The effect of sodium chloride supplementation in the drinking water on water and feed intake and egg quality of laying hens under cyclic heat stress

Einfluss eines Zusatzes von Natriumchlorid zum Trinkwasser auf die Wasser- und Futteraufnahme sowie die Eiqualität von Legehennen bei zyklischem Hitzestress

N.V. Dai¹, W. Bessei² and Z. Nasir²


Introduction

The effects of high ambient temperature on chicken were investigated by many experiments. In laying hens, heat stress resulted in decrease in egg quality, egg weight, shell thickness (Warren, 1939; Wilson, 1949; Smith, 1978; Saffar and Rose, 2002; Mashaly et al., 2004) and egg production (Uruglu et al., 2001). High temperature results in increase in body temperature of birds (Heywang, 1938; Lee et al., 1945; Wilson, 1949; Boone and Hughes, 1971; Donkoh, 1989; Smith, 2001), decrease in body weight (Smith, 1978; Bonnet et al., 1997), depression in feed intake (Wilson, 1949; Emmans, 1974; Kamal, 1975; Cobb, 1991; Li et al., 1992; May and Lott, 1992; Bird et al., 1988), and increase in water consumption (Wilson, 1949; Portsmouth, 1979; May and Lott, 1992). Drinking is closely associated with feeding (Hill et al., 1979 loc. cit. Appleby et al., 1992). Water: feed ratio of laying hens ranged from 1.8 to 2.0 at normal temperature (20°C) (Singleton, 2004), and it was 1.5 in broilers at 22°C (Deeb and Cahander, 1998). It increased from 1.74 at 21.1°C to 2.08 at 28°C (Bell, 2002), and it was about 2.8 in laying hens at 34°C (Dai and Bessei, 2007).

Numerous methods of reducing the negative effects of high ambient temperature were studied over the years. Water intake has been shown to be a management factor of major importance to the heat stressed hens (Balnave and Brake, 2005) and survival of chicken in hot environment depends on the consumption of large volumes of water (Fox, 1951). The increase in water consumption benefits the bird by increasing amount of heat dissipated by respiratory tract (Belay and Teeter, 1993) and maintenance body water balance (Borges et al., 2003). Bessei et al. (1998) revealed that birds with excess water consumption under moderate conditions, maintained high feed intake and egg production under heat stress while birds with low water intake reduced egg production.

High water intake, however, lead to increasing excretion of minerals through digestive tract, and the increased respiratory activity changes the balance of minerals in the blood.

Introduction

Therefore, it is generally acknowledged that supplementation of minerals is necessary to maintain physiological function during hot weather (Ait-Boulahsen et al., 1989; Belay et al., 1992; Brake et al., 1994).

Sodium chloride (NaCl) supplementation in the drinking water was reported to increase water intake of chicken (Damron and Kelly, 1987; Smith, 2001; Richter et al., 2006). Broilers can tolerate up to 0.2% NaCl in the drinking water (Affifi et al., 1992). Supplementation 2 g NaCl/l in the drinking water (Yoselewitz and Balnave, 1989; Khapafalla and Bessei, 1996) for laying hens increased eggshell defects. However, in high ambient temperature, NaCl supplementation is reported to reduce the negative effects of high temperature on broilers. Broilers receiving 0.376% (Smith, 1994) and 0.39% (Deyhim and Teeter, 1991) NaCl in drinking had better weight gain at 35°C. Addition of 0.08% NaCl in the drinking water did not reduce the effect of cyclic heat stress (24–35–24°C) on broilers (Deyhim and Teeter, 1995). While the responses of laying hens and broilers to drinking water or diet containing NaCl in moderate conditions had been extensively studied, supplementation of NaCl in the drinking water of laying hens under heat stress has received less attention. Therefore, this experiment was carried out to study the effect of NaCl supplementation in the drinking water on water and feed intake, body temperature, egg production and egg quality of laying hens under heat challenge.

