The effects of increasing levels of dietary garlic bulb on growth performance, systolic blood pressure, hematology, and ascites syndrome in broiler chickens

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ABSTRACT The effects of dietary garlic bulb were studied separately on hematological parameters, ascites incidence, and growth performance of an ascites susceptible broiler hybrid under both standard temperature conditions (STC) and cold temperature conditions (CTC). A total of 336 one-day-old male broiler chickens were allocated to 4 experimental groups with 4 replicates of 21 birds each under STC. In addition, the same grouping with another 336 birds was used for CTC. Under CTC, the birds were exposed to cold temperatures for induction of ascites. Experimental groups were defined by the inclusion of 0 (control), 5, 10 or 15 g/kg garlic bulbs in the diets under both STC and CTC. Growth performance, systolic blood pressure (as a measure of systemic arterial blood pressure), physiological and biochemical parameters, as well as ascites indices (right ventricle [RV], total ventricle [TV] weights, and RV/TV) were evaluated. Systolic blood pressure was determined using an indirect method with a sphygmomanometer, a pediatric cuff, and a Doppler device. The final body weight decreased quadratically \( (P = 0.003) \), with increasing garlic bulb levels in the diets under STC. The feed conversion ratio showed no significant differences among all groups under both STC and CTC. No significant differences were observed in total mortality and ascites-related mortality in all groups under STC, although total mortality (L: \( P = 0.01; \) Q: \( P = 0.001) \) and ascites-related mortality (L: \( P = 0.007; \) Q: \( P = 0.001) \) were significantly different among the diets under CTC. Under STC, the systolic blood pressure, packed cell volume, hemoglobin, RV, TV, and RV/TV did not vary significantly among the diets. However, red blood cell count and erythrocyte osmotic fragility decreased linearly \( (P < 0.005) \) with increasing garlic levels in the diets under STC. Under CTC, the systolic blood pressure, packed cell volume, red blood cell count, and erythrocyte osmotic fragility decreased \( (P < 0.05) \) with increasing garlic levels. It is concluded that the inclusion of 5 g/kg garlic bulb in susceptible broiler chicken diets has a systemic anti-hypertensive effect and could decrease ascites incidence without impairing broiler chicken performance.

Key words: ascites, garlic bulbs, systolic blood pressure, hematological parameters, broiler performance

INTRODUCTION

Genetic and nutritional improvements have increased the growth rate and decreased the feed conversion ratio of modern commercial broiler chickens (Baghbanzadeh and Decuypere, 2008; Hassanzadeh, 2010). This resulted in a situation where, by the 1950s, a live body weight of commercial broiler chickens of 3 kg at 14 weeks of age was attained (Havenstein et al., 1994). The same live body weight can be achieved today at only 37 days of age (Shariatmadari, 2012). These developments however make broilers highly susceptible to metabolic disorders (Julian, 1993, 2005; Tona et al., 2005). Ascites syndrome is one of the most important metabolic disorders in modern broiler chickens (Druyan et al., 2009; Gupta, 2011) worldwide (Wiedman et al., 2013) and results in mortality rates of up to 8% in broiler flocks (and 20 to 30% in heavy flocks) (Pakdel et al., 2002). The highest incidence of ascites syndrome has been observed in fast growing birds (Arce-Menocal et al., 2009). Under normal conditions, Tona et al. (2005) reported that nearly 50% of noninfectious mortality was due to ascites in broiler chickens. The peak of ascites-related mortality occurs at the end of the growing period, which is very important in terms of economic losses (Tona et al., 2005;
Hassanzadeh, 2009). This syndrome is caused by the imbalance between oxygen delivery and oxygen demands, resulting in hypoxemia (Baghbazaddeh and Decuypere, 2008; Druyan et al., 2009; Hassanzadeh, 2009, 2010). Hypoxemia increases pulmonary arterial pressure (PAP) and consequently causes hypertension of the RV (Julian, 1993; Wideman et al., 2010). Whilst this increase in PAP is well established in ascites susceptible broilers (Wideman et al., 2010; Wideman and Tackett, 2000), an increase in mean systemic arterial pressure (MAP) has been reported in cool temperature stresses broilers (Wideman and Tackett, 2000). We investigate here the potential role of systolic blood pressure reduction using a herbal anti-hypertensive (garlic) for control of broilers ascites.

