Effects of drinking water differing in dissolved oxygen concentration on growth performance of broiler

Einfluss unterschiedlicher Gehalte an gelöstem Sauerstoff im Tränkwasser auf die Wachstumsleistung von Broilern

E. Dinçer, A. Karabayr and M. Mendes

Introduction

Water, comprising 60-85% of bird body weight, is found in all tissues and cells. It takes a role in many important metabolic events, such as regulation of body temperature, digestion, translocation and absorption of feeds, hydrolysis of proteins, fats and carbohydrates, sight and hearing functions, respiration and perspiration (Dugan et al., 1991; Türeik and Çelen, 1996; Karabayır, 2001). The quality of drinking water is described by its physical, chemical, and microbial characteristics. Among these quality criteria, level of dissolved oxygen is also important along with pH and temperature. Oxygen enriched water was reported to enhance feed conversion and thereby increase growth performance in broilers (Zimmerman et al., 1991). Barton et al., (1986) found a positive correlation between dissolved oxygen level and body weight after evaluating 300 commercial broiler farms. From this point, it may be expect that differences in the dissolved oxygen level in drinking water may affect two important growth parameters in broilers – mature weight and growth rate.

It is generally accepted that the most important characteristic of live material is growth (Kocabas et al., 1997; Lawrence and Fowler, 2002). Growth can be defined as changes in organisms caused by the interaction of genotype and environment throughout their life spans or in a certain period of time, in terms of an observed characteristic. Growth curves are used to define the changes in the investigated characteristics based on time or age (Salomon et al., 1987). The shape of growth curves changes depending on the species, investigated characteristics, time (age) and environment. As, in general, living organisms show a non-linear growth for most of their characteristics, in practice non-linear growth curve analyses is that they have two biological parameters. These are mature weight and growth rate. Mature weight explains average live weight, while, growth rate explains the rate of approaching mature weight. Animals with high growth rate attain their mature weight faster, which means these animals grow faster (Etsov et al., 2006). Growth curves enable us to forecast the future growth of an animal, and thereby select animals for breeding purposes when they are young (Erş, 1990; Axas, 1995). Also, with the help of growth curves, it is possible to revise growing systems effectively at early stages. In this study, the effect of drinking waters with different oxygen levels on growth performance of broilers was investigated.

Material and Methods

This study was carried out at experimental rooms of the Animal Science Department, Agriculture Faculty, Çanakkale Onsekiz Mart University. Fifty Ross 308 broiler chickens were used and divided into two groups (Table 1): Control (with 5.50 mg/l dissolved oxygen, n=25 (14 male and 11 female)) and Treatment (with 13.85 mg/l dissolved oxygen, n=25 (4 male and 21 female)). Stocking density was 7 birds per m². The temperature of the unit was adjusted to 33°C in the first two weeks, 30°C in the 3rd week, 27°C in the 4th week and 24°C in the 5th and 6th weeks of the study. Enrichment of water with dissolved oxygen started when chickens were seven days old. Chickens were reared then up to 49 days of age. Body weight of chickens was recorded individually each day. Nipple drinkers and round feeders were used to supply chickens with water and feed. For both groups drinking water from the same reservoir was used. Animals in the control group were directly given the reservoir water, whereas, birds in the treatment group were given reservoir water supplemented with 3.0 l min⁻¹ dissolved oxygen via an oxygen cylinder. Dissolved oxygen concentration in drinking water was measured by an oxygenmeter. pH and water temperature were determined, as well. Feed and water were offered ad libitum to the chickens throughout the trial. Birds were fed a starter diet between 0-3 weeks of age and a grower diet between 3 and 5 weeks and a finisher diet in the last week of the trial (Table 2). Housing conditions (temperature, humidity etc.) were similar for both the groups. Initial live weight, live weight change and feed consumption of chicks were determined by a balance (5 g precision). Water consumption of birds was measured by a water meter. Preliminary studies were undertaken to determine the planned dissolved oxygen concentrations. Based on these studies, 5.50 mg/L and 13.85 mg/L concentrations were chosen.
Statistical analyses