Materials and methods

A total of 48 Hisex hens (80 weeks old) were kept in individual laying cages in climatic chambers and were randomly allocated to three experimental groups of 16 hens each. The birds had been raised on deep litter and then transferred to cages, in a windowless forced ventilated poultry house, at 20 weeks of age. They were subjected to induced laying pause at 65 weeks of age to ensure good egg production level and good feather cover during the experiment. These groups were given 0; 0.2 and 0.4% NaCl in the drinking water for seven consecutive days of heat stress. Before and after heat stress, birds were given normal drinking water. Water was provided through nipple drinkers. Birds were fed layer diet containing 11.45 MJ/kg Metabolizable Energy, 16.97% crude protein, 3.73% calcium, 0.62% phosphorus, 0.22% sodium and 0.33% chloride, 0.79% Lysine, and 0.42% Methionine. Feed was provided ad libitum. The duration of the study was 3 weeks (from 25
April to 15 May 2007). Before the experiment, the birds were kept to adapt to the new environment at temperature of 21 ± 1°C for 7 days. In experimental period, the room temperature was constant at 21 ± 1°C for one week before heat stress. During heat stress, temperature was cycled from 21 ± 1°C to 34 ± 1°C (from 9 to 22 o’clock) for 7 days, and then returned to 21 ± 1°C for one week. Humidity was not controlled. 14-hours lighting schedule was maintained during experiment.

Water and feed intake, water: feed ratio, body weight, body temperature, egg production, egg weight, eggshell thickness, eggshell deformation, eggshell strength, yolk colour and Haugh Units (HU) were recorded. Daily water and feed consumption were determined by weighing feed or water in the morning of the first day, and weighing back in the next morning. The body weight was recorded at 1st and the last day of experiment, and at 7th day of heat stress. The number of eggs laid by each bird was recorded daily. Egg was weighted to the nearest one-tenth gram. Eggshell defects including broken, cracked, leaking, soft-shelled eggs and misshapen eggs were daily determined by visual inspection. Body temperature was recorded at the day before, and at 1st, 3rd, 5th and 7th day of heat stress. All eggs were collected on the day before, 3rd, 5th and 7th day of heat stress for quality measurement. Eggs were identified by bird and brought on the day of collection to the laboratory of the Institut für Tierhaltung und Tierzüchtung, Universität Hohenheim, Germany. The egg samples were stored overnight at 10 to 15°C.

The shell breaking strength and shell deformation were measured by the quasi-static compression test using Instron (Model 4301, Instron Ltd., Coronation Road, High Wycombe, Bucks HP 123 SY, England), where the eggs were compressed at a constant speed of 5.0 mm/min between the poles and the steel surfaces. The shell deformation was determined to the nearest 0.001 mm as the applied force reached 10 N. The compression fracture strength (CFS) was determined at the time of fracture. Both measurements were recorded by a computer connected to the Instron.

Shell thickness (including the membranes) was measured on three pieces (broad, equator and sharp end) from the equator of each egg using a thickness micrometer gauge. The shell thickness was determined after rinsing shells with distilled water and oven-dried at 70°C for 4 hours. Yolk colour was scored using the DSM Yolk Color Fan of DSM Nutritional Products (P.O. Box 3255, CH-4002, Basel, Switzerland). It comprises 15 blades ranging beginning at pale yellow (1) to dark orange (15). Albumen height in millimeters for calculating HU was measured by a tripod micrometer connected to a computer using special software made by Fa.HHEYD-Messzeuge 73728, Esslingen, Germany.

All data were recorded on the basis of individual bird. Therefore individual birds were considered as a replication. The experimental data were statistically analyzed by JMP 5.0.1 program (SALL et al., 2005). The effect of salt supplementation was tested by the MANOVA analysis with salt concentration as fixed effect and the period (before, during and after heat stress) as the repeated measurement. Differences between means of salt concentrations within the periods were tested by Student’s t-test. Using ANOVA procedure. Differences of means between periods with salt concentration were tested by Matched Pairs test. MANOVA and Matched Pairs analysis was not applied for egg quality analysis since hens did not lay every day, and the data contained too many missing values.

Results

The results of the MANOVA are shown in Table 1. The effect of experimental period (time), which comprises the effect of increasing and decreasing temperature, was significantly different for water intake, feed intake, water: feed ratio, body temperature and body weight. NaCl supplementation influenced water intake, water: feed ratio, but not feed intake, body weight and body temperature. The interaction time x NaCl was significant for water intake, feed intake as well as water: feed ratio. Laying rate was not significantly affected by period, NaCl and the interaction of period and NaCl supplementation. There was no mortality in any experimental group, hence no data are presented.

