The cooked samples were cooled under normal running tap water for 20 minutes. The cooking loss was determined by calculating the weight difference before and after cooking. Drip loss was calculated as the difference between initial and final weight after storage at 4°C for 24 hours. The shear force value was determined according to the method described by Chae et al., (2005). Fatty acid methyl esters of breast and thigh meat samples were analyzed by gas chromatography (6890N, Agilent Technology, CA, USA), and samples were injected with an auto-sampler (7683B, Agilent Technology). The fatty acid content was determined by comparing the relative peak retention times of the sample and the peak areas of known calibration standards.

Biochemical analysis

On day 35, the blood samples (approximately 3 mL) were collected by venous puncture of the wing vein in eight male broilers from each treatment using disposable 5 mL syringes and directly transferred into non-heparinized tubes. Serum was separated by centrifugation of blood samples at 3000 rpm and 4°C for 15 minutes and stored at -20°C until assayed. Serum biochemical properties include glucose (GLU), total protein (TP), albumin (ALB), total cholesterol (TC), high-density lipoproteins (HDL), Neutral fat (NF), aspartate aminotransferase (AST), alanine aminotransferase (ALT) concentrations were measured using commercially available diagnostic kits (Ratastie 2, FI-01620 Vantaa, Thermo Fisher Scientific Oy, Finland) in an automatic biochemistry analyzer system (Konelab 20 analyzer, Thermo Fisher Scientific, Vantaa, Finland). Bone mineral density (BMD) was quantified by bone densitometry (pDEXA, Norland Medical Systems Inc., White Plains, NY, USA).

Statistical analysis

Data were statistically analyzed using the General Linear Model procedure of SAS (2009) computer program (Version 9.1, SAS Institute). Duncan's multiple-range test was performed to identify the differences between groups at $P < 0.05$. Statistical differences between the treatment groups were marked by letters a, b and c.

Results

The growth performance of broilers during an entire experimental period is presented in Table 1. Differences in drinking water temperature had a significant effect ($P < 0.01$) on the BWG and FI of broilers. A drinking water temperature of 15.4°C was significantly increased BWG and FI compared to ordinary tap water and at 24.3°C water temperature. However, no difference was observed in BWG when broilers were given 15.4°C and 24.3°C drinking water during the hot-dry summer period. The feed-to-gain ratio did not differ between the water treatment groups.

Table 1. Effects of drinking water temperature on the performance of broilers

Treatments	BWG (g)	FI (g)	F:G
------------------------------------ 22–35 days ----------------------------------			
T_1	825.29^b	1549.46^c	1.88
T_2	1137.38^a	2178.63^a	1.92
T_3	1024.85^a	2010.22^b	1.96
SEM	35.29	63.29	0.018
P-value	0.0002	<0.0001	0.23

T_1, ordinary tap water; T_2 and T_3, water temperatures 15.4°C and 24.3°C respectively; SEM, standard error of mean; $^{a\text{-}c}$ within the same column with different superscripts suggest significant differences ($P < 0.05$); BWG, body weight gain; FI, feed intake; F:G, feed-to-gain ratio.

In Table 2, the pH, drip loss, cooking loss, shear force value, and color of breast meat, except yellowness color did not differ, except for yellowness color. A significantly ($P < 0.05$) lower yellow color was observed in the group exposed to 15.4°C water treatment. However, ordinary tap water did not differ statistically in meat color yellowness among the groups treated with drinking water.

Table 2. Effects of drinking water temperature on meat quality of broilers

Treatments	pH	Meat color			Drip loss (%)	Cooking loss (%)	Shear force (kgf)
		Lightness (L*)	Redness (a*)	Yellowness (b*)			
T_1	5.74	51.58	4.17	5.10^{ab}	1.09	6.05	2.41
T_2	5.82	47.82	5.14	4.38^{b}	1.20	6.43	2.13
T_3	5.81	50.63	4.57	5.89^{a}	1.14	6.52	1.80
SEM	0.02	0.77	0.63	0.23	0.06	0.38	0.18
P-value	0.18	0.11	0.84	0.02	0.80	0.88	0.42

T_1, ordinary tap water; T_2 and T_3, water temperatures 15.4°C and 24.3°C, respectively; SEM, standard error of mean; $^{a\text{-}b}$ within the same column with different superscripts denoting significant differences ($P < 0.05$).

