EFFECTS OF CHROMIUM AND MANGANESE ON PERFORMANCE, EGG QUALITY AND SERUM LIPID LEVELS OF JAPANESE QUAIL EXPOSED TO HEAT STRESS

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Abstract
This study was performed to investigate the effects of chromium and manganese supplementation on performance, interior and exterior egg quality and blood lipids of laying quail exposed to heat stress. Two hundred and fifty two, eight weeks old Japanese quail were assigned into seven groups with three replicates containing 12 birds in each. Quail in control (thermo-neutral and heat stress) groups were fed basal diets and the treatment groups were fed basal diets supplemented with 20 mg/kg Cr, 60 mg/kg Mn, 120 mg/kg Mn, 20 mg/kg Cr+60 mg/kg Mn and 20 mg/kg Cr+120 mg/kg Mn for eight weeks.

Heat stress reduced food consumption, which was increased in the treatment groups except 20 mg Cr supplemented group (p<0.05). Supplementation of 20 mg/kg Cr had no effect on decreased egg weight whereas Mn, and Cr+Mn improved egg weight (p<0.001). Supplementation of 20 mg/kg Cr and 120 mg/kg Mn increased the specific gravity of the egg (p<0.01). Heat stress also altered the eggshell thickness, which was increased by the supplementation of Cr, both levels of Mn and Cr+Mn combination. Chromium, both levels of Mn and Cr+Mn combination reduced the elevated total cholesterol levels (p<0.01), but no change was observed in HDL-C level in heat stress control group but the HDL-C levels were increased in treatment groups.

In conclusion, supplementation of 20 mg/kg Cr had limited effects on exterior egg quality but 120 mg/kg Mn supplementation to the diets of heat distressed laying quail improved egg quality and both Cr and Mn supplementation improved the altered lipid parameters.

Key words: Chromium, egg quality, lipids, manganese, quail.

Introduction
Environmental stressors exert their effects directly or indirectly on the productive performance and the well-being of the domestic animals including poultry species (De Basilio et al., 2002). High ambient temperatures, above the zone of thermo-neutrality for domestic fowl have deleterious effects on body weight, food consumption, feed efficiency, egg production and eggshell quality (Bollengier-Lee et al., 1998; Abu-Dieyeh, 2006b; Kocaman et al., 2006; Ramnath et al., 2007). It has been shown that heat stress causes the alterations in serum lipids (Dabbert et al., 1996; Sands and Smith, 2002).

Minerals have been recognized as essential nutrients for growth and reproductive performance of poultry. Addition of some macro minerals, vitamins, chemical compounds into diet or water, and acclimation of birds to heat besides the improvement of management techniques have been studied to reduce the adverse effects of heat stress for many years (Keskin and Durgun, 1997; Bollengier-Lee et al., 1998; Abu-Dieyeh, 2006b; Kocaman et al., 2006; Ramnath et al., 2007). It has been shown that heat stress causes the alterations in serum lipids (Dabbert et al., 1996; Sands and Smith, 2002).

Investigations have been performed on supplementation of trace minerals such as trivalent chromium (Cr) and manganese (Mn) to the diets of heat-distressed poultry species (Sands and Smith, 1999; Amatya et al. 2004; Gültekin, 2007) to prevent stress-induced losses of these minerals (Mertz, 1993; Moonsie-Shageer and Mowat, 1993). Supplementation of Cr to quail diets (Gültekin, 2007) and supplementation of Mn and Cr separately to diets of broilers (Sands and Smith, 1999; 2002) diminished the negative effects of the heat stress. However, to the authors’ knowledge there is no study investigating the effects of supplementation of Cr, Mn and their combination in heat-distressed quail. Therefore, this study was performed to investigate the effects of supplemental Cr, Mn and
Cr+Mn on food consumption, feed efficiency, body weight, egg production, interior and exterior egg quality, and serum lipids in heat distressed laying quail.

Material and Methods

Animals and management

Two hundred and fifty two, eight weeks old Japanese quail (Coturnix coturnix japonica) were used in the study. The birds were weighed to provide an equal body weight in all groups at the beginning of the study, and then they were assigned into seven groups with three replicates containing 12 birds in each after one week of adaptation. First and second groups were kept as thermoneutral and heat stress controls. The temperature was set to 19.33±1.4°C for thermo-neutral control group and 31.39±1.76°C for heat stress control and treatment groups. The humidity was determined as 51.88±6.02 and 83.61±7.47 % in the rooms that the thermo-neutral and heat stress controls placed respectively. The quail hens in both control groups received the commercial basal diets containing 2820 ME kcal/kg and 17.50 % CP. The quail in treatment groups were fed basal diets supplemented with 20 mg/kg Cr (CrCl3.6H2O), 60 and 120 mg/kg Mn (MnSO4.H2O), 20 mg/kg Cr + 60 mg/kg Mn and 20 mg/kg Cr + 120 mg/kg Mn for eight weeks. Birds were reared in cages on a 17 hour lighting schedule. Food and water were supplied ad libitum throughout the experiment.