Water and feed intake, water: feed ratio

Data of water intake, feed intake, and water: feed ratio on 6th day after heat stress was missing due to technical problems. The influence of NaCl supplementation on water intake is shown in Figure 1 and Table 2. Means of water intake during heat stress was significantly higher than before and after heat stress in all groups. Water intake decreased to normal on the first day the temperature decreased to normal and NaCl was withdrawn from drinking water (Figure 1).

Heat stress increased water intake by 40.5% than before heat stress in control group while interaction heat stress (time) and NaCl supplementation increased by 74.7% with 0.2% NaCl supplementation and 108% with 0.4% NaCl supplementation than before heat stress. During heat stress, the mean water intake of the NaCl-supplemented groups was significantly higher than of the control group. After heat stress, both NaCl-supplemented groups returned to the level of the pre-stress period. Mean water consumption of the control group was lower than before.

Table 1. Results of MANOVA analysis (P-values) for water and feed intake, water: feed ratio, body temperature and body weight before, heat stress and after heat stress, and NaCl supplementation in drinking water

<table>
<thead>
<tr>
<th>Factor</th>
<th>Parameters</th>
<th>Water intake</th>
<th>Feed intake</th>
<th>Water to feed ratio</th>
<th>Body weight</th>
<th>Body temperature</th>
<th>Laying rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>&lt; 0.0001</td>
<td>0.0224</td>
<td>0.0052</td>
<td>0.0193</td>
<td>&lt; 0.0001</td>
<td>0.4670</td>
<td></td>
</tr>
<tr>
<td>NaCl</td>
<td>0.0003</td>
<td>0.802</td>
<td>0.0014</td>
<td>0.7056</td>
<td>0.1166</td>
<td>0.2924</td>
<td></td>
</tr>
<tr>
<td>Time*NaCl</td>
<td>0.0155</td>
<td>0.0039</td>
<td>0.0088</td>
<td>0.3206</td>
<td>0.8724</td>
<td>0.6163</td>
<td></td>
</tr>
</tbody>
</table>

heat stress and differed significantly from 0.2% NaCl supplemented group. The 0.4% NaCl supplemented group did not differ from the control and 0.2% supplemented group. The means of feed intake are presented in the Figure 2 and Table 2. The means of feed intake were lower during heat stress in all treatments, but the differences were only significant in the 0.2% NaCl supplemented group compared to before and after heat stress. Feed intake declined immediately in all groups at the first day of heat stress (Figure 2). There was a high variation from day to day, particularly in the NaCl supplemented groups. Although the effect of NaCl on feed intake was not significant, there was a tendency of lower means of the 0.2% and 0.4% NaCl supplemented groups compared to the control group.

Water: feed ratio (Figure 3 and Table 2 during heat stress was significantly higher than before and after heat stress. In the heat stress period, water: feed ratio increased from 2.01 to 2.88 in control group, 2.18 to 4.52 in 0.2% NaCl group, and 2.11 to 4.56 in 0.4% NaCl group. After heat stress, water: feed ratio in control group was significantly lower than before heat stress. Water: feed ratio of both NaCl supplemented groups in the heat stress and after heat stress was significantly higher compared with control. The differences between NaCl supplemented groups were not significant.

Egg production

The results of the laying rate are given in the Table 3 and Figure 4. There was no immediate response of laying rate when the temperature increased in the heat stress period in the control group. Only after heat stress period, the laying rate declined from 75.2% to 72.4%. The differences were, however, not significant. In contrast to control group, the egg production of the NaCl supplemented groups decreased during the heat stress period and increased afterwards. However, significant differences between means were not found. Figure 4 revealed that laying rate declined the first day of heat stress in all groups. There was a general trend of recovery afterward. The means between groups of KCl supplementation were not significantly different.

Body weight

Means of body weight in control and 0.2% NaCl group (Table 4) were not significantly different during the time of experiment. However, on 7th day after heat stress, body weight of birds in 0.4% NaCl group was significantly lower than that of birds on 7th day of heat stress. There was no significant difference of body weight between treatment groups and control group in any experimental period.

Body temperature

Means of body temperature are presented in Table 5. Body temperature of birds before heat stress in all groups was significantly lower than body temperature of birds during heat stress. The highest body temperature was found on the first day of heat stress, thereafter it decreased slightly. NaCl supplementation did not affect body temperature; however, from 3rd to 7th day of heat stress, there was a tendency of lower body temperature (0.1 to 0.2°C) with 0.4% NaCl supplementation in comparison with control and 0.2% NaCl group.