Genetic, physiological, environmental, and nutritional factors affect the incidence of ascites syndrome (Balog et al., 2003; Gupta, 2011). Environmental factors such as cold temperatures increase metabolic activity and thus oxygen demands. High oxygen demand in turn increases the incidence of ascites. Ascites-related mortality is caused by pulmonary hypertension; therefore, any factor that reduces blood pressure, especially PAP, may help to control ascites (Wideman, 2000, 2001; Wideman et al., 2010). Nutritional approaches can be used as tools to reduce ascites-related mortality (Baghbazaddeh and Decuypere, 2008; Rajani et al., 2011). The possible effect of lowering systemic arterial blood pressure, measured by systolic blood pressure, in the control of broilers ascites is not clear.

Garlic has been used as a medicinal plant for more than 4000 years (Corzo-Matinez et al., 2007). A close relationship has been shown in epidemiological, clinical, and preclinical studies between feeding habits, including garlic intake, and the incidence of cardiovascular diseases in humans (Amagase et al., 2001; Bozin et al., 2008). The anti-hypertensive, antimicrobial, and antioxidant properties of garlic in human and animal studies (Chen et al., 2008) together with its positive effect on several cardiovascular risk factors have been confirmed (Rana et al., 2011). The aqueous extract of garlic has MAP anti-hypertensive effects in mammalian species (Al-Qattan et al., 1999).

The use of regular garlic (Allium sativum) and wild garlic (Allium ursinum) in rat diets significantly decreases systolic blood pressure compared to a control group (Preuss et al., 2001). Garlic powder has considerable effects on the production performance of broiler chickens (Pourali et al., 2010). The use of garlic as a feed additive in broiler diets has been shown to improve feed conversion ratios and to reduce mortality (Tollba and Hassan, 2003) in contrast to other studies showing that garlic paste had no effect on feed intake, body weight gain, or feed efficiency in broiler chickens (Horton et al., 1991; Choi et al., 2010).

Several reports have documented that garlic reduces blood pressure in humans and experimental animals such as rats and dogs (Khalid, 2001; Preuss et al., 2001; Rivlin, 2001; Elkayam et al., 2003; Williams et al., 2004), but the effects of garlic on systolic blood pressure in broiler chickens remains unknown.

Up to now, no studies have reported the effects of garlic bulb on systolic blood pressure and ascites incidence in broiler chickens. Therefore, the present study was conducted to provide clear insights regarding the effects of the inclusion of increasing levels of garlic bulb in the diet on systolic blood pressure, ascites incidence, hematological parameters, and growth performance in broiler chickens reared under both standard and cold-temperature conditions.

**MATERIALS AND METHODS**

**Garlic Bulb**

Garlic bulbs (Allium sativum) including cloves and hulls, were obtained from a garlic farm (Hamedan province, Iran) and were kept in the dark at room temperature to use as fed in broiler diets. Garlic bulb was ground with corn and soybean meal by a hammer mill. The chemical composition of garlic bulb was determined for dry matter, crude protein, ether extract, starch, ash, calcium, phosphorus, and other minerals (K, Na, Cl, Mg, Fe, Mn, Cu and Zn) based on the Association of Official Analytical Chemists (AOAC, 1990) methods with codes: 934.01, 976.05, 920.39, 920.40, 942.05, 935.13, 965.17 and 968.08, respectively. Total phenolics and tannin concentrations in the garlic bulb were measured by Folin-Ciocalteu reagent (Terrill et al., 1992).

**Birds and Housing**

This research was conducted using 2 separate experiments. The experimental protocols were approved by the Animal Care Committee of Tarbiat Modares University (Tehran, Iran). Experiments were conducted based on the Arian strain management guide (Corporation Support of Animal Affairs, 2008) under both STC and CTC. Under STC, a total of 336 one-day-old male broiler chickens (Arian 386, from a local hatchery in Babolkenar, Iran) were allocated to 4 experimental diets with 4 replicates of 21 birds each. Treatments consisted of the inclusion of the garlic bulb (cloves and hulls) at levels of 0 g/kg (GB0), 5 g/kg (GB5), 10 g/kg (GB10), or 15 g/kg (GB15) based on DM in diets. Although the birds under CTC were subjected to a cold temperature stress (induced ascites) schedule, the number of birds, treatments, and replications were similar to those under STC. The inclusion of amounts of 5, 10, or 15 g/kg garlic bulb in diets based on DM were equivalent to the amounts 10.7, 21.4 or 32.1 g/kg garlic bulb as fed.