The levels of total monounsaturated, polyunsaturated, unsaturated, and saturated fatty acids of breast and thigh meat of broilers are summarized in Table 3. It showed that the fatty acid composition of breast and thigh meat was not altered by the groups' water temperature differences.

Table 3. Effects of drinking water temperature on the fatty acid profile of broilers

Treatments	MUFA (%)	PUFA (%)	UFA (%)	SFA (%)
-----------------------------Breast meat-----------------------------				
T_1	45.98	21.69	67.67	32.33
T_2	45.80	21.45	67.26	32.74
T_3	47.07	20.05	67.11	32.89
SEM	0.37	0.50	0.26	0.26
P-value	0.34	0.37	0.69	0.69
-----------------------------Thigh meat-----------------------------				
T_1	45.42	22.34	67.76	32.24
T_2	46.13	21.36	67.49	32.51
T_3	45.98	21.26	67.24	32.76
SEM	0.40	0.47	0.22	0.22
P-value	0.77	0.62	0.66	0.66

T_1, ordinary tap water; T_2 and T_3, water temperatures 15.4°C and 24.3°C respectively; SEM, standard error of mean; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; UFA, unsaturated fatty acids and SFA, saturated fatty acids.

There were no significant differences in ALB, TC, HDL, TP, NF, and AST serum concentrations under the different treatments (Table 4). However, the GLU and ALT level in serum was altered ($P < 0.05$). Higher GLU concentration was found in the group exposed to ordinary tap water, and the lowest was observed in the group treated with drinking water at 15.4°C. Similarly, the higher concentration of serum ALT was detected in the group treated with water at 15.4°C, and the lowest value was found in the ordinary tap water treated group.

Table 4. Effects of drinking water temperature on serum characteristics of broilers

Treatments	ALB (g/dl)	TC (mg/dl)	GLU (mg/dl)	HDL (mg/dl)	TP (g/dl)	NF (mg/dl)	AST (IU/L)	ALT (IU/L)	BMD (g/cm^2)
T_1	1.33	195.24	318.47^{a}	127.29	3.34	117.42	223.78	1.82^{b}	0.169
T_2	1.48	181.97	289.43^{b}	133.98	3.67	135.45	244.21	3.25^{a}	0.174
T_3	1.39	179.93	301.86^{ab}	123.50	3.68	141.21	312.99	2.3^{a}	0.166
SEM	0.04	4.03	4.82	3.73	0.11	7.59	16.62	0.22	0.003
P-value	0.20	0.26	0.03	0.54	0.38	0.44	0.06	0.02	0.46

T_1, ordinary tap water; T_2 and T_3, water temperatures 15.4°C and 24.3°C respectively; SEM, standard error of mean; $^{a\text{-}b}$within the same column with different superscripts denoting significant differences ($P < 0.05$); ALB, albumin; TC, total cholesterol; GLU, glucose; HDL, high density lipoproteins; TP, total proteins, NF, neutral fats; AST, aspartate aminotransferase; ALT, alanine aminotransferase and BMD, bone mineral density.

Discussion

Several earlier studies reported that broilers subjected to heat stress or high environmental temperature in summer adversely affected the growth performance and immune response (Bartlett and Smith, 2003; Sohail *et al*., 2012). High air temperature is a key environmental stressor, which decreases the feed intake of broilers because energy obtained from the lower feed consumption results in reduced weight gain (May et al., 2000). The current study observed the highest weight gain and increased feed intake when broilers were exposed to cold water (15.4°C) during the hot-dry summer. It may result from drinking cold water. Drinking cold water could alleviate the deleterious effect of high ambient temperature via reduction of panting and maintenance of homeostasis, resulting in increased feed intake and improved weight gain. It is consistent with the findings of Aboiza et al., (2011), who reported that weight gain was increased when cold water was administered to broilers exposed to heat conditions in summer. Similarly, Park et al.,