The effect of dissolved oxygen water on growth performance of chickens was analyzed by repeated measurements analysis of variance model (1).

\[ Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + \epsilon_{ijk} \]  

Where, 
\[ Y_{ijk} \]: measured value of chicken \( k \) in group \( i \) on observation day \( j \) 
\[ \mu \]: general population mean 
\[ \alpha_i \]: group effect (\( i=1, 2; i=1 \) (control), \( i=2 \) (dissolved oxygen=13.85 mg/l)) 
\[ \beta_j \]: effect of sex (\( j=1,2 \)) 
\[ \gamma_{ij} \]: interaction effect between group and sex 
\[ \epsilon_{ijk} \]: random error term (WINER et al. 1991; KESKIN and MONDES, 2001).

The Gompertz growth model was chosen to describe age-weight relation in chickens, as the Gompertz growth model was found more effective than other models such as Richards, Logistic, Brody, and Von Bertalanffy in a preliminary analysis. Gompertz growth curves were fitted to age-weight data of chickens in order to compare growth curves. At the end of the test it was observed that growth curves were parallel both for control and treatment groups (P=0.196). Therefore, it was concluded that the overall growth model may fit to all the chickens of the two groups.

Results

As a result of the repeated measurements analysis of variance, day x group x sex interaction effect (P=0.412), day x group interaction effect (P=0.246), group x sex interaction effect (P=0.286) and main effects of groups (P=0.325) were not statistically significant. On the other hand, day effect, sex effect and day x sex interaction effect were significant (P=0.000). A multiple comparison of means by Tukey test revealed no difference between sex in the first 15 days (P=0.196). However, live weight of males from day 16 onwards started to differ from live weight of females (P=0.049). This situation became more apparent from day 22 onwards (P=0.002).

Table 1. Dissolved oxygen, pH and temperature value of drinking water

<table>
<thead>
<tr>
<th>Groups</th>
<th>Dissolved oxygen (mg/l)</th>
<th>pH</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.50</td>
<td>7.30</td>
<td>25.5</td>
</tr>
<tr>
<td>Treatment</td>
<td>13.85</td>
<td>7.34</td>
<td>24.9</td>
</tr>
</tbody>
</table>

Durbin-Watson statistic (DW) were used. The Gompertz growth model was fitted to the body weight and age data of chickens, using the NLIN procedure of the SAS software. The Marquardt iterative procedure was used to reduce the residuals and improve the fit (SAS Inc., 1999; BAYRAM et al., 2004). Statistical significance of non-linear model parameters was determined using 95% asymptotic confidence intervals. The Gompertz model was defined as

\[ W = A \exp\left(\exp\left(-b(t-t^*)\right)\right) \]  

Where \( W \) is the weight (g) at the day \( t \); \( A \) is the maximum weight (g) at maturity; \( b \) is the rate of growth; \( t^* \) is the age (days) of the maximum daily weight gain (EDMANS, 1989).

The analysis was performed separately by groups. Firstly, individual growth curves were determined for each chicken in each group. Then, the F test given in equation (3) was used for testing homogeneity of individual growth curves. At the end of the test it was observed that growth curves were parallel both for control and treatment groups (P=0.10). Therefore, it was concluded that the overall growth model may fit to all the chickens of the two groups.

\[ F = \frac{S_2^2/(m-1)}{S_1/(\sum_{i=1}^{m} n_i - 2m)} \]  

Where, \( m \) number of days, \( n \) number of chickens, \( S_2 \) sum of square between regression coefficients for each group and \( S_1 \) sum of square of deviation from regression for each group (KOCABA et al., 1997).