Diets were formulated to meet the nutrient requirements of broiler chickens based on the recommendations of Arian breeders (Arian broiler chicken management guide; Corporation Support of Animal Affairs, 2008). Feed (as mash) and water were offered ad libitum throughout the studies. Ingredients and composition of
per pen (8 birds per treatment) were randomly se-

Systolic Blood Pressure

the total and ascites-related mortality rates.

made for feed body weight gain, conversion ratio, and 

measured weekly and cumulatively. Calculations were 

the dead broilers. Feed intake and body weight were 

mined in order to calculate the RV/TV weight ratio in 

agnosis of ascites syndrome were water belly and RV 

tality and ascites-related mortality. The criteria for di-

Measurement of Mortality and Performance

The birds were monitored 4 times daily for total morta-

Aliment and ascites-related mortality. The criteria for dia-

nosis of ascites syndrome were water belly and RV and 

and 0 h darkness until the broilers were 3-day-old, fol-

At the end of each experiment, 2 conscious birds 

the starter (1 to 14 days of age), grower (15 to 28 days of age), and finisher (29 to 42 days of age) diets are shown in Table 1. Under STC, the initial 32°C room temperature was gradually reduced to 24°C by the third week and remained constant until the end of the experiment. Under CTC, cold stress was used to trigger ascites and the broilers were exposed to a temperature of 32°C at one-day-old, with stepwise reductions to 25°C ± 1°C, 20°C ± 1°C and 15°C ± 1°C on days 7, 14, and 21, respectively. At this point, a temperature of 15°C ± 1°C was maintained until the end of the experiment (Luger et al., 2001). The initial lighting program was 24 h light and 0 h darkness until the broilers were 3-day-old, followed by 23 h light and 1 h darkness to the end of both experiments.

Systolic Blood Pressure

At the end of each experiment, 2 conscious birds per pen (8 birds per treatment) were randomly se-

lected, and systolic blood pressure was measured on the 

brachial artery. Systolic blood pressure was determined 

using an indirect method with a sphygmomanometer 

(Riester, no. 1440 Babyphon, Jungingen, Germany), a 

pediatric cuff (Reister, Nylon-Velcro, infant circumfer-

ence 5 to 7.5 cm), ultrasound transmission gel (Shafa-

donic, Tehran, Iran), and a Pocket Doppler Model 841-A 

(Park Medical Electronics Inc., NV) device equipped 

with a 8.2 MHz probe (Lichtenberger, 2005). Briefly, 

the birds were placed in a dorsal recumbent position 

on a table. The cuff was snugly wrapped around the 

distal humerus and was secured. The ultrasound gel 

was placed on the probe and around the elbow joint. 

Thereafter the probe was placed on the articulation of 

the distal humerus with the proximal ulna and radius. 

The bird was allowed a couple of minutes to acclimatize 

to the experimental environment. The cuff bladder was 

inflated to 300 mm Hg to cause cessation of blood flow, 

and then slowly deflated (about 2 to 5 mm Hg/s) un-

til the first pulsatile sound was heard from the Pocket 

Doppler device. The pressure on the sphygmomanome-

ter was recorded as the systolic blood pressure at the 

end of experiments (Varmaghany et al., 2013).

Hemotological Parameters

The blood samples from 3 birds per pen (12 birds per group) were randomly taken from a wing vein at the end of the experiments at 42 days of age. Packed cell volume was determined in whole blood samples by centrifugation of microhematocrit capillary tubes at 15,500 × g for 5 min (Jain, 1986). Red blood cells
were counted in a hemocytometer chamber using Natt and Herrick’s solution to obtain a 1 to 200 blood dilution (Maxwell et al., 1986). The concentration of hemoglobin was determined based on the cyanmethemoglobin method using a commercial kit (ZiestChem, Tehran, Iran). Erythrocyte osmotic fragility was determined in whole blood samples as a criterion of red blood cells membrane fluidity by Dacie’s method (Buffenstein et al., 2001), with some modifications using a microplate reader (Awareness Technology Inc., Stat Fax 3200, FL).