Eggshell defects

Means of eggshell defects are presented in the Table 6. The total egg shell defects in the week of heat stress (11.4 and
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Table 2. Water intake, feed intake and water: feed ratio in response to experimental periods and NaCl supplementation in drinking water (mean ± SD)

<table>
<thead>
<tr>
<th>NaCl supplementation (%)</th>
<th>Before heat stress</th>
<th>During heat stress</th>
<th>After heat stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water intake (ml/bird/day)</td>
<td>Feed intake (g/bird/day)</td>
<td>Water: feed ratio</td>
</tr>
<tr>
<td>Control</td>
<td>210 A ± 47.52</td>
<td>108 ± 16.98</td>
<td>2.01 A ± 0.39</td>
</tr>
<tr>
<td>0.2</td>
<td>233 A ± 39.82</td>
<td>107 AB ± 20.13</td>
<td>2.18 A ± 0.36</td>
</tr>
<tr>
<td>0.4</td>
<td>211 A ± 29.19</td>
<td>101 ± 8.56</td>
<td>2.11 A ± 0.25</td>
</tr>
</tbody>
</table>

Means for the same column without common small letters and for the same row without common capital letters are significantly different (P < 0.05).

Fit of the model (one way ANOVA): R² = 0.52, P < 0.0001 (water intake during heat stress); R² = 0.19, P = 0.02 (water intake after heat stress). R² = 0.60, P < 0.0001 (water: feed ratio during heat stress); R² = 0.20, P < 0.02 (water: feed ratio after heat stress).

10.3% respectively) were not higher than in the week of before heat stress (15.2 and 11.2%, respectively) in control and 0.4% NaCl group. In 0.2% NaCl group, eggshell defects slightly increased on the week of heat stress.

**Egg quality**

There was no change in thickness, strength, deformation of the eggshell, yolk color and HU before and during heat stress (Table 7). Egg weight of control and 0.4% NaCl was similar between before and during heat stress period. Egg weight of group receiving 0.2% NaCl on 3rd and 5th day of heat stress was tendentiously lower than before and after heat stress. There was no significant difference between NaCl supplementation and control group of eggshell strength, shell deformation, yolk color and HU during heat stress. There was a higher egg weight at 0.4% NaCl supplementation on 5th day of heat stress in comparison with 0.2% NaCl and higher eggshell thickness of the control group on 3rd and 5th day of heat stress in comparison with the treatment groups.

**Discussion**

High ambient temperature and/or humidity were reported to deleteriously affect egg weight, egg number and eggshell quality in laying hens (Warren, 1939; Wilson, 1949; Smith, 1978; Smith, 2001, Saifar and Rose, 2002). High producing hens are particularly susceptible to high temperature because of the metabolic heat production related to egg building. When metabolic heat production exceeds the capacity of passive heat dissipation, the birds activate their physiological and behavioral defense mechanisms for heat stress. These comprise the decrease in blood flow to the uterus (Wolfenson et al., 1981), panting (Donkoh, 1989), reduction of feed consumption and increase in water consumption (May and Lott, 1992). The immediate increase in water intake helps birds to increase the dissipation of heat from respiratory surfaces, and the decrease in feed intake reduces the contribution of metabolic heat to the total heat load. Reduction of feed intake as a response of increased deep body temperature is being considered as the main factor of reducing egg production.

Figure 3. Daily water: feed ratio in response to experimental periods and NaCl supplementation in drinking water

Tägliches Wasser: Futter-Verhältnis über die Versuchsphasen für die NaCl-Zulagestufen zum Trinkwasser

Arch.Geflügelk. 4/2009
The temperature conditions in the present experiment have been set so as to simulate the diurnal changes under tropical conditions with cyclic increase during the day time and decrease during the night time. Heat stress increased water intake, water: feed ratio and body temperature while egg production, body weight and feed intake were not significantly affected. According to the general responses of the hens, the present schedule can be considered as the mild heat stress for laying hens at 80 weeks of age. This indicated that laying hens at the last of laying period cope better with heat stress than laying hens at younger age. The week effects of heat stress on laying hens in the present study may be due to lower heat production produced by egg production.