Table 2. Crude protein and metabolic energy of feed

<table>
<thead>
<tr>
<th>Feeds</th>
<th>Crude Protein (%)</th>
<th>ME (kcal/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter</td>
<td>24.1</td>
<td>2818</td>
</tr>
<tr>
<td>Growth</td>
<td>25.3</td>
<td>2892</td>
</tr>
<tr>
<td>Finisher</td>
<td>22.4</td>
<td>2912</td>
</tr>
</tbody>
</table>

Table 3. Feed and water consumption by weeks

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Control Feed (g)</th>
<th>Water (ml)</th>
<th>Treatment Feed (g)</th>
<th>Water (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7285</td>
<td>9955.4</td>
<td>7050</td>
<td>9635.2</td>
</tr>
<tr>
<td>2</td>
<td>14200</td>
<td>20565.2</td>
<td>13885</td>
<td>20032.8</td>
</tr>
<tr>
<td>3</td>
<td>21365</td>
<td>32843.4</td>
<td>20615</td>
<td>31164.6</td>
</tr>
<tr>
<td>4</td>
<td>27190</td>
<td>44756.3</td>
<td>24920</td>
<td>41038.2</td>
</tr>
<tr>
<td>5</td>
<td>31650</td>
<td>48058.4</td>
<td>31205</td>
<td>47331.0</td>
</tr>
<tr>
<td>6</td>
<td>31930</td>
<td>51192.5</td>
<td>31475</td>
<td>50470.0</td>
</tr>
<tr>
<td>Grand total</td>
<td>133940</td>
<td>207371.2</td>
<td>129150</td>
<td>199671.8</td>
</tr>
</tbody>
</table>
Feed and water consumption of chickens by weeks are given in Table 3. Total feed and water consumption of chickens in control group (feed 133,940 g; water 207,371 ml) was higher than in treatment group (feed 129,150 g; water 199,672 ml). However, water consumption per kg feed consumed was similar in both groups (1.55). Least squares means, standard error of mean maturity and degree of maturity (DM) by sex are given for each group in Table 4. Weekly live weight gain of females and males in treatment group was slightly higher than for control group, and this case was more visible with increasing age. But generally, live weight means of females and males in the treatment group were very similar to that of the control group. These findings can also be envisioned in Figure 1 and Figure 2, where age dependent live weight changes are shown.

Degree of maturity was found higher for females when compared to males in control group. The same case is valid for treatment group. DM values of males and females in control and treatment groups were quite similar. The estimation of growth parameters of females and males by groups are given in Table 5. The Gompertz growth model fitted the chickens weight and age data very well with $R^2 > 98\%$. All parameter estimates and growth characteristics for chickens based on Gompertz growth model were significant (Table 5; $P<0.05$). Mature weight of females (4.841 g) of treatment group was higher than of females (4.348 g) of the control group ($P=0.022$; Table 5). However, growth rate or maturing index ($b$) values of females of control and treatment groups were same (0.046). Females in treatment group (27.7 ± 0.46) attained maximum growth one day earlier than those in control group (28.8 ± 0.44). The mature weight of males (6,604 g) of treatment group was higher than that of males (6,526 g) of control group ($P=0.225$; Table 5). However, this difference was rather small. Growth rate and age (days) at maximum daily weight gain of males were similar for both groups.

Weekly feed conversion efficiency of control and the treatment groups are presented in Table 6. Group based feed conversion efficiency was calculated since feed consumption was determined on group basis. Feed conversion efficiency of treatment group was slightly higher than of control group, especially in weeks 3, 4 and 5. Asymptotic correlations of parameter estimates are given in Table 7. When these correlations are high (absolute value greater than 0.95) the precision of parameter estimates is suspect. Table 7 shows that none of these estimates was greater than 0.95. Therefore, it was concluded that precision of parameter estimates was okay.