Plasma was prepared by centrifugation (1,000 × g for 20 min) and was stored at −20°C until analysis (Tankson et al., 2002). Plasma triiodothyronine (T3) and thyroxine (T4) concentrations were analyzed by ELISA (Pishtaz Teb, Tehran, Iran).

**Ascites-Related Parameters**

Postmortem examinations were performed on all dead chickens during the experiments to diagnose ascites. Moreover, on day 42, a total of 40 birds per treatment (10 birds per pen) were randomly selected, euthanized, and used for RV/TV determination. Ascites-related mortality was diagnosed when accumulation of abdominal or pericardial fluid was observed, and the weight ratio of RV to TV (RV/TV) was higher than 0.29 (Julian et al., 1987; Julian, 2005). To calculate the RV/TV, the hearts were collected, and the pericardium, peripheral adipose tissues, and atria were trimmed. The left ventricle and RV were separated and their individual weights were measured on an analytical balance (Scaltec SBA41, Germany; precision 10⁻⁵ g), and the RV/TV was calculated (Julian, 2005).

**Statistical Analysis**

The pen was used as the experimental unit, and a one-way analysis of variance was performed using the GLM procedure with SAS software (SAS, 1990) in a completely randomized design. The means were compared by Duncan’s multiple range test (∗∗P < 0.01). Polynomial orthogonal contrasts were carried out for garlic bulb levels to investigate linear and quadratic trends.

**RESULTS**

**Chemical Composition of Garlic Bulbs**

The results indicated that the DM of garlic bulb was 467.8 g/kg as fed. The chemical composition of the garlic bulb was crude protein, 121.5 g/kg; ether extract, 7.8 g/kg; starch, 654.5 g/kg; ash, 59.00 g/kg; Ca, 8.86 g/kg; P, 2.89 g/kg; Na, 1.22 g/kg; K, 9.73 g/kg; Mg, 0.95 g/kg; Fe, 0.83 g/kg; Mn, 0.042 g/kg; Cu, 0.005 g/kg; and Zn, 0.036 g/kg DM. The total phenolics and tannin concentrations of garlic bulb were 12.4 and 2.9 g/kg DM, respectively.

**Growth Performance**

The growth performance of the broiler chickens reared under STC is shown in Table 2. The initial live body weight was similar in all groups, but the final live body weight and body weight gain at 1 to 42 d increased in quadratic manner with increasing garlic bulb levels in the diets (∗∗P < 0.01). Feeding of GB at the highest level (15 g/kg) decreased final body weight and 1 to 42 d body weight gain (∗∗P < 0.05). The feed intake was linearly decreased (∗∗P < 0.05) with increasing of garlic bulb levels in the diets at 1 to 42 days of age. The feed conversion ratio was similar among treatments. In addition, no significant differences were found in the total mortality and mortality due to ascites between groups.

The growth performance of broiler chickens reared under CTC is shown in Table 3. The results illustrate that initial and final body weight, body weight gain, feed intake, and feed conversion ratio were similar among groups at the end of the experiment. Feeding GB decreased the ascites related and total mortality (∗∗P < 0.01), while mortality due to causes other than ascites was not influenced by feeding GB.

**Hematological and Ascites-Related Parameters**

The systolic blood pressure, packed cell volume (PCV), hemoglobin, RV, TV, and RV/TV did not significantly differ among treatments under STC. The concentration of hemoglobin was not influenced by the diets and was 9.64, 11.97, 9.36 and 10.67 g/dl for GB0, GB5, GB10, and GB15, respectively. Red blood cell count and erythrocyte osmotic fragility were linearly reduced (∗∗P < 0.05) with increasing levels of GB in the diets under STC (Table 4). The increase in GB levels up to 10 g/kg increased the plasma T₃ and T₄ concentrations and further GB level (15 g/kg) dramatically decreased these values (∗P < 0.05). In addition, the weights of TV did not significantly differ among the diets and were 9.77, 10.64, 10.32 and 10.43 g for GB0, GB5, GB10 and GB15, respectively.

