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Effects of Chilled Drinking Water on Performance of Laying Hens during Constant High Ambient Temperature

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ABSTRACT : The present study was conducted to evaluate the effect of chilled drinking water on the productivity of laying hens under constant high ambient temperature. A total of seventy-two, 123-day-old Hy-line brown layers was divided into two equal groups. The first group (UDWG) was given unchilled water (23.0±2.5°C) as a control, and the second group (CDWG) was given chilled water (16.0±0.5°C). The laying hens were kept at 30°C constant temperature with 50% relative humidity and were exposed to 17 h of light per day. Feed intake, egg production, egg quality (egg weight, shell weight, shell thickness, egg color, yolk color, and Haugh unit), and blood samples were collected and analyzed. The results showed that the feed intake of CDWG laying hens was significantly higher (11.64%) than the UDWG counterparts ($p<0.01$). Egg production of CDWG was also significantly higher (11.27%) than the UDWG counterparts ($p<0.001$). Furthermore, we observed that the CDWG laying hens had significantly higher (11.72%) levels ($p<0.10$) of blood calcium, with a corresponding value of 21.92 mg/dl compared to the UDWG hens (19.62 mg/dl). The higher calcium concentration in the CDWG animals may contribute to increased egg production. The CDWG laying hens also contained higher (12.53%) phosphorus concentrations in blood compared to the UDWG (4.22 mg/dl vs. 3.75 mg/dl), although not statistically different ($p>0.10$). Egg weight and egg quality were not affected by chilled drinking water. In conclusion, providing chilled drinking for laying hens under high ambient temperature improved feed intake and egg production. (**Key Words :** Chilled Drinking Water, Egg Production, Egg Quality, Heat Stress, Laying Hen)

INTRODUCTION

Water is involved in every aspect of poultry metabolism. From a physiological perspective, water consumed by the bird is used for nutrient transportation, enzymatic and chemical reactions in the body, lubrication of joints and organs, and body temperature regulation (Fairchild and Ritz, 2006). At normal temperatures, poultry consume at least twice as much water as feed. When heat stress occurs, water consumption will double to quadruple (Carter and Sneed, 1987).

Poultry production efficiency is adversely affected by high ambient temperature and humidity. Several studies have been conducted on the effects of high environmental temperature and humidity on the performance of different poultry species, including broilers (Cooper and Washburn, 1998; Shim et al., 2006; Zulkifli et al., 2007; Yu and Bao, 2008), broiler breeders (Mc Daniel et al., 1995; Chung et al., 2005), young chickens (Henken et al., 1983), and laying hens (Miller and Sunde, 1975; Arima et al., 1976; Emery et al., 1984; Muiruri and Harrison, 1991; Whitehead et al., 1998; Mashaly et al., 2004), and have found that high environmental temperatures have deleterious effects on hen's productivity.

Laying hens are susceptible to heat stress for several reasons; their metabolic heat production is high (Blem, 2000), because there is little heat dissipation by convection and radiation, and in addition, hens have no sweat glands (Etches et al., 1995; Dawson and Whittow, 2000). Heat stress on laying hens depresses egg production (Arima et al., 1976; Muiruri and Harrison, 1991; Whitehead et al., 1998; Mashaly et al., 2004), egg weight (Miller and Sunde, 1975; Balnave and Muheereza, 1997), shell quality (Miller and Sunde, 1975; Arima et al., 1976; Emery et al., 1984; Mahmound et al., 1996), body weight (Scott and Balnave, 1988) and is generally accompanied by a reduction in feed intake, which could reduce egg production.

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Table 1. Composition of diets fed to laying hens

Ingredients (%)	Composition
Corn	55.00
Wheat bran	9.70
Soybean meal	20.00
Corn gluten meal	5.00
Salt	0.30
Vitamin-mineral premix[1]	0.50
L-lysine	0.50
DL-methionine	0.50
Limestone	7.50
Tricalcium phosphate	1.00
Calculated nutrient composition[2]	
ME (kcal/kg, %)	2,740
Crude protein (%)	15.50
Lysine (%)	0.70
Methionine (%)	0.30
Calcium (%)	3.30
Phosphorus (%)	1.00

[1] Provided following nutrients per kg of diet: vitamin A, 123,000 IU; vitamin D_3, 2,500 IU; vitamin E, 20 IU; riboflavin, 5.6 mg; pyridoxine, 1.6 mg; vitamin B_{12}, 14 mg; niacin, 30 mg; panthothenic acid, 12 mg; folic acid, 1.0 mg; biotin, 0.12 mg.

[2] Calculated based on the feed ingredient composition data from manufacturer's value.