Sample collection and analyses

Birds were weighed at the beginning and end of the study. Egg production was recorded daily, egg weight and food consumption were recorded weekly intervals. Feed efficiency was calculated by determining the amount of food consumed per kg of egg. Ten eggs from each group were collected in the middle and at the end of the study to determine interior and exterior egg quality. The egg quality parameter were expressed as the mean of two samplings. Specific gravity of a whole egg (g/cm³) was measured on the same day of egg collection by the method of Archimedes’s (Thompson and Hamilton, 1982; Hempe et al., 1988). The other egg quality parameters were measured 24 h later. Eggshell thickness was determined by the mean of measurements taken from three different sides of the shell. Albumen and yolk indexes and Haugh unit were calculated (Wells, 1968). The color of the egg yolk was determined from the color scale (Roche, Sweden).

At the end of the experiment, 12 blood samples were collected from each group and sera were separated by centrifugation at 1300 g after one hour incubation at room temperature, and stored at -20°C until analysis. Sera were analyzed for serum triglycerides, total cholesterol and high density lipoprotein-cholesterol (HDL-C) with a Shimadzu UV 1208 spectrophotometer using commercial kits (Biolabo, French).

Statistical analyses

Statistical analyses of data were performed by SPSS 9.0 version for Windows. One-way analysis of variance (ANOVA) was used for the differences between groups. When the F values were significant, the Duncan’s Multiple Range Test was performed. Data were expressed as means ± SEMs.

Results

Heat stress and supplementation of either Cr or Mn and their combination had no effects on body weigh, egg production, feed efficiency, Haugh unit, albumen and egg yolk indexes and egg yolk color. Heat stress caused reductions in food consumption (P<0.05). The reduced food consumption was increased in the treatment groups except 20 mg Cr supplemented group. Egg weight was decreased by heat stress. Supplementation of 20 mg/kg Cr had no effect on decreased egg weight whereas Mn, and both of the Cr + Mn combinations improved egg weight (P<0.001). The reduced specific gravity of the egg with heat stress increased with 20 mg/kg Cr and 120 mg/kg Mn supplementation (P<0.01). Heat stress also altered the eggshell thickness, which was increased by the supplementation of Cr, both levels of Mn, and both of the Cr + Mn combinations (P<0.05).

The serum triglycerides was not influenced by either heat stress or the treatments whereas Cr, both levels of Mn and both of the Cr + Mn combinations reduced the elevated total cholesterol levels due to heat stress (P<0.01). No change was observed in HDL-C level in heat stress control group but the HDL-C levels were increased by all treatments with the exception of 20 mg/kg Cr +120 mg/kg Mn combination (P<0.01) (Table 1).

Discussion

It is well known that high environmental temperature adversely affects production of animals including poultry species. In the present study, heat stress suppressed the feed intake significantly but body weight slightly. The reduction in food intake is consistent with the result of previous studies conducted on broilers (Naseem et al., 2005; Abu-Dieyeh, 2006a,b), laying hens (Marsden et al., 1987; Yardibi and Türkay, 2008) and laying quail (Keskin...
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and Durgun, 1997; Özbey et al., 2006; Gültekin, 2007). The adverse effects of heat stress on feed efficiency was reported in some studies (Abu-Dieyeh, 2006 a,b; Kocaman et al., 2006; Özbey et al., 2006) whereas in the current study, high temperature did not affect feed efficiency in consistent with the results obtained by Deaton et al. (1984).

Investigations have been performed on supplementation of trace minerals including Cr (Amatya et al. 2004; Gültekin, 2007) and Mn (Sands and Smith, 1999) to the diets of heat stressed poultry species to minimize stress-induced losses because the effects of Cr are more marked in the animals under stress (Mertz, 1993; Moonsie-Shageer and Mowat, 1993). Sands and Smith (1999) have reported that supplementation of Cr improves weight gain without affecting feed intake whereas Mn supplementation had no beneficial effect on heat-stressed broilers. In another broiler study conducted by Amatya et al. (2004), Cr supplementation improved weight gain, feed efficiency and nutrient utilization. In a laying quail study (Gültekin, 2007), Cr supplementation had no effect on body weight, body composition and egg production under heat stress. In the present study, either supplementation of Cr and Mn separately or their combination had no effects on body weight, feed efficiency. However, the reduced food consumption was increased by all the treatments except 20 mg Cr supplementation.