Table 5 shows that the systolic blood pressure, packed cell volume, red blood cell count, and erythrocyte osmotic fragility decreased by feeding GB compared to the control (GB0) group (∗∗P < 0.05).

There were no further differences among the 5, 10 and 15 g/kg GB diets excepting the red blood cell count for which the lowest value related to the GB15 group, with significant differences between the control GB0 and GB10 groups. The concentration of hemoglobin for the diets containing 0, 5, 10, or 15 g/kg GB was 9.41, 10.00, 9.68 and 9.24 g/dl, respectively.
Table 2. Broiler chicken performance reared under standard temperature condition.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GB0†</th>
<th>GB5</th>
<th>GB10</th>
<th>GB15</th>
<th>SEM</th>
<th>P-Value</th>
<th>Contrast</th>
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</thead>
<tbody>
<tr>
<td>Body weight (g)</td>
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</tr>
<tr>
<td>1 day of age</td>
<td>41.78</td>
<td>41.54</td>
<td>41.42</td>
<td>41.42</td>
<td>0.10</td>
<td>0.600</td>
<td>0.229</td>
</tr>
<tr>
<td>42 day of age</td>
<td>2259a</td>
<td>2425a</td>
<td>2360a</td>
<td>2114b</td>
<td>39.33</td>
<td>0.011</td>
<td>0.071</td>
</tr>
<tr>
<td>Body weight gain (g/bird/day)</td>
<td></td>
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<tr>
<td>1–42 day of age</td>
<td>52.8a</td>
<td>56.8a</td>
<td>55.2a</td>
<td>49.3b</td>
<td>0.85</td>
<td>0.034</td>
<td>0.123</td>
</tr>
<tr>
<td>Feed intake (g/bird/day)</td>
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<tr>
<td>1–42 day of age</td>
<td>94.2</td>
<td>90.9</td>
<td>86.3</td>
<td>79.4</td>
<td>2.41</td>
<td>0.166</td>
<td>0.031</td>
</tr>
<tr>
<td>Mortality (No. of dead birds / No. of Total birds*100)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascites</td>
<td>5.9</td>
<td>3.6</td>
<td>3.6</td>
<td>5.9</td>
<td>0.972</td>
<td>0.723</td>
<td>0.998</td>
</tr>
<tr>
<td>Other cases</td>
<td>4.8</td>
<td>4.7</td>
<td>5.9</td>
<td>5.9</td>
<td>0.737</td>
<td>0.908</td>
<td>0.525</td>
</tr>
<tr>
<td>Total</td>
<td>10.7</td>
<td>8.3</td>
<td>9.5</td>
<td>11.8</td>
<td>1.220</td>
<td>0.794</td>
<td>0.694</td>
</tr>
</tbody>
</table>

†GB0, GB5, GB10, and GB15 diets contained 0 (control) 5, 10, or 15 g garlic/kg DM, respectively.

a–bMeans with different superscripts in each row are significantly (P ≤ 0.05).

Table 3. Broiler chicken performance reared under cold temperature condition.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GB0†</th>
<th>GB5</th>
<th>GB10</th>
<th>GB15</th>
<th>SEM</th>
<th>P-Value</th>
<th>Contrast</th>
</tr>
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<tbody>
<tr>
<td>Body weight (g)</td>
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</tr>
<tr>
<td>1 day of age</td>
<td>41.41</td>
<td>41.88</td>
<td>42.03</td>
<td>41.56</td>
<td>0.17</td>
<td>0.619</td>
<td>0.707</td>
</tr>
<tr>
<td>42 day of age</td>
<td>1901b</td>
<td>2079a</td>
<td>1877b</td>
<td>1899b</td>
<td>27.17</td>
<td>0.010</td>
<td>0.251</td>
</tr>
<tr>
<td>Body weight gain (g/bird/day)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1–42 day of age</td>
<td>44.3b</td>
<td>48.5a</td>
<td>43.7b</td>
<td>44.2b</td>
<td>0.64</td>
<td>0.01</td>
<td>0.249</td>
</tr>
<tr>
<td>Feed intake (g/bird/day)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1–42 day of age</td>
<td>94.7</td>
<td>92.8</td>
<td>94.2</td>
<td>88.2</td>
<td>1.86</td>
<td>0.636</td>
<td>0.316</td>
</tr>
<tr>
<td>Mortality (No. of dead birds / No. of Total birds*100)</td>
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<td></td>
<td></td>
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<td>0.908</td>
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<td>11.8</td>
<td>1.220</td>
<td>0.794</td>
<td>0.694</td>
</tr>
</tbody>
</table>