To alleviate the effects of heat stress on laying hens, several approaches have been examined over the years (Deaton et al., 1981; Smith, 1981; Carr and Carter, 1985; de Andrade et al., 1977; Balnave and Muheereza, 1997; Wolfenson et al., 2001; Awoniyi, 2003; Balnave, 2004; Seven, 2008). These are include: roof insulation, orientation of buildings to maximize natural ventilation, installation of fans to increase ventilation, evaporative cooling, and improving dietary nutrient requirements. The approaches to facilitate heat conduction, which are not used commercially in poultry farms, include provision of water-cooled floor-level perches inside the cages (Muiruri and Harrison, 1991; Reilly et al., 1991), immersion of hens' legs in cool water (van Kampen, 1988), and provision of cool drinking water (Beker and Teeter, 1994; van Kampen, 1988).

There is little published information available regarding the effect of drinking water temperature on modern layers during heat exposure (Xin et al., 2002). Some layer farmers in South Korea have fed groundwater at 16°C (Sung, 1993) to laying hens subjected to heat stress and asserted that cool drinking water improves egg production of laying hens on summer days over 30°C. This study was conducted to evaluate the effect of 16°C chilled drinking water to the productivity of laying hens under 30°C constant ambient temperature.

MATERIALS AND METHODS

Animal housing and management

The layers were randomly housed in a battery type metal wire cages. The dimensions of each cage was 60×60 ×40 cm each cage (6 layers/cage), having 3 floors with 12 division in each floor. Each floor were divided into two blocks and placed in a controlled chamber (4×4.2×2.6 m) with 30°C constant temperature. Each individual bird cage was equipped with a feeding and drinking station. For the chilled drinking water group (CDWG), water at 16.0±0.5°C passed through from the chiller directly into the cup and nipple waterer (Jeon et al., 2006). Six birds in each cage were given 1 kg commercial feed daily (Table 1). Leftovers were collected and weighed the following day for feed intake analysis.

Experimental design

Total of seventy-two 123-day-old Hy-line brown layers weighing 1.3 to 1.7 kg were divided into two groups. Each group was replicated into six, and there were six hens in each replication. The first group (UDWG) was given unchilled drinking water (23.0±2.5°C) and the second group (CDWG) was given chilled drinking water (16.0±0.5°C). Water was available *ad libitum*. The hens brought from the experimental poultry house to the chambers were allowed a three-week adaptation period before the experiment. The hens were kept at 30°C constant temperature with approximately 50% relative humidity and were exposed to 17 h of light a day.

Data and sample collection

Feed intake was determined by collecting and weighing the leftovers in each cage the next day before feeding. Daily values for each replication were further averaged into weekly intervals. Egg production and egg quality were also determined on weekly basis. Eggs were collected and recorded daily at 3 pm. At the end of the week, the collected eggs were pooled and analyzed for each cage, basis for the egg quality analysis (egg weight, shell weight, egg shell strength, shell thickness (FHK, Japan), egg shell color, yolk color, and Haugh unit (TSS, England)). Eggs were weighed, and the shell strength was determined by a shell-breaking method shell strength analyzer (QC-SPA, TSS, England). Albumen height and Haugh Unit were evaluated with albumen height gauge (TSS-QCH, TSS, England). The device measures Haugh Unit by the method of Haugh (1973). Using the individual weight of each egg and the weight of its components, yolk percentage, albumen percentage and shell percentage were determined. Eggshell weight was determined after drying. At the end of the experiment, blood analyses were also conducted in an attempt to explain the observed differences. Blood analyses was done by collecting blood sample from 3 randomly selected hens from each treatment and transferred it into the reagent disc which were analyzed for approximately 12

Table 2. Feed intake (g/bird/7 d) of laying hens given unchilled drinking water or chilled drinking water under heat stress

Experimental period (wk)	Treatment		CV[5]	p-value
	UDWG[1] (n[3] = 36) Mean±SD[4]	CDWG[2] (n = 36) Mean±SD		
1	599±38^{4,B}	703±17^{A}	4.5	0.0001
2	763±72	837±56	8.1	0.0739
3	745±69^{b}	825±36^{a}	7.0	0.0285
4	747±42^{b}	820±60^{a}	6.6	0.0352
Overall	713±86^{B}	796±70^{A}	10.4	0.0007

[1] UDWG = Unchilled drinking water group. [2] CDWG = Chilled drinking water group.

[3] n = Nnumber of laying hens. [4] Mean±SD. [5] CV = Coefficient of variance.

$^{A, B}$ Means with different superscripts in the same row differ with statistical significance of $p<0.01$.

$^{a, b}$ Means with different superscripts in the same row differ with statistical significance of $p<0.05$.

minutes on a compact portable analyzer (VetScan, Germany).