### Table 4. Least Squares means, standard error of mean weights and degree of maturity (DM) values in control and treatment groups in every week

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td></td>
<td>Mean±SE</td>
<td>DM (%)</td>
</tr>
<tr>
<td>1</td>
<td>288 ± 14.3</td>
<td>0.06 (0.05)</td>
</tr>
<tr>
<td>2</td>
<td>601 ± 34.5</td>
<td>0.14 (0.10)</td>
</tr>
<tr>
<td>3</td>
<td>1022 ± 47.6</td>
<td>0.24 (0.18)</td>
</tr>
<tr>
<td>4</td>
<td>1546 ± 67.8</td>
<td>0.36 (0.30)</td>
</tr>
<tr>
<td>5</td>
<td>2076 ± 90.1</td>
<td>0.48 (0.41)</td>
</tr>
<tr>
<td>6</td>
<td>2568 ± 153.0</td>
<td>0.59 (0.53)</td>
</tr>
</tbody>
</table>

![Figure 1. Growth curves for females in control and treatment groups](image-url)
Discussion

Although, the observed live weight of treatment group was slightly higher than of control group, the difference was not statistically significant. Hence, it could be an indication that the effect of oxygen enrichment on the live weight gain over groups was not important. On the other hand, it is of interest to have preliminary information that enrichment of tap water with oxygen can enhance live weight gain, as mean chicken weight of treatment group (2,988 g) which included a smaller number of male chickens was very close to the control group (3,065 g). A similar case is also valid for feed conversion efficiency of control and treatment groups. However, feed conversion efficiency of treatment group was slightly higher than of control group, especially in weeks 3, 4 and 5. On the other hand, the presence of more males (14 male) in control group in comparison to treatment group (4 male) resulted in feed conversion efficiency of treatment group lower than expected. However, these finding suggest that feed conversion efficiency in group receiving 13.85 mg/l dissolved oxygen (treatment group) may be better than in control group (5.50 mg/l dissolved oxygen). BARTON et al. (1986) reported that oxygen-enriched drinking water is claimed to improving broiler growth performance, primarily by improving feed conversion. ZIMMERMAN et al. (1991) supported this result. From this point of view, results of this study show similarity with the others. However, levels of dissolved oxygen were different in those studies.

The fact that higher dissolved oxygen level in drinking water resulted in a live weight gain similar to that of control group with less quantity of feed (4,335 g less) was economically important. In addition, evaluating the whole 6-week period revealed that animals in treatment group consumed 4,790 g less feed than those in control group. Considering that only 25 birds were used in each group in this study, the economical dimension can be better estimated for farms having ten thousands of birds, where the greatest input are feed expenses.

It may be of more importance for farms that females in treatment group reached maturity (27.7 days) one day be-

Table 5. Growth characteristics of females and males in control and treatment groups based on the Gompertz model

<table>
<thead>
<tr>
<th>Groups</th>
<th>Parameter</th>
<th>Female</th>
<th>95% CI</th>
<th>Male</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control A</td>
<td>A</td>
<td>4348</td>
<td>± 82.3</td>
<td>4182</td>
<td>- 4514</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.046</td>
<td>± 0.001</td>
<td>0.045</td>
<td>- 0.048</td>
</tr>
<tr>
<td></td>
<td>t^*</td>
<td>28.8</td>
<td>± 0.44</td>
<td>27.9</td>
<td>- 29.7</td>
</tr>
<tr>
<td></td>
<td>R^2 (%)</td>
<td>99.9</td>
<td>-</td>
<td>99.9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>RMSE</td>
<td>265</td>
<td>-</td>
<td>467</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>DW</td>
<td>2.04</td>
<td>-</td>
<td>1.76</td>
<td>-</td>
</tr>
<tr>
<td>Treatment A</td>
<td>A</td>
<td>4841</td>
<td>± 93.4</td>
<td>4653</td>
<td>- 5030</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.046</td>
<td>± 0.001</td>
<td>0.042</td>
<td>- 0.040</td>
</tr>
<tr>
<td></td>
<td>t^*</td>
<td>27.7</td>
<td>± 0.46</td>
<td>28.9</td>
<td>- 30.7</td>
</tr>
<tr>
<td></td>
<td>R^2 (%)</td>
<td>98.9</td>
<td>-</td>
<td>99.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>RMSE</td>
<td>292</td>
<td>-</td>
<td>636</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>DW</td>
<td>1.98</td>
<td>-</td>
<td>1.57</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 2. Growth curves for males in control and treatment groups