†GB0, GB5, GB10, and GB15 diets contained 0 (control) 5, 10, or 15 g garlic/kg DM, respectively.

a–bMeans with different superscripts in each row are significantly (P ≤ 0.05).

The T4 was decreased in the GB15 group compared to the GB5 group (P < 0.05), while the T3 was not influenced by the GB levels. Feeding GB significantly decreased the RV/TV compared to the control group (P < 0.05). The weights of TV were 9.71, 10.09, 9.67 and 10.76 g in treatments GB0, GB5, GB10, and GB15, respectively.

DISCUSSION

Chemical Composition of Garlic Bulb

The chemical composition of garlic is highly variable. Garlic bulbs have 760 g/kg cloves and 240 g/kg outer and inner husks (Qureshi et al., 1983a,b). The DM, crude protein, ether extract, and ash content of garlic bulbs have been reported as 343, 102, 6 and 15 g/kg as fed and for garlic husks 918, 131, 42 and 56 g/kg as fed (Bampidis et al., 2005), which differ from the results of the present study. The most likely reasons for the observed differences are concerned with the parts of tested garlic and the processing method used to yield garlic supplements.

Growth Performance

Under STC, the lowest final body weight was obtained by the birds fed diets containing 15 g/kg garlic bulb at the end of experiment (P < 0.005). High growth rate is the most important contributory factor for the incidence of ascites in broiler chickens (Julian, 1993; Luger et al., 2002; Baghbanzadeh and Decuypere, 2008; Arce-Menocal et al., 2009; Hassanzadeh, 2010). However, those broiler chickens which are fast growing tend to have pulmonary hypertension and ascites and begin to decrease body weight, finally showing retarded growth (Luger et al., 2001; Hassanzadeh, 2010). Higher (numerically) total mortality and ascites-related mortality was associated with lower body weight in broilers fed diets containing 15 g/kg garlic bulb. During
Table 4. Systolic blood pressure, hematological parameters, and ascites-related indices of broiler chickens reared under standard temperature at 42 days of age.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference ranges</th>
<th>GB0</th>
<th>GB5</th>
<th>GB10</th>
<th>GB15</th>
<th>SEM</th>
<th>P-Value</th>
<th>Linear</th>
<th>Quadratic</th>
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</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>151</td>
<td>118.5</td>
<td>105.75</td>
<td>108.25</td>
<td>105.00</td>
<td>2.939</td>
<td>0.364</td>
<td>0.167</td>
<td>0.422</td>
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<tr>
<td>Hematology</td>
<td></td>
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<tr>
<td>PCV (%)</td>
<td>29–48^1</td>
<td>35.87</td>
<td>31.10</td>
<td>32.47</td>
<td>33.00</td>
<td>1.016</td>
<td>0.429</td>
<td>0.366</td>
<td>0.254</td>
</tr>
<tr>
<td>RBC (10^6/μl)</td>
<td>3.2–3.8^1</td>
<td>3.24</td>
<td>2.94</td>
<td>2.86</td>
<td>2.81</td>
<td>0.074</td>
<td>0.169</td>
<td>0.043</td>
<td>0.393</td>
</tr>
<tr>
<td>EOF (%)</td>
<td>14.8^1</td>
<td>31.11</td>
<td>23.13</td>
<td>22.04</td>
<td>19.60</td>
<td>1.865</td>
<td>0.072</td>
<td>0.017</td>
<td>0.320</td>
</tr>
<tr>
<td>Thyroid hormones (ng/ml)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>1.7–2.6^1</td>
<td>3.04</td>
<td>3.89</td>
<td>4.05</td>
<td>2.54</td>
<td>0.284</td>
<td>0.192</td>
<td>0.579</td>
<td>0.044</td>
</tr>
<tr>
<td>T4</td>
<td>14–31.4^1</td>
<td>11.40</td>
<td>12.54</td>
<td>14.17</td>
<td>9.62</td>
<td>0.697</td>
<td>0.116</td>
<td>0.513</td>
<td>0.039</td>
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<tr>
<td>Ascites-related parameters</td>
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<tr>
<td>RV (g)</td>
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<tr>
<td>RV/TV</td>
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</tbody>
</table>