The increase in water intake of birds due to heat stress was reported by Wilson (1949), NRC (1994), Portsmouth (1979), May and Lott (1992), and Bell (2002). In the present study, heat stress increased water intake, water: feed ratio and body temperature while egg production, body weight and feed intake were not significantly affected. According to the general responses of the hens, the present schedule can be considered as the mild heat stress for laying hens at 80 weeks of age. This indicated that laying hens at the last of laying period cope better with heat stress than laying hens at younger age. The week effects of heat stress on laying hens in the present study may be due to lower heat production produced by egg production.

The increase in water intake of birds due to heat stress was reported by Wilson (1949), NRC (1994), Portsmouth (1979), May and Lott (1992), and Bell (2002). In the present study, heat stress increased water intake of birds as compared with water intake before heat stress in all groups (Table 2 and Figure 1). Hens consumed more water in control group (40.5%), and in the 0.4% NaCl group (108%) for increasing temperature from 21°C to about 34°C. High water consumption was maintained during the period of heat stress. This is not in agreement with Smith (2001), who reported that the water intake of laying hens will increase rapidly when ambient temperature rise above 21°C and will return to its normal level when exposure to high temperature continues. There was a consistent response of increasing water intake with increasing salt concentration in the drinking water. Similar results were found by Smith and Teeter (1987), Teeter (1994), Art-Boula Hsen (1995), Dehirm and Teeter et al. (1995). Increase in water intake has been shown to be an important factor to overcome heat stress in poultry (Fox, 1951; Bessei et al., 1998; Balnav and Brace, 2005). Increase in water helps birds to dissipate heat through the respiratory system, and reduces body temperature. In the present study, body temperature increased significantly in response to heat stress (Table 5).

There was no significant response in body temperature with NaCl supplementation, and only the group receiving 0.4% NaCl showed a tendentious decrease in body temperature. This indicates that the increase in water intake without NaCl supply was sufficient to maintain normal physiological conditions. The positive effect of increase in water intake due to NaCl supplementation on body temperature of laying hens may be expressed under extended or more severe heat stress. Dai and Bessei (2008) reported that body temperature of broilers increased up to 43.1°C at 40 days of age under tropical field conditions. 0.4% NaCl supply in the drinking water significantly reduced body temperature at 40 days of age.

The increase in water intake during heat stress is usually accompanied with the decline in feed intake (Emmans, 1974; Bird et al., 1988; Li et al., 1992; Urgulu et al., 2001).

Table 3. Laying rate (%) in response to experimental periods and NaCl supplementation in drinking water (mean ± SD)

<table>
<thead>
<tr>
<th>NaCl solution (%)</th>
<th>Before heat stress</th>
<th>During heat stress</th>
<th>After heat stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>75.1 ± 25.0</td>
<td>75.2 ± 20.5</td>
<td>72.4 ± 27.2</td>
</tr>
<tr>
<td>0.2</td>
<td>78.1 ± 23.4</td>
<td>70.5 ± 15.7</td>
<td>77.1 ± 20.8</td>
</tr>
<tr>
<td>0.4</td>
<td>84.7 ± 14.7</td>
<td>82.8 ± 18.1</td>
<td>83.8 ± 19.4</td>
</tr>
</tbody>
</table>

*Means for the same column without common small letters and for the same row without common capital letters are significantly different (P < 0.05)

Figure 4. Daily Laying rate in response to experimental periods and NaCl supplementation in drinking water

Tägliche Legeleistung über die Versuchsphase für die NaCl-Zulagesetufen zum Trinkwasser
Table 5. Body temperature (°C) in response to experimental periods and NaCl supplementation in drinking water (mean ± SD) Körpertemperatur (°C) während der Hitzelastung für die NaCl-Zulage zum Trinkwasser (Mittelwert ± SD)

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 3</td>
<td>Day 5</td>
<td>Day 7</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>40.6 ± 0.28</td>
<td>41.4 ± 0.20</td>
<td>41.2 ± 0.27</td>
<td>41.1 ± 0.22</td>
<td>41.2 ± 0.32</td>
</tr>
<tr>
<td>0.2</td>
<td>40.8 ± 0.47</td>
<td>41.4 ± 0.26</td>
<td>41.2 ± 0.22</td>
<td>41.3 ± 0.38</td>
<td>41.3 ± 0.26</td>
</tr>
<tr>
<td>0.4</td>
<td>40.8 ± 0.24</td>
<td>41.3 ± 0.19</td>
<td>41.1 ± 0.24</td>
<td>41.1 ± 0.30</td>
<td>41.1 ± 0.29</td>
</tr>
</tbody>
</table>