Statistical analysis

The data were subjected to analysis of variance (ANOVA) using software (SAS, 1999) to compare the effects of providing chilled drinking water and unchilled drinking water on productivity of laying hens under high ambient temperature. We chose $p<0.05$ as the minimum acceptable level of significant, except for the blood analysis which we used a significant level of $p<0.10$ due to relatively small sample sizes. Results are presented as mean, standard deviation, and coefficient of variance.

RESULTS AND DISCUSSION

The feed intake of laying hens that were given chilled drinking water under constant high ambient temperature was significantly higher ($p<0.01$) than that of the laying hens given unchilled drinking water (Table 2). This means that, providing chilled drinking water for laying hens under heat stress increases feed consumption. This finding was also observed in previous studies of Glatz (1997), Janssen and Musharaf (1984), Leeson and Summers (1975). In addition, Teeter et al. (1987) reported that KCl drinking water fortification increased feed consumption and growth rate when the temperature of consumed water was lower than the broiler's body temperature, and that lowering the water temperature without salt addition to stimulate water intake also proved to be beneficial. Puma et al. (2001) reported that broilers increased their feed and water intake under warm environmental conditions (35°C) when they were provided cooler drinking water in the range of 20-32°C. Moreover, Degen and Kam (1998) concluded that roosters prefer cool drinking water than warm drinking water in both summer and winter. However, Xin et al. (2002) reported when 6 laying hens per treatment were given drinking water of 15, 19, 23, or 27°C under a diurnal air temperature of 27°C to 38°C feed intake was most for laying hens in the 23°C drinking water group. The differences between the observations of Xin et al. (2002) with the previous studies (Glatz, 1997; Puma et al., 2001) and our present results may be due to small sample size, age, and type of bird used, or due to the experimental methodology that was being applied.

The laying hens in the CDWG produced significantly more ($p<0.001$) eggs than those in the UDWG (Table 3). It seems that increasing the feed intake positively affect the intake of calcium and thus, egg production. Xin et al. (2002) also reported that decreased feed consumption during hot weather negatively affects the intake of calcium and other nutrients. Thus, in the present research, we hypothesized that increases in feed consumption increased calcium intake (Figure 1) and other nutrients needed for the

Table 3. Egg production (%) of laying hens given unchilled drinking water or chilled drinking water under heat stress

Experimental period (wk)	Treatment		CV[5]	p-value
	UDWG[1] (n[3] = 36) Mean±SD[4]	CDWG[2] (n = 36) Mean±SD		
1	73.4±3.9^{4,b}	78.2±4.1^{a}	5.3	0.0445
2	75.4±4.4	78.2±5.9	6.7	0.3344
3	68.7±3.8^{B}	82.1±7.2^{A}	7.6	0.0009
4	69.0±6.9^{b}	80.6±3.9^{a}	7.5	0.0050
Overall	71.7±5.4^{B}	79.7±5.4^{A}	7.2	0.0001

[1] UDWG = Unchilled drinking water group. [2] CDWG = Chilled drinking water group.

[3] n = Nnumber of laying hens. [4] Mean±SD. [5] CV = Coefficient of variance.

$^{A, B}$ Means with different superscripts in the same row differ with statistical significance of $p<0.001$.

$^{a, b}$ Means with different superscripts in the same row differ with statistical significance of $p<0.05$.

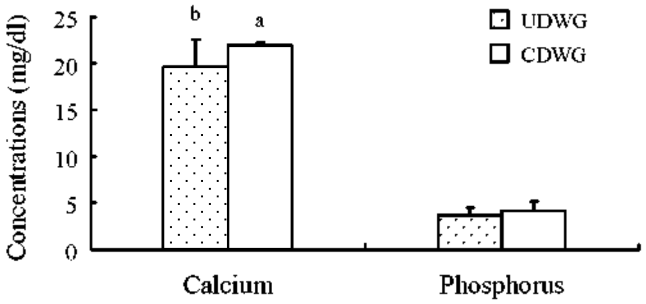

Figure 1. Concentrations of calcium and phosphorus in blood of laying hens given unchilled drinking water or chilled drinking water under heat stress for four weeks. White bars represent blood concentrations in unchilled drinking water group and black bars represent chilled drinking water group, shown as the Mean±SD (number of laying hens = 6). [a, b] Treatments with different letter are different at $p<0.10$.

productivity of heat-challenged hens. Furthermore, Mahmoud et al. (1996) suggested that alterations in pH balance, status of Ca^{2+}, and diminished ability of duodenal cells to transport calcium could be critical factors in the detrimental effects of heat stress on egg production, egg shell characteristics and skeletal integrity that are often documented in laying hens. Bar et al. (2002) reported that increasing dietary Ca^{2+} from 24-25 to 36-40 gk/g improved egg production, shell weight, shell thickness, and decreased mortality.