(2015) observed that body weight gain and immune competence of the broilers were increased under inverse lighting and altered diet composition with the cold-water temperature at 9°C under extreme heat stress of 33±1°C for five hours daily for 27-32 days. In the study of Park et al., (2013) observed that warm environmental conditions significantly reduced feed intake of chickens. In this case, broilers may reduce their feed intake to suppress metabolic heat production and minimize the load under the excessive ambient temperature. The current study findings were consistent with Puma *et al*., (2001), who reported increased feed and water intake when cold drinking water was supplied to broilers under hot environmental temperatures. However, comparatively cold drinking water for broilers in summer reduces body temperature to dissipate metabolic heat and balance homeostasis. Abioja et al. (2011) showed broilers exposed to cold water from days 35 to 56 during hot and dry environments did not alter FCR, which was similar to our findings.

According to Mota-Rojas et al. (2006), preslaughter stressors such as heat stress, feed withdrawal, transport, and water deprivation may influence meat quality. Several related studies have also shown that following exposure to high temperatures, the poultry meat quality at low pH was associated with poorer water holding capacity, which increased cooking and drip losses. Regarding the water temperature during summer in this study, a numerically higher pH value, lower L* and higher a* were observed in birds treated with drinking water at 15.4°C and 24.3°C compared with the group treated with ordinary tap water. Previous studies found that broilers exposed to high temperatures had a lower pH value, L* and lower a* than the standard temperature group (Zhang et al., 2012). However, the current study findings indicate that set water temperature may regulate the homeostasis mechanism during the summer period and increase meat's pH and redness (a*) value. The decreased redness (a*) value indicated further oxidation of muscle myoglobin in summer than in winter (Petracci et al., 2004). In addition, the yellowness (b*) of meat differed significantly ($P < 0.05$) with varying drinking water temperatures, which partly supported the previous study findings of increased yellowness of meat compared with control under acute or chronic heat exposure ranging from 3 to 7 weeks (Aksit et al., 2006). However, biochemical changes were observed in birds subjected to high air temperature that may be associated with ante-postmortem muscle glycolysis (Dadgar et al., 2010).

No differences were found in the fatty acid composition of the breast and thigh meat in groups treated with drinking water at different temperatures during summer. In contrast, seasonal variation in winter or summer greatly affected the fatty acid profile (Geldenhuys et al., 2015).

The biochemical properties of blood serum are susceptible to changes in ambient temperature. They are an essential indicator of physiological response in birds exposed to stress agents. In the summer, the increased catabolic effect and concentration of adrenocorticotropic hormone increased the serum levels of glucose, uric acid, and triglycerides. In the current study, serum total GLU and ALT concentrations differed significantly among the water treatment groups. Similarly, the AST concentration in serum was numerically higher in groups exposed to drinking water at 15.4°C and 24.3°C than those treated with tap water. The differences were not significant. Various stressors including high air temperature increase the glucose concentration directly in response to an increase in glucocorticoid levels that primarily affect metabolism and gluconeogenesis from muscle tissue protein (Borges et al., 2007). Higher concentrations of plasma glucose and cholesterol as well as lower levels of albumin and protein, were observed under heat exposure (Tawfeek et al., 2014). However, tap water at high temperatures in summer reduced the feed intake, and the broilers compensated metabolic energy via gluconeogenesis and lipolysis, resulting in increased blood glucose and cholesterol compared with other groups treated with drinking water. The AST and ALT enzymes are efficient indicators for diagnosing liver function. In this study, the higher value of AST and ALT were obtained in both groups exposed to a constant drinking water temperature, and this can be due to the high nutrient intake resulting in increased AST and ALT levels. The increased level of AST and ALT might be due to the liver's metabolic demand, which led to hepatocellular degeneration (Senanayake et. al., 2011).

Conclusion

This study's present findings indicate that drinking water temperature in summer may have an important effect on growth performance, meat quality, and immune status. Broilers exposed to drinking water at temperatures of 15.4^{o}C or 24.3^{o}C compared to ordinary tap water at high ambient temperature significantly increased weight gain and feed consumption, decreased the concentration of GLU, and increased ALT levels in serum. Thus, the temperature of drinking water below the ambient temperature has beneficial effects on birds' health by dissipating metabolic heat and controlling the thermoregulatory mechanisms in the body.

Conflict of Interests

The authors declare that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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