* Means for the same column without common small letters and for the same row without common capital letters are significantly different (P < 0.05)

Table 6. Eggshell defects in number and percentage in response to experimental periods and NaCl supplementation in drinking water Eischalendefekte absolut und in Prozent für die Versuchsperioden und die NaCl-Zulage zum Trinkwasser

<table>
<thead>
<tr>
<th>NaCl solution (%)</th>
<th>Eggshell defects/week</th>
<th>Total eggs/week</th>
<th>% defects</th>
<th>Eggshell defects/week</th>
<th>Total eggs/week</th>
<th>% defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12</td>
<td>79</td>
<td>15.19</td>
<td>9</td>
<td>79</td>
<td>11.39</td>
</tr>
<tr>
<td>0.2</td>
<td>10</td>
<td>82</td>
<td>12.19</td>
<td>16</td>
<td>77</td>
<td>20.78</td>
</tr>
<tr>
<td>0.4</td>
<td>10</td>
<td>89</td>
<td>11.24</td>
<td>9</td>
<td>87</td>
<td>10.34</td>
</tr>
</tbody>
</table>

However, no difference in feed consumption due to heat stress (34 °C) was noted in the present study (Table 2 and Figure 2). This difference may be related to different intensity of heat stresses. Cyclic heat stress was reported to have less negative effects than constant heat stress (Morris, 2004). In the week of heat stress, feed intake of birds receiving NaCl in the drinking water and normal water was not significantly different. Feed intake of birds receiving 0.2% NaCl in the drinking water decreased slightly in the week of heat stress. Feed intake returned to normal after heat stress in all groups.

Drinking is closely associated with feeding (Hill et al., 1979 loc. cit. Appleby et al., 1992). Water: feed ratio of White Leghorn hens was 1.74 at 21.1 °C (Bell, 2002). This ratio (Table 2 and Figure 3) in our study was about 2 before heat stress (21 ± 1 °C), and it increased to 2.88 during heat stress (34 ± 1 °C) in the control group and 4.56 in the 0.4% NaCl group. The increased amount of water consumption caused the differences of water: feed ratios in the heat stress period. Water: feed ratio increased with NaCl supplementation, from about 2.88 in control to 4.36 in 0.2% and 4.56 in 0.4% NaCl group during the heat stress. NaCl in the diet increased water: feed intake ratio (Smith, 2001) from 1.7 on a diet containing 0.18% salt to 8.71 when 8% salt was added to the diet. After heat stress, this ratio declined to 1.85 in control group which was significantly lower in comparison with treatment groups at the same time. This decrease was mainly due to the lower water intake of birds in control group. It reveals that NaCl continued to affect water consumption of hens after withdrawing NaCl from drinking water.

There were different effects of heat stress on body weight (Table 4). In the control and 0.4% NaCl group body weight showed a decreasing tendency while it slightly increased in the 0.2% NaCl group. However, significant differences between groups were not found. Decrease in feed consumption and loss in live weight at high temperatures have been reported by many researchers (Deaton et al., 1982; Tanor et al., 1984; Puguri and Coon, 1985), although weight loss is not always significant (Emery et al., 1984).

Egg production in the control group (Figure 4) declined on fourth day of heat stress; thereafter it increased slightly and then continuously decreased after heat stress. The decline in egg laying rate during heat stress was also found in 0.2% NaCl group as well. There was a tendency of increasing laying rate towards the end of the heat stress period in treatment groups. In the 0.4% NaCl group there was no immediate response to heat stress, and the birds maintained their high level of production throughout all the experimental periods. Similar results have been reported by Dai and Bessei (2008) when the same concentrations of KCl were examined. But after the heat stress period, the laying rate of control group was continuously lower while in the both NaCl treatment groups, laying rate increases to as before heat stress. When the effect of NaCl on heat stress is considered, the level of performance among the groups before the heat stress is important. Incidentally, before heat stress, laying rate of the 0.4% NaCl treated hens was about 10% higher than that of the control group (84.8% vs. 75.1%) while the 0.2% NaCl group took an intermediate position. Although the difference was not significant, the higher egg production is related to higher metabolic heat load and as temperature increased the hens not only increased the water: feed ratio, but also reduced the egg out put. These responses to heat stress might be the reason that the laying rate returned to the level before heat stress period in the both NaCl supplemented groups. The control birds under heat stress maintained their laying rate while water intake and water: feed ratio was only moderately increased (Table 2 and Figure 3). The response of water intake and water: feed ratio was obviously sufficient to maintain the level of laying rate for the period of heat stress. The drop in laying rate in the control group in the period of after heat stress can be considered as a delayed
Table 7. Means of some egg quality parameters in response to experimental periods and NaCl supplementation in drinking water (± SD)