1GB0, GB5, GB10, and GB15 diets contained 0 (control) 5, 10, or 15 g garlic/kg DM, respectively.
3Sturkie (2000).
4Rajani et al. (2011).
5Julian et al. (1987).

Table 5. Systolic blood pressure, hematological parameters, and ascites-related indices of broiler chickens reared under cold temperature at 42 days of age.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference ranges</th>
<th>GB0</th>
<th>GB5</th>
<th>GB10</th>
<th>GB15</th>
<th>SEM</th>
<th>P-Value</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>151</td>
<td>134.25a</td>
<td>110.75b</td>
<td>110.00b</td>
<td>107.00b</td>
<td>3.995</td>
<td>0.035</td>
<td>0.013</td>
<td>0.131</td>
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<tr>
<td>Hematology</td>
<td></td>
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</tr>
<tr>
<td>PCV (%)</td>
<td>29–48^1</td>
<td>38.70a</td>
<td>31.90b</td>
<td>33.00b</td>
<td>33.60b</td>
<td>0.882</td>
<td>0.012</td>
<td>0.028</td>
<td>0.013</td>
</tr>
<tr>
<td>RBC (10^6/μl)</td>
<td>3.2–3.8^1</td>
<td>3.42a</td>
<td>3.06b,c</td>
<td>3.22b</td>
<td>2.95c</td>
<td>0.062</td>
<td>0.003</td>
<td>0.002</td>
<td>0.356</td>
</tr>
<tr>
<td>EOF (%)</td>
<td>14.8^1</td>
<td>35.88a</td>
<td>28.78b</td>
<td>28.00b</td>
<td>25.18b</td>
<td>1.238</td>
<td>0.003</td>
<td>0.001</td>
<td>0.198</td>
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<tr>
<td>Thyroid hormones (ng/ml)</td>
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<tr>
<td>T3</td>
<td>1.7–2.6^1</td>
<td>3.27</td>
<td>4.00</td>
<td>3.94</td>
<td>3.72</td>
<td>0.300</td>
<td>0.856</td>
<td>0.665</td>
<td>0.483</td>
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<tr>
<td>T4</td>
<td>14–31.4^1</td>
<td>14.87a,b</td>
<td>18.70a</td>
<td>15.55a,b</td>
<td>12.07b</td>
<td>0.852</td>
<td>0.031</td>
<td>0.076</td>
<td>0.018</td>
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<tr>
<td>Ascites-related parameters</td>
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<td>RV (g)</td>
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</table>

1GB0, GB5, GB10, and GB15: 0 (control) 5, 10 and 15 g garlic/kg DM, respectively.
3Sturkie (2000).
4Rajani et al. (2011).
5Julian et al. (1987).
6Means with different superscripts in each row are significantly (P ≤ 0.05).

the entire experimental period, the highest and lowest body weight gain was observed by inclusion of 5 and 15 g/kg garlic bulb in the diets, respectively. Scheele et al. (2003) reported that body weight gain was lower in broiler chicken flocks that had high mortality rates. These results are consistent with the findings of the present study. The inclusion of different levels of GB in diets did not have an effect on feed conversion ratio during 1 to 42 days of age. Moreover, the decrease in feed intake during days 1 to 42, with increasing garlic bulb levels under STC, may be related to the palatability of the diets. Garlic and its products have a pungent smell and can reduce diet palatability (Chen et al., 2008), leading to feed intake reduction.