Wachstumskurve der männlichen Broiler der Kontroll- und Behandlungsgruppe
fore females of control group (28.8 days). Both, slaughter weight (2,798 g) and mature weight (4,841 g) of this group was higher than of control group (2,568 g and 4,348 g). On the other hand, it is a very interesting observation that levels of dissolved oxygen has not affected mature weight, growth rate and age (days) at maximum daily weight gain of male birds. Figure 1 and Figure 2 support these findings. It was expected that within the first two weeks, live weight of males and females in both groups are similar, but after second week live weight gain should be higher in males than in females. Furthermore, it was observed that enrichment of drinking water with oxygen did not affect degree of maturity (DM) of birds, but it has to be considered that control and treatment groups included different numbers of males.

In conclusion, it can be stated that under conditions of the present experiment oxygen enriched drinking water did not significantly affect live weight gain and feed conversion rate of the birds.

Acknowledgements

Contributions from Kula Gıda Kombinaları Company is acknowledged.

Summary

The objective of this study was to adapt the Gompertz function to growth data of chickens to testing the effects of oxygen-enriched drinking water on growth performance of Ross 308 broilers. Daily body weight change of chickens was determined from seven days of age to 49 days of age. Two treatment groups were included: control (5.50 mg/l dissolved oxygen), treatment (13.85 mg/l dissolved oxygen). The effect of oxygen-enriched drinking water on growth performance of chickens was determined by repeated measures analysis of variance. Gompertz growth function was applied to estimate growth parameters such as mature weight, growth rate and the age (days) at maximum daily weight gain of males and females for each group. Repeated measures analysis of variance showed a significant day x sex interaction effect (P=0.000). Tukey multiple comparison test revealed no difference between sex in the first 15 days (P=0.196). However, live weight of males form day 16 onward started to differ from the live weight of females (P=0.039). Though feed conversion efficiencies of the two groups were similar, feed conversion efficiency of the treatment group was slightly better than that of the control group especially in weeks 3, 4 and 5. The Gompertz growth model fitted to chicken weight and age data very well with R²=98%. Mature weight of females of treatment group (4,841 g ± 93.4) was higher than of control group (4,348 g ± 82.3). However, growth rate of females for treatment and control groups were same (0.46). Females in treatment group (27.7 d ± 0.46) attained the maximum growth one day earlier than those in control group (28.8 d ± 0.44). Mature weight (6,604 g ± 175) of males of treatment group was higher than that (6,526 g ± 149) of males of control group. Growth rate and age (days) at maximum daily weight gain of males were similar for both groups.

Key words

Broiler, drinking water, dissolved oxygen, Gompertz growth curve

Zusammenfassung

Einfluss unterschiedlicher Gehalte an gelöstem Sauerstoff im Tränkwasser auf die Wachstumsleistung von Broilern

Das Ziel der Untersuchung war die Anpassung der Gompertz-Funktion an die Lebendgewichtsentwicklung von Hühnern zur Abschätzung der Effekte einer Anreicherung des Tränkwassers mit gelöstem Sauerstoff auf die Wachstumsleistung von Ross 308 Broilern. Hierzu wurde die Ver-

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.99</td>
<td>0.95</td>
</tr>
<tr>
<td>2</td>
<td>1.35</td>
<td>1.38</td>
</tr>
<tr>
<td>3</td>
<td>1.55</td>
<td>1.48</td>
</tr>
<tr>
<td>4</td>
<td>1.60</td>
<td>1.57</td>
</tr>
<tr>
<td>5</td>
<td>1.64</td>
<td>1.63</td>
</tr>
<tr>
<td>6</td>
<td>1.75</td>
<td>1.77</td>
</tr>
</tbody>
</table>

Table 6. Weekly feed conversion efficiency of the control and the treatment groups