Heat stress reduced egg production in several studies (Donoghue et al., 1989; Bollengier-Lee et al., 1998; Yardibi and Türkay, 2008). However, Roland et al. (1996) found no reduction in egg production in heat-stressed laying hens. In this study, although statistically not significant, egg production was slightly reduced. This slight reduction in egg production may be due to either suppressed food consumption or heat stress per se (Abu-Dieyeh, 2006b). The reproductive decline may be also mediated by disturbance in ovulation due to the reduced release of luteinizing hormone from hypothalamus (Donoghue et al. 1989). In the present study, either supplementation of Cr and Mn separately or their combination had no effects on egg production.

At high temperatures, birds regulate heat loss through evaporation of water from their lungs, which results in a decline in blood pCO₂ and HCO₃⁻ with the increasing pH in response to heat stress inducing nutritional requirements for HCO₃⁻. The acid-base imbalance called respiratory alkalosis alters Na:Cl ratio thus reduces food consumption (Keskin and Durgun, 1997; Naseem et al., 2005). Calcium is the primarily component of eggshell and the specific gravity is directly related to dietary Ca level (Roland et al., 1996). The reduced egg weight and the alteration in shell thickness and specific gravity may result from the insufficient intake of nutrients including minerals such as calcium (Ca) due to reduced food consumption or insufficient HCO₃⁻ level to form CaCO₃ due to excess expiration of CO₂ or both. Confirming the previous studies, the reduced egg weight (Marsden et al., 1987; Bollengier-Lee et al., 1998), eggshell thickness (Yardibi and Türkay, 2008) and specific gravity of the whole egg reflects the detrimental effects of heat stress on eggshell quality. Mabe et al. (2003), suggested that organic and inorganic sources of combined Zn, Mn, and Cu do not significantly influence eggshell material deposited during shell formation but improve elastic modulus of the eggs. In this study, supplementation of 20 mg/kg Cr had no effect on decreased egg weight whereas Mn, and both of the Cr and Mn combinations improved egg weight. The reduced specific gravity of the egg with heat stress increased with 20 mg/kg Cr and 120 mg/kg Mn supplementation. The altered eggshell thickness was increased by the supplementation of Cr, both levels of Mn, and both of the Cr and Mn combinations. On the other hand, either supplementation of Cr and Mn separately or their combination had no effects on interior egg quality.

In the study of John et al. (1977), heat stress did not affect serum cholesterol in pigeon. However, in the present study, heat stress increased serum cholesterol while no effect of temperature was determined on serum triglycerides. In contrast, Sands and Smith (2002) reported significant effect of temperature on triglycerides but they found no effect of Cr supplementation on serum concentrations of NEFA, triglycerides, total- and HDL-cholesterol while NEFA level was reduced by Mn supplementation. On the other hand, in this study supplementation of Cr, Mn and their combination reduced the increased serum cholesterol levels consistent with the results of a broiler study of Akilli (2006) and a laying quail study of Gültekin (2007) who reported that total cholesterol due to heat stress were decreased by supplemental Cr. These authors found that the elevated serum triglycerides were also reduced by Cr supplementation. Supplementation of Cr to heat-distressed quail diets increased the serum HDL (Gültekin, 2007). Similarly, in the present study, the increases in HDL levels regardless of heat stress is consistent with the results of the studies in those HDL was increased by Cr in laying hens (Kolsuz and Uyanık, 2002) and in fattening quail (Uyanık et al., 2005), and Mn (Sands and Smith, 2002; Uyanık et al., 2004) in broilers.

The results of this study have shown that heat stress reduced the food consumption, egg weight, eggshell quality, and increased serum total cholesterol levels. Supplementation of especially 120 mg/kg Mn to the diets of heat-distressed laying quail improved exterior egg quality whereas 20 mg/kg Cr had limited positive effects. Supplementation Cr, Mn and Cr+Mn combination improved the altered lipid parameters.
References


Table 1. Effects of Cr, Mn and Cr+Mn Supplementation on Performance, Egg Quality and Serum Lipid Parameters in Heat Distressed Laying Quail

