The effect of season on dead on arrival rate and meat quality characteristics of broiler chicken transported in commercial slaughter conditions

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SUMMARY
The aim of the study was to determine the effect of season on dead on arrival rate and meat quality characteristics of broiler chicken in commercial transport and slaughter conditions. The study was performed on the broiler chickens reared under similar commercial conditions from 12 different flocks (4 seasons × 3 replicates). Transportation distance was approximately 80 km and duration was 2 h per transport. Meat samples were taken on April, July, October, and December for spring, summer, autumn and winter seasons, respectively during 2018. Broilers in trucks were waited in holding barn for 1 h and the numbers of dead on arrival (DOA) were recorded per transport. Meat colour, pH₄h, drip loss, cooking loss and Warner Bratzler shear force (WBSF) were determined. The effect of season on DOA rate (P < 0.05) and all investigated meat quality characteristics (P < 0.001) was significant. DOA rate was highest in the winter while the rate was lower in spring and autumn. In winter, pH₄h, a*₂₄h and b*₂₄h were higher than other seasons, while L*₂₄h, drip loss and WBSF were lower than other seasons. The incidence of PSE meat was the highest in summer (31.12%), while the incidence of DFD meat was the highest in winter (55.55%). The lowest incidence of normal breast meat was in winter season.

In conclusion, transportation of broiler chickens in winter resulted with highest DOA rate, as well as decreased incidence of normal breast meat. On the other hand, the incidence of PSE meat was the highest in summer. In order to reduce the DOA rate and to improve the meat quality, transportation of broiler chickens within thermal comfort zone ranges is recommended.

KEY WORDS
Broiler chicken, DOA, meat quality, PSE meat, transportation.

INTRODUCTION
Transportation is a fundamental component of the poultry production, because poultry are constantly transported for several reasons such as breeding or slaughter. Broiler chickens may expose to several stressors during transport from the farms to the slaughterhouses, even under optimal conditions. The stressors consist of thermal stress, acceleration, vibration, movement, withdrawal of water or feed, social disruption and noise. Among those factors, thermal stress is an important threat for poultry industry, especially during the end of the farming period or pre-slaughter stages. Heat or cold stress creates detrimental effects on meat quality and increases mortality rate. Thereby, the thermal stressors can cause great economic losses. Mortality of the birds between catching in the farm and unloading from their crates at the slaughterhouse are defined as “dead on arrival” (DOA). DOA is an important determinant for assessment of animal health and welfare. Furthermore, DOA rate also reflects economic loss due to condemned and inappropriate meat for human consumption. Ambient temperature and humidity are main reasons for mortality, since 40% of the DOA is related with heat or cold stress. The effect of ambient temperature and relative humidity on broiler chickens may alter according to seasons, stocking density in crates, ventilation in trailer and holding barn conditions. The DOA rate has been reported by several authors between 0.15 - 0.68%.

Thermal stress can also cause unsuitable changes in meat quality parameters such as pale, soft and exudative (PSE) or dark, firm and dry (DFD) meat. Most of consumers don’t prefer these products because of noticeable colour differences and low meat quality. Recently, several researchers have studied the relationships between raw breast meat colour and defective meat problems. They reported that lightness (L*) values can be used as an indicator of the PSE or DFD meat as well as for the estimation of the incidence of meat defects. Season of transportation may also have an influence on meat quality characteristics. When chickens exposed to the cold, water holding capacity, WBSF and meat colour might be influenced adversely, while higher drip loss, cooking loss and WBSF values with paler meat colour were reported for chickens transported in hot weathers. On the other hand, no significant season effect on meat quality was also reported in some studies.
The objective of the present study was to determine the effect of season on DOA rate and meat quality characteristics of broiler chickens in commercial transport and slaughter conditions.