Wöchentliche Futterverwertung der Kontroll- und Behandlungsgruppe

<table>
<thead>
<tr>
<th>Groups</th>
<th>Parameter†</th>
<th>A</th>
<th>b</th>
<th>t*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>A</td>
<td>1.00 (1.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>-0.92 (-0.93)</td>
<td>1.00 (1.00)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t*</td>
<td>0.94 (0.91)</td>
<td>-0.91 (-0.91)</td>
<td>1.00 (1.00)</td>
</tr>
<tr>
<td>Treatment</td>
<td>A</td>
<td>1.00 (1.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>-0.93 (-0.93)</td>
<td>1.00 (1.00)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t*</td>
<td>0.91 (0.94)</td>
<td>-0.91 (-0.94)</td>
<td>1.00 (1.00)</td>
</tr>
</tbody>
</table>

A: mature weight, b: Growth rate, t*: the age (days) of the maximum daily weight gain

Table 7. Asymptotic correlations between the estimated parameters

Asymptotische Korrelationen zwischen den geschätzten Parametern

<table>
<thead>
<tr>
<th>Groups</th>
<th>Parameter†</th>
<th>Female (Male)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>b</td>
<td>t*</td>
</tr>
</tbody>
</table>

* A: mature weight, b: Growth rate, t*: the age (days) of the maximum daily weight gain
änderung des Körpergewichts zwischen dem 7. und 49. Lebенstag erfasst. Der Versuchs umfasste zwei Behandlungs- 
gruppen: Kontrolle (5,50 mg/1 gelöster Sauerstoff), Sau- 
erstoff-Behandlung (13,85 mg/1 gelöster Sauerstoff). Der 
Einfluss der Sauerstoff-Anreicherung im Tränkwasser auf 

die Mastleistung wurde mittels der Prozedur „Repeated 
Measurements“ ausgewertet. Die Gompertz-Funktion wur- 
den gleiches Alter bei der maximalen Wachstumsrate bei den Hähnen 

Dagegen waren die Wachstumsgeschwindigkeit und das 

Verteilt, Wachstumsrate und Alter beim maximalen Wachs-

tum, bei den männlichen und weiblichen Broilern der bei-

den Behandlungsgruppen angewendet. 

Die Repeated Measurements Analyse ergab signifikante 

Alters x Geschlechts-Interaktionen (P=0.000). Während in 
den ersten 15 Versuchstagen noch keine signifikanten Ge-

schlechtsunterschiede mittels Tukey Test nachgewiesen 

werden konnten (P=0.196), unterschieden sich die Ge-

wichte der männlichen und weiblichen Broiler ab dem 16. 

Tag deutlicher (P=0.039). Obwohl die Futterverwertung in 

wicht, Wachstumsrate und Alter beim maximalen Wachs-

Das Reifegewicht der weiblichen Broiler der Sauerstoff-Behandlung (4.841 g ± 93.4) 

war höher als in der Kontrollgruppe (4.348 g ± 82.3). Da-

gegen war die Wachstumsrate der weiblichen Tiere bei der 

Kontrolle und bei der Sauerstoff-Behandlung nicht unter-

schiedlich (0.46). Die weiblichen Tiere der Sauerstoff-Be-

handlung erreichten die maximale Wachstumsrate einen 

Tag früher als die Hennen der Kontrollgruppe (27,7 d ± 

0,46 gegenüber 28,8 d ± 0,44). Das Reifegewicht der Hän-

ne bei der Sauerstoff-Behandlung (6.604 g ± 175) war hö-

er als das der Hennen der Kontrollgruppe (6.526 g ± 149). 

Dagegen waren die Wachstumsgeschwindigkeit und das 

Alter bei der maximalen Wachstumsrate bei den Hähnen 

der beiden Behandlungsgruppen nicht unterschiedlich.

Stichworte
Broiler, Tränkwasser, gelöster Sauerstoff, Gompertz-Funktion

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Correspondence: Assoc. Prof. Dr. Mehmet Mendes, Çanakkale Onsekiz Mart 
University Agriculture Faculty Animal Science Department, Çanakkale 17020, 
Turkey, e-mail: mmendes@comu.edu.tr

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