No significant differences were found in body weight, body weight gain, feed intake, and feed conversion ratio among groups during 1 to 42 days of age under CTC. Diets supplemented with garlic and its by-products had variable effects on broiler chicken growth performance. The inclusion of 1 g/kg garlic powder in the diets had a negative effect on growth performance (Pourali et al., 2010) while the inclusion of 1 to 3 g/kg garlic powder in finisher diets was shown to improve growth performance (Raeesi et al., 2010). In other studies, the inclusion of garlic powder in the diets had no effects on body weight gain and feed conversion ratio in broiler chickens (Horton et al., 1991; Konjufca et al., 1997; Onibi et al., 2009; Choi et al., 2010). It seems that basal diets, the amount of garlic included in the diets, and the age of the birds are the main reasons for these observations.

Total mortality and ascites-related mortality rates were reduced in the birds fed diets with the inclusion of 5 g/kg GB under CTC. Ascites-related mortality rate was 4 to 5% in chickens reared under standard conditions (Pakdel et al., 2002) and was 23% in ascites-induced birds (Luger et al., 2002). Ascites-related...
mortality under both STC and CTC in the current study was 3.6 to 6.9% and 4.7 to 20.3%, respectively. A marked reduction in mortality was observed in broiler chickens fed a diet supplemented with garlic powder (Tollba and Hassan, 2003), a result in agreement with the current study. Epidemiological, clinical, and preclinical studies have shown that garlic reduces the occurrence of cardiovascular disease (Bozin et al., 2008). The ability of garlic to reduce mortality might be due to its systemic anti-hypertensive properties (McMahon and Vargas, 1993; Al-Qattan et al., 1999; Khalid, 2001; Preuss et al., 2001; Chen et al., 2008), its positive effects on the cardio-vascular system (Rana et al., 2011), and liver protection effects (Berges et al., 2004).

**Hematological and Ascites-Related Parameters**

Hematological parameters have an important role in the pathophysiology of ascites in poultry, especially broiler chickens (Luger et al., 2001; Scheele et al., 2003). The levels of garlic had no effect on hemoglobin content. This finding is consistent with Rahimi et al. (2011) report. The lowest packed cell volume was observed in the birds fed diets containing 5 g/kg GB under CTC. The packed cell volume is an indicator for ascites since erythropoiesis occurs in response to hypoxia (Rajani et al., 2011) as a natural physiological response in birds (Sturkie, 2000). The value of packed cell volume in broiler chicks and hens are 0.29 and 0.48, respectively (Sturkie, 2000). The packed cell volume is an indicator for ascites since erythropoiesis occurs in response to hypoxia (Rajani et al., 2011) and the birds fed diets containing 5 g/kg GB under CTC. It can be concluded that olive leaves are more effective in reducing systolic blood pressure than garlic bulbs. Conversely, the cuff size has an important role in the explanation of this difference. The cuff size was 7.5 to 13 cm in previous experiments (Varmaghany et al., 2013) but was 5 to 7.5 cm in the present study. The results of the current study showed that systolic blood pressure decreased with increasing GB inclusion in diets under STC. Garlic reduces blood pressure in humans and animals (Al-Qattan et al., 1999; Khalid, 2001; Preuss et al., 2001; Chen et al., 2008) which is in agreement with the results of the present study. Based on available sources, no study exists regarding the changes in the systolic blood pressure of broilers fed garlic or its products. Anti-hypertensive drugs are divided into 4 main categories including beta-blockers, diuretics, angiotensin-converting enzyme inhibitors, and calcium channel blockers (Weiss et al., 2006). The anti-hypertensive properties of garlic may be due to the angiotensin-converting enzyme inhibitory or calcium channel blocking properties of allicin (Preuss et al., 2001; Sharifi et al., 2004).

**CONCLUSION**

The inclusion of 5 g/kg garlic bulb in broiler chicken diets reduced the systolic blood pressure, RV/TV ratio, packed cell volume, total mortality, and ascites-related mortality under CTC. Moreover, the inclusion of 5 g/kg garlic bulb in broiler chicken diets led to a better final body weight and body weight gain under both STC and CTC. It can be concluded that the inclusion of 5 g/kg garlic bulb in broiler chicken diets could help to prevent ascites in susceptible broilers.

**REFERENCES**


Dietary Hypotension Induced by Garlic Controls the Broilers’ Ascites