<table>
<thead>
<tr>
<th>Heat stress</th>
<th>Thermoneutral Control</th>
<th>Control</th>
<th>20 mg/kg Cr</th>
<th>60 mg/kg Mn</th>
<th>120 mg/kg Mn</th>
<th>20 mg/kg Cr + 60 mg/kg Mn</th>
<th>20 mg/kg Cr + 120 mg/kg Mn</th>
<th>P</th>
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<tbody>
<tr>
<td><strong>Performance parameters (n=12)</strong></td>
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<tr>
<td>Initial body weight (g)</td>
<td>231.30±4.36</td>
<td>226.21±4.02</td>
<td>223.72±3.76</td>
<td>233.60±4.17</td>
<td>237.80±4.39</td>
<td>238.03±3.76</td>
<td>233.60±4.18</td>
<td>-</td>
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<tr>
<td>Final body weight (g)</td>
<td>221.86±6.07</td>
<td>212.71±7.94</td>
<td>207.29±5.71</td>
<td>210.36±5.71</td>
<td>214.67±5.28</td>
<td>207.64±5.72</td>
<td>215.23±6.93</td>
<td>-</td>
</tr>
<tr>
<td>Egg production (%)</td>
<td>85.74±2.53</td>
<td>77.58±1.25</td>
<td>83.18±2.06</td>
<td>79.02±2.97</td>
<td>81.37±2.78</td>
<td>79.69±5.28</td>
<td>75.48±4.70</td>
<td>-</td>
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<tr>
<td>Food consumption (g/quail/day)</td>
<td>35.37±0.65a</td>
<td>27.63±0.46c</td>
<td>28.15±0.97ac</td>
<td>32.99±3.32ab</td>
<td>34.39±0.84a</td>
<td>31.64±2.07abc</td>
<td>34.25±0.94a *</td>
<td>-</td>
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<tr>
<td>Feed efficiency</td>
<td>3.52±0.07</td>
<td>3.27±0.03</td>
<td>3.19±0.08</td>
<td>3.69±0.41</td>
<td>3.62±0.12</td>
<td>3.42±0.13</td>
<td>3.99±0.29</td>
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<tr>
<td><strong>Egg quality parameters (n=10)</strong></td>
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<tr>
<td>Egg weight (g)</td>
<td>11.76±0.14a</td>
<td>10.89±0.10c</td>
<td>10.62±0.02c</td>
<td>11.33±0.14b</td>
<td>11.66±0.17ab</td>
<td>11.63±0.02ab</td>
<td>11.49±0.17ab ***</td>
<td>-</td>
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<tr>
<td>Specific gravity (g/cm³)</td>
<td>1.070±0.001a</td>
<td>1.063±0.001b</td>
<td>1.067±0.0008ab</td>
<td>1.064±0.001b</td>
<td>1.066±0.0009ab</td>
<td>1.065±0.0001b</td>
<td>1.063±0.001b **</td>
<td>-</td>
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<tr>
<td>Shell thickness (mm x 10⁻²)</td>
<td>21.53±0.56a</td>
<td>19.96±0.45c</td>
<td>20.90±0.25ab</td>
<td>20.54±0.25ab</td>
<td>21.36±0.27ab</td>
<td>20.73±0.23ab</td>
<td>20.23±0.28bc</td>
<td>*</td>
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<tr>
<td>Haugh unit</td>
<td>87.22±0.57</td>
<td>88.52±0.72</td>
<td>88.03±0.48</td>
<td>88.45±0.97</td>
<td>87.62±0.97</td>
<td>86.65±1.14</td>
<td>87.08±0.86</td>
<td>-</td>
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<tr>
<td>Albumen index</td>
<td>41.0±0.58</td>
<td>51.90±1.30</td>
<td>14.04±0.53</td>
<td>14.78±0.63</td>
<td>14.04±0.36</td>
<td>13.93±0.43</td>
<td>14.26±0.39</td>
<td>-</td>
</tr>
<tr>
<td>Yolk index</td>
<td>51.85±0.99</td>
<td>51.20±1.93</td>
<td>50.06±0.48</td>
<td>52.03±0.80</td>
<td>51.05±0.37</td>
<td>52.03±0.61</td>
<td>52.14±0.39</td>
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<tr>
<td>Color</td>
<td>8.00±0.18</td>
<td>7.55±0.33</td>
<td>7.58±0.29</td>
<td>7.50±0.11</td>
<td>8.07±0.28</td>
<td>7.25±0.16</td>
<td>7.94±0.29</td>
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<td><strong>Serum lipide (n=12)</strong></td>
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<td>Triglycerides (mg/dL)</td>
<td>836.30±32.57</td>
<td>849.19±42.57</td>
<td>809.00±83.88</td>
<td>734.12±52.29</td>
<td>782.49±54.85</td>
<td>739.77±87.38</td>
<td>717.98±55.84</td>
<td>-</td>
</tr>
<tr>
<td>Total cholesterol (mg/dL)</td>
<td>162.88±11.09b</td>
<td>209.65±9.90a</td>
<td>158.85±6.34b</td>
<td>160.01±10.80b</td>
<td>163.04±12.22b</td>
<td>176.08±10.68b</td>
<td>151.29±13.39b **</td>
<td>-</td>
</tr>
<tr>
<td>HDL (mg/dL)</td>
<td>47.10±2.46c</td>
<td>49.38±3.33ac</td>
<td>61.19±3.61a</td>
<td>61.48±4.19a</td>
<td>67.84±3.49a</td>
<td>59.23±5.46ab</td>
<td>48.94±5.54bc **</td>
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</table>

*: Not significant, *P<0.05, **P<0.01, ***P<0.001

**The values within the same row with different superscript differ significantly.