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Effects of Transportation Distance, Slaughter Age, and Seasonal Factors on Total Losses in Broiler Chickens

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ABSTRACT

This study aimed at determining the total losses associated with the season, transportation distance, and slaughter age during the transportation of broilers from poultry farms to slaughterhouses in Turkey. All data and parameters were statistically analyzed and the change in total loss during transportation was evaluated by two-way analysis of variance to determine which factors or variables affect this change. Total transportation losses were compared among the four seasons of the year, two slaughter ages (younger broiler, 31-39 days of age; older broilers 40-46 days of age) and three distance ranges (short, ≤50 km; medium, 51-150 km; and long, ≥151 km). Total losses of 259.40 g, 307.35 g, and 350.14 g were determined for short, medium and long distances, respectively, indicating that losses increased with transportation distance ($p<0.05$). Broilers slaughtered at a younger age presented lower total losses than those slaughtered at an older age ($p<0.05$). When seasons were evaluated, the highest total loss was determined in the summer, which was not statistically different from that calculated for autumn, whereas total transportation losses in spring and winter were found relatively lower. The study showed long-distance transportation in the winter considerably increased total losses to levels similar to those obtained in the summer.

INTRODUCTION

During the transportation of broiler chickens in integrated production systems from poultry farms to processing plants and during pre-slaughter stages, significant production losses may occur due to human and environmental factors. Economic losses in broiler production occur particularly during catching of the broilers on the farms, loading into vehicles, transportation conditions, and lairage time in the processing plant (Warriss *et al.,* 1992; Nijdam *et al.,* 2004; Schwartzkopf-Genswein *et al.,* 2012; Vieira *et al.,* 2015; Vecerek *et al.* 2016).

Catching on the farms and loading into vehicles are stages of the production process which are significantly affected by the human factor. Stress and other adverse incidents that may be caused by the personnel during catching and loading negatively affect the quality of broiler chicken meat and increase losses due to pre-slaughter mortality (Ekstrand, 1998; Knierim & Gocke, 2003; Orlic *et al.,* 2007; Haslam *et al.,* 2008; Zhang *et al.,* 2009; Adzitey, 2011;).

Losses during transportation from the farms to the processing plants depend both on broiler-related factors, such as body weight, age, and health status (Dadgar *et al.,* 2011; Strawford *et al.,* 2011; Schwartzkopf-Genswein *et al.,* 2012), as well as on transportation conditions, such vehicle, crate, and road conditions, and bird density in the crates (Bayliss & Hinton, 1990; Chauvin *et al.,* 2011). Environmental factors, including temperature and humidity (Warriss *et al.*, 2005;

Chauvin *et al.,* 2011), season and time of the day (Moran & Bilgili, 1995; Petracci *et al.,* 2006; Vecerek *et al.,* 2006; Drain *et al.,* 2007; Voslarova *et