**MATERIALS AND METHODS**

**Animals, study design and slaughter processes**

The study was carried out on Ross-308 broilers from 12 different flocks (4 seasons × 3 replicates). Broiler chickens were reared under similar commercial conditions in Samsun city, Turkey. The flocks were maintained on 23 h light and 1 h dark lighting regime, and feed and water were supplied ad libitum. The feed in the rearing farm were withdrawn 8 hours before loading in all flocks. The dimensions of the plastic crates were 80 cm length × 45 cm width × 30 cm height. The type of trailers was similar and there were 320 crates in each vehicle. The space between crates was about 10 cm, and space among crate stacks and roof was about 20 cm. In addition, no lateral curtains of truck were available during the winter season for protection to exposure of cold temperatures. The minimum area for each broiler chicken was obtained by using the formula of the Farm Animal Welfare Council.26 The formula, A = 0.021W0.67, is based on mean slaughter weight, where A is the area in square metres and W is the mean slaughter weight of animal in kg. Stocking densities in crates for all transports were within the range of values suggested by the FAWC.26 Transport distance was approximately 80 km and duration was 2 h per transport. Average speed of the vehicle was 40 km/h and transportation was completed without any stops, sudden accelerations or decelerations in all transports. The data logger (T esto 174H) was placed outside of the slaughterhouse to record temperature and humidity values throughout the study (Table 1). The slaughtering processes were carried out between 11:30 p.m. and 8:00 a.m. according to workload of the slaughterhouse. Study was conducted on April, July, October and December for spring, summer, autumn and winter seasons, respectively during 2018. Numbers of broilers transported in each season were, 8983 in spring, 8992 in autumn and 9003 in winter. Broilers were manually cut for the comparison of different seasons regarding DOA rates. Chi-square analysis was used. Thirty broilers from each flock, totally 360 broilers, were randomly chosen to investigate meat quality parameters.

**Meat quality analysis**

M. pectoralis major was removed from the 30 carcasses for each replicate. Muscle pH at 4 h after slaughter (pH4) was determined by inserting a portable pH meter (T esto 205) probe into the cranial section of each left breast sample. Meat colour was determined by a Minolta chromometer (Model CR 400). The CIE criteria were used and D65 was selected as the light source. Calibration of the chromometer was carried out with a standard white plate (Y=93.8, x=0.316, y=0.3323). Lightness (L*), redness (a*), and yellowness (b*) was measured on medial surface (bone side and near the median line) of the left M. pectoralis major, in an area free of obvious defects. Meat samples were stored at 4°C and under constant white light (750 lx) for 24 h, and then second measurements were performed. The method described by Honikel was used to determine the drip loss. Briefly, approximately 20 g meat samples were taken from M. pectoralis major. After a 24 h storage period at 4°C in the refrigerator, the samples were reweighed. Drip loss (%) was calculated by the percentage of weight loss to initial sample weight.

In order to determine cooking loss, the samples were firstly weighed and then packed under vacuum and cooked for 20 min in an 80°C water bath. After a 24 h storage period at 4°C in the refrigerator, the samples were softly dried with paper towels to remove excess moisture and reweighed. Cooking loss (%) was calculated by the percentage of weight loss to initial sample weight.

The method described by Pekel et al.23 was used to determine WBSF value. In this analysis, cooked meat samples from cooking loss analysis were used. Three sub-samples from each cooked meat samples were cut parallel to the muscle fibres with a cross section of 1×1 cm and 2.5-3 cm length. An Instron Universal Testing Machine (Model 3343) was used to measure WBSF value at a crosshead speed of 200 mm/min.

**Sample classification**

Breast meat samples were classified as PSE, DFD, or normal meat based on L*24h Value. L*24h ≥ 49.0 as PSE, L*24h ≤ 44.0 as DFD, and 44.0 < L*24h < 49.0 as normal meat.13,15

**Statistical analysis**

Kruskal-Wallis and Mann-Whitney U tests were used in comparison of different seasons regarding DOA rates. Chi-

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**Table 1 - Certain transportation and slaughtering characteristics by season.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Spring (n=90)</th>
<th>Summer (n=90)</th>
<th>Autumn (n=90)</th>
<th>Winter (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking density (m²/bird)</td>
<td>0.039±0.001</td>
<td>0.045±0.001</td>
<td>0.042±0.001</td>
<td>0.043±0.001</td>
</tr>
<tr>
<td>A value (m²/bird)</td>
<td>0.035±0.001</td>
<td>0.036±0.001</td>
<td>0.036±0.001</td>
<td>0.035±0.001</td>
</tr>
<tr>
<td>Slaughter weight (kg)</td>
<td>2.17±0.30</td>
<td>2.21±0.36</td>
<td>2.19±0.34</td>
<td>2.18±0.33</td>
</tr>
<tr>
<td>Slaughter age (d)</td>
<td>42.00±0.56</td>
<td>41.86±0.77</td>
<td>41.68±0.65</td>
<td>41.78±0.75</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>8.52±0.53</td>
<td>18.69±0.18</td>
<td>7.66±0.09</td>
<td>-1.32±0.24</td>
</tr>
<tr>
<td>Humidity (%)</td>
<td>72.11±2.06</td>
<td>89.76±0.46</td>
<td>96.04±0.53</td>
<td>92.76±0.35</td>
</tr>
</tbody>
</table>
RESULTS

The effect of season on DOA rate was significant ($P < 0.05$) and DOA rate was the highest in winter season (Figure 1). Meat quality characteristics by season are shown in Table 2. The effect of season on all investigated meat quality characteristics was significant ($P < 0.001$). In winter season, $\text{pH}_{4h}$ and $b^*_{24h}$ were higher and $L^*_{24h}$ and WBSF were lower than other seasons. The incidence of DFD, normal and PSE meat by season are shown in Table 3. The incidence of PSE meat was the highest in summer (31.12%), while the incidence of DFD meat was the highest in winter (55.55%). In addition, the lowest incidence of normal breast meat was obtained in winter. DFD and PSE incidences in all dataset were 28.61 and 11.39%, respectively, while there were no meat defects in 60% of the chickens.

FIGURE 1 - DOA rates by season. a, b, c: DOA rates in different column with different letters differ significantly ($P < 0.05$).

DISCUSSION

Poultry and pigs are susceptible to stress, especially heat stress. Therefore, poultry and pig meat are vulnerable to meat quality defect30. Many researchers found that pre-slaughter stress factors such as pre-slaughter handling, ambient temperature and humidity, holding area conditions might affect both DOA rate and meat quality in broiler chickens1,21,30,31.

### Table 2 - Mean (± SEM) values for meat quality characteristics by season.

<table>
<thead>
<tr>
<th>Meat quality characteristics</th>
<th>Spring (n=90)</th>
<th>Summer (n=90)</th>
<th>Autumn (n=90)</th>
<th>Winter (n=90)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{pH}_{4h}$</td>
<td>6.05±0.02</td>
<td>6.05±0.01</td>
<td>6.12±0.01</td>
<td>6.28±0.02</td>
<td>***</td>
</tr>
<tr>
<td>$L^*_{0}$</td>
<td>47.20±0.24</td>
<td>46.36±0.23</td>
<td>46.06±0.24</td>
<td>44.49±0.18</td>
<td>***</td>
</tr>
<tr>
<td>$L^*_{24h}$</td>
<td>46.63±0.26</td>
<td>46.40±0.28</td>
<td>44.71±0.20</td>
<td>43.77±0.18</td>
<td>***</td>
</tr>
<tr>
<td>$a^*_{0}$</td>
<td>2.76±0.08</td>
<td>2.58±0.09</td>
<td>2.21±0.07</td>
<td>2.69±0.09</td>
<td>***</td>
</tr>
<tr>
<td>$a^*_{24h}$</td>
<td>2.69±0.09</td>
<td>1.97±0.08</td>
<td>2.25±0.09</td>
<td>2.76±0.09</td>
<td>***</td>
</tr>
<tr>
<td>$b^*_{0}$</td>
<td>5.38±0.17</td>
<td>4.60±0.13</td>
<td>6.20±0.12</td>
<td>5.44±0.17</td>
<td>***</td>
</tr>
<tr>
<td>$b^*_{24h}$</td>
<td>4.48±0.13</td>
<td>5.53±0.17</td>
<td>5.63±0.13</td>
<td>6.18±0.16</td>
<td>***</td>
</tr>
<tr>
<td>Drip Loss (%)</td>
<td>2.70±0.05</td>
<td>2.79±0.13</td>
<td>2.20±0.04</td>
<td>1.86±0.05</td>
<td>***</td>
</tr>
<tr>
<td>Cooking Loss (%)</td>
<td>19.06±0.24</td>
<td>19.27±0.32</td>
<td>16.02±0.27</td>
<td>18.09±0.27</td>
<td>***</td>
</tr>
<tr>
<td>WBSF (kg)</td>
<td>2.10±0.07</td>
<td>2.48±0.08</td>
<td>1.88±0.04</td>
<td>1.57±0.05</td>
<td>***</td>
</tr>
</tbody>
</table>

a, b, c: Mean values in the same row with different letters differ significantly ($P<0.05$).
Sig.: Significance, *** ($P < 0.001$).

### Table 3 - The incidences of DFD, normal and PSE meat by season.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Spring (n=90)</th>
<th>Summer (n=90)</th>
<th>Autumn (n=90)</th>
<th>Winter (n=90)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>DFD</td>
<td>15</td>
<td>16.67a</td>
<td>7</td>
<td>7.77a</td>
<td>31</td>
</tr>
<tr>
<td>Normal</td>
<td>64</td>
<td>71.11a</td>
<td>55</td>
<td>61.11a</td>
<td>57</td>
</tr>
<tr>
<td>PSE</td>
<td>11</td>
<td>12.12a</td>
<td>28</td>
<td>31.12a</td>
<td>2</td>
</tr>
</tbody>
</table>

a, b, c: Incidence values in the same row with different letters differ significantly ($P<0.05$).
Sig.: Significance, ** ($P < 0.01$); *** ($P < 0.001$).
The effect of season on DOA rate
Broilers transported in cool ambient temperatures (-5°C to 5°C) might be subjected to the high level of stress and their plasma corticosterone levels might be higher compared to other seasons13. Vecerék et al.19 and Caffrey et al.14 found that DOA rate was higher in both summer and winter than that in other seasons. Vecerék et al.19 also found the significant relationship of DOA rate with environmental temperatures. The researchers observed that the DOA rate was the highest (about 0.80%) at the ambient temperatures between -6°C and -3.1°C. In present study, DOA rate was the highest in winter (0.322%) and the rate was below recommended maximum level by EU (0.5%)15. In addition, the lowest DOA rate was observed in autumn (0.155%). In the present study, one possible explanation for higher DOA rate in winter might be that challenging environmental conditions were only associated with the winter season, while temperature/humidity levels found in the remaining seasons were overall mild. It was determined that transport under conditions of low ambient temperatures in winter represents a more stressful event than transport during other seasons. Therefore, transportation in the winter season might be considered the most stressful environmental challenge for broiler chickens1.

These results are in accordance with results reported by previous researchers9,12,33,34. Nijdam et al.3 found that when the ambient temperature was between 5°C and 15°C (within thermal comfort zone), DOA rate decreased. If the ambient temperature is very hot or cold, broiler chickens cannot sustain thermoregulation and may die from hyperthermia or hypothermia13,19.

The effect of season on meat quality characteristics
Pre-slaughter heat stress accelerates the rate of rigor mortis development and contributes protein denaturation. If there is a rapid decline in pH at early post-mortem stages when carcass temperatures are high, this event results in undesirable alterations such as the pale, soft and exudative (PSE) meat22,39,40. The majority of researchers point out that a decrease in pH and redness with an increase in drip loss, cooking loss and lightness of the breast meat were observed in hot ambient conditions compared with optimum or cold weather conditions14,18. In addition, some researchers found that exposure of broiler chickens to heat stress before slaughter results in higher shear force (tougher meat)27,41,42. However, some studies29,24,43 that found no significant influence of heat stress on meat quality parameters of broiler breast were also available. Chickens transported in summer had paler (+2.63 L* unit), less red (-0.79 a* unit) and less yellow (-0.65 b* unit) breast meat after 24 h blooming with higher drip loss and WBSF values than those transported in winter. These results are in accordance with those reports by Warriss and Brown29, Petracci et al.18,41 and Bianchi et al.13. In this study, although average environmental temperature was 18°C in summer, the temperature was probably high in crates. Heat exposure probably resulted in PSE meat. In the current study, the WBSF value could be expected to be lower in the summer group, which had also higher PSE meat incidence. However, incidence of PSE meat in summer group was only 31.12%. On the other hand, a higher meat ultimate pH may also result in lower shear force value17. Barbut et al.17 found a lower shear force value for DFD meat compared to PSE meat. Therefore, in the current study, the fact that DFD meat incidence was very high in the winter season (35.55% vs 7.77%) may be one of the possible reasons for the higher WBSF value in the summer group compared to the winter group. On the other hand, cold ambient temperatures before slaughter process may cause stress to broiler chicken and might affect meat quality characteristics. Several researchers found that breast meat from cold-stressed birds had lower drip loss, lower shear force (more tender) and darker colour due to higher pH compared with those from optimum weather conditions32,35. Similar results were also found in the current study. Seasonal cold exposure during transportation leads to glycogen depletion in the muscle of broiler chicken in order to maintain body temperature. As a result, these broiler chickens have less muscle glycogen stores during slaughter to transform it to lactic acid, which might result in high meat pH.

Incidence of DFD, normal and PSE meat
It is pretty difficult to compare the incidence of PSE or DFD with other studies because of differences in limit values of L* for PSE meat. In the previous studies, incidence of PSE meat in chicken breast was reported as 37-47% for USA43 (who classified breast meat as PSE-like if L*>54), 20% for England43 (pH<5.7 and L*>53.0) and 10% for Europe44. The overall incidence of PSE meat was 11.39% in the current study, which is in accordance with previous studies. Petracci et al.18 reported that the incidence of PSE meat (L*>56.0) was higher in summer (26.7%) than winter (5.9%). A similar pattern of increase in PSE meat was reported by Van Laack et al.16 (L*>55.0) and Bianchi et al.13 (L*>53.0). Supporting these reports, the highest incidence of PSE meat was observed in summer (31.12%) while no PSE meat was occurred in winter (0%) in present study.

The overall incidence of DFD meat was 28.61% in the current study. Chickens transported in winter had the highest incidence of DFD meat (55.55%), while summer transportations resulted in the lowest incidence (7.77%). Dadgar et al.20 reported the DFD meat incidence as 8% in the chickens transported between -8°C to 0°C. Lower DFD meat incidence in Dadgar et al.20 might be a result of DFD defining criteria in their study (pH>6.1 and L*<46) was different from the current study.

CONCLUSIONS
In the conditions of the current study, season affected both DOA rate and meat quality characteristics. The results may indicate that transportation in winter might be resulted with increased DOA rate and decreased normal breast meat incidence. However, the incidence of PSE meat was the highest in summer. Therefore, transportations of broiler chickens within thermal comfort zone ranges are recommended to reduce the DOA rate and to improve the meat quality. On the other hand, it should be considered that results found in the current study are valid for environmental conditions in the Northern Region of Turkey. Therefore, these results cannot be generalized for either other Regions of Turkey or other European/Asiatic Regions.
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References