Our assumption was also supported by our blood calcium concentration results. We observed that the blood calcium concentration in laying hens of the CDWG was 11.72% higher than the UDWG counterparts ($p<0.10$). Blood phosphorus concentration of laying hens in CDWG, was 12.53% higher than UDWG, although it was not statistically significant ($p>0.10$). Calcium is needed for bone and eggshell formation (Scanes et al., 2004), and calcium metabolism is involved in an array of factors, including phosphorus, micronutrients, vitamin D_3, other hormones, and respiration (Silversides and Scott, 2001). A dietary phosphorus content of 4.5 g/kg appears to be sufficient for maintaining egg production and shell quality in aged laying hens given 36-40 g/kg calcium (Bar et al., 2002).

We observed that providing chilled drinking water to laying hens under high ambient temperature, did not show any direct influence on egg weight (Table 4) or egg quality (Table 5). According to Emery et al. (1984) the reduction in egg weight and shell thickness observed at cyclic temperatures were not simply results of a reduction in nutrient intake at high temperatures but also the direct affect of heat stress on the hens. This conclusion by Emery et al. (1984) was noted in pair-feeding layers under different temperature regiments, and suggested that feed intake alone will not rectify an egg weight or shell quality problem that might exist in the summer months. However, Deaton et al. (1986) reported that a difference in feed or nutrient intake was the causative factor for reduced egg weight. Contrary to the results of the present study, Xin et al. (2002) reported that egg weight of laying hens given 23°C and 27°C

Table 4. Egg weight (g) of laying hens given unchilled drinking water or chilled drinking water under heat stress

Experimental period (wk)	Treatment		CV[5]	p-value
	UDWG[1] (n[3] = 36) Mean±SD[4]	CDWG[2] (n = 36) Mean±SD		
1	51.0±3.4[4]	51.4±6.3	9.8	0.8244
2	48.2±3.4	48.0±4.9	8.7	0.2607
3	51.0±3.4	51.4±6.3	9.8	0.8244
4	51.8±3.0	51.6±2.9	5.7	0.6909
Overall	50.5±3.5	50.6±5.4	9.0	0.7367

[1] UDWG = Unchilled drinking water group. [2] CDWG = Chilled drinking water group.
[3] n = Number of laying hens. [4] Mean±SD. [5] CV = Coefficient of variance.

Table 5. Overall means of egg quality parameters of laying hens given unchilled drinking water or chilled drinking water under heat stress

Parameters	Treatment		CV[5]	p-value
	UDWG[1] (n[3] = 36) Mean±SD[4]	CDWG[2] (n = 36) Mean±SD		
Egg shell strength (kg/cm^2)	5.47±0.26[4]	5.41±0.33	6.7	0.7517
Egg shell thickness (μm)	36.65±3.24	38.13±2.31	7.1	0.3056
Egg shell color	23.31±0.73	24.23±0.92	5.4	0.6104
Egg yolk color	6.50±2.92	6.24±2.93	8.5	0.5785
Haugh unit	111.46±15.15	103.03±2.18	7.8	0.5642

[1] UDWG = Unchilled drinking water group. [2] CDWG = Chilled drinking water group.
[3] n = Number of laying hens. [4] Mean±SD. [5] CV = Coefficient of variance.

drinking water was heavier than that of hens given 15°C and 19°C drinking water under a diurnal air temperature of 27°C to 38°C. The differences could be due to the sample size, age, and type of bird used, or to the experimental methodology that was being applied. It was reported that egg weight is influenced by strain, age of the breeder flock and age at photostimulation (TAS, 2008). They reported that as the bird ages, the average egg weight initially increases. Accordingly, the average hen egg weight is determined by the age of the breeder hen, not by the time following photostimulation. This means that if a flock is photostimulated at younger age than the normal 29-30 weeks, the first eggs laid will be smaller. Conversly, if the flock is photostimulated at a later age, its first egg will be heavier. They added that the rate of egg production can have impact on egg size, whereby poor egg production tend to produce heavier eggs. Furthermore, factors such as high environmental temperatures (above 25°C), non-standard lighting regimes, and nutritional factors can affect egg size in laying hens.

The study showed that the feed intake and egg production of laying hens given chilled drinking water under constant high ambient temperature were significantly higher than those of the laying hens given unchilled drinking water. However, no significant differences were observed in egg weight or in egg quality. Calcium concentrations were higher in the CDWG birds than in the UDWG birds. Higher calcium concentrations may contribute to increased egg production of laying hens in the CDWG. In conclusion, providing chilled drinking for laying hens under high ambient temperature, improved their feed intake and egg productivity.

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