*Mittelwerte einiger Eiqualitätsparameter während der Hitzebelastung für die NaCl-Zulage zum Trinkwasser (± SD)*

<table>
<thead>
<tr>
<th>NaCl Solution (%)</th>
<th>n</th>
<th>Day before</th>
<th>Heat stress</th>
<th>Heat stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>Day 3</td>
<td>Day 5</td>
</tr>
<tr>
<td>Control</td>
<td>12</td>
<td>69.25 ± 5.39</td>
<td>11</td>
<td>69.96 ± 6.82</td>
</tr>
<tr>
<td>0.2</td>
<td>15</td>
<td>69.41 ± 5.25</td>
<td>10</td>
<td>65.34 ± 2.81</td>
</tr>
<tr>
<td>0.4</td>
<td>13</td>
<td>68.89 ± 5.19</td>
<td>13</td>
<td>68.42 ± 6.49</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
<td>29.71 ± 8.01</td>
<td>8</td>
<td>29.41 ± 6.06</td>
</tr>
<tr>
<td>0.2</td>
<td>13</td>
<td>31.81 ± 7.4</td>
<td>4</td>
<td>32.86 ± 1.99</td>
</tr>
<tr>
<td>0.4</td>
<td>12</td>
<td>30.17 ± 7.01</td>
<td>8</td>
<td>29.16 ± 7.45</td>
</tr>
<tr>
<td>Control</td>
<td>7</td>
<td>0.065 ± 0.016</td>
<td>8</td>
<td>0.066 ± 0.013</td>
</tr>
<tr>
<td>0.2</td>
<td>11</td>
<td>0.053 ± 0.009</td>
<td>4</td>
<td>0.062 ± 0.014</td>
</tr>
<tr>
<td>0.4</td>
<td>12</td>
<td>0.064 ± 0.012</td>
<td>8</td>
<td>0.057 ± 0.013</td>
</tr>
<tr>
<td>Control</td>
<td>13</td>
<td>36.47 ± 2.59</td>
<td>11</td>
<td>37.91 &lt;sup&gt;a&lt;/sup&gt; ± 1.61</td>
</tr>
<tr>
<td>0.2</td>
<td>13</td>
<td>36.97 ± 2.74</td>
<td>10</td>
<td>36.23 &lt;sup&gt;ab&lt;/sup&gt; ± 3.45</td>
</tr>
<tr>
<td>0.4</td>
<td>12</td>
<td>35.47 ± 2.19</td>
<td>13</td>
<td>34.89 &lt;sup&gt;b&lt;/sup&gt; ± 3.18</td>
</tr>
<tr>
<td>Control</td>
<td>13</td>
<td>9.69 ± 0.48</td>
<td>12</td>
<td>9.50 ± 0.52</td>
</tr>
<tr>
<td>0.2</td>
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<td>9.62 ± 0.65</td>
<td>8</td>
<td>9.62 ± 0.51</td>
</tr>
<tr>
<td>0.4</td>
<td>12</td>
<td>9.75 ± 0.62</td>
<td>13</td>
<td>9.61 ± 0.51</td>
</tr>
<tr>
<td>Control</td>
<td>14</td>
<td>71.99 ± 10.55</td>
<td>12</td>
<td>63.44 ± 13.29</td>
</tr>
<tr>
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<td>72.93 ± 9.65</td>
<td>9</td>
<td>71.86 ± 15.22</td>
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<tr>
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<td>11</td>
<td>66.95 ± 7.61</td>
<td>13</td>
<td>61.45 ± 10.31</td>
</tr>
</tbody>
</table>

* Means for the same column without common letters are significantly different (P < 0.05)
* Fit of the model (one way ANOVA): R² = 0.16, P = 0.05 (egg weight at day 5 of heat stress); R² = 0.18, P = 0.05 (eggshell thickness at day 3 of heat stress).

Heat stress in this study seems to have no effect on shell strength, shell deformation, yolk color and HU. SAFFAR and ROSE (2002) showed that there were negative linear regressions between egg shell thickness, shell deformation and increasing ambient temperature. However, there was no statistically significant effect of temperature on HU. This is in agreement with WILLIAM (1992), who showed that HU is not greatly influenced by environment, even heat stress. The most important factor is the age of the hens.

In the present studies, however, egg weight showed no consistent response to heat stress or NaCl supplementation. While egg weight of the 0.2% NaCl group declined at day 3 of heat stress to 65.3 g, and increased again to the level of the before at day 7 of heat stress (68.9 g), there was neither a response to heat stress in the control nor in the 0.4% NaCl group. Therefore, the significantly lower egg weight of the 0.2% NaCl group at day 5 of the heat stress can not be considered as reliable. The incidence and duration of heat stress was probably not sufficient to influence egg weight. A decrease of egg weight due to high temperature has been reported by Wilson (1949), EMERY et al. (1984) and Warren (1939).

The present results showed that eggshell thickness seem to be not affected by heat stress. This finding is in contrast to EMERY et al. (1984), who showed that with cyclic temperature from 21.1 and 37.7°C (mean, 29.4°C) for 2 weeks, eggshell thickness was significantly reduced. WILSON (1949) revealed that eggshell thickness was reduced by ambient temperature in excess of 26.46°C. Above 34°C, this decrease was more noticeable. The differ-
ent results between present study and previous results may be due to intensity and the time of heat stress. Higher eggshell thickness was found in birds receiving normal drinking water as compared to birds receiving 0.4% NaCl on 3rd day of heat stress. This finding was also shown in eggshell deformation at day 3 of heat stress. When egg weight and eggshell thickness were considered, there was a weak effect of NaCl supplementation and heat stress on these parameters.

In conclusion, heat stress increased water consumption, water: feed ratio and body temperature of laying hens while feed intake, egg production, egg weight, body weight, eggshell thickness, eggshell strength, egg deformation, yolk color and HU seem to be not affected significantly.

In conclusion, the results of the present experiment indicate that cyclic temperature used represents a mild heat stress, which clearly increased water intake, water: feed ratio and deep body temperature of the hens. Duration and intensity of heat stress were not severe enough to produce consistent effects on feed intake and egg production. A beneficial effect of 0.4% NaCl was indicated by a lower body temperature under heat stress. More positive effects of NaCl supplementation in drinking water are expected under higher and continuous heat stress.

To what extent the beneficial effects of NaCl in drinking water results in increasing water intake as such and the supplementation of other minerals have still to be elucidated.

Summary

The objective of this study was to study the responses of laying hens to cyclic heat stress and effect of increasing water intake of laying hens through NaCl supplementation in the drinking water on body weight, body temperature and productivity traits under heat challenge. A total of 48 hens were kept in environmental controlled chambers and randomly allocated to three experimental groups of 16 hens each. These groups were given 0, 0.2 and 0.4% NaCl in the drinking water during cyclic heat stress. The room temperature was constant at 21 ± 1°C for one week before heat stress. During heat stress, temperature was cycled from 21 ± 1°C to 34 ± 1°C (from 9 to 22 o'clock) for 7 days, and then returned to 21 ± 1°C for one week.

The result showed that heat stress increased water consumption, water: feed ratio and body temperature of laying hens while feed intake, egg production, egg weight, body weight, eggshell thickness, eggshell strength, egg deformation, yolk color and HU were not affected. NaCl supplementation significantly increased water intake and water: feed ratio as compared to control group. NaCl supplementation (0.2 and 0.4%) reduced feed intake and tendentiously decreased egg out put during heat stress period, but after heat stress the laying rate reached to the pre-heat stress level in the both treatments. The control birds, in contrast, did not reduce laying rate and feed consumption during heat stress, but laying rate declined in the period after heat stress. This effect was explained by insufficient increase water consumption of the control birds in response to heat stress.

Key words

Layer, sodium chloride, heat stress, water intake, feed intake, egg quality
gov.on.ca/english/livestock/poultry/facts/88-111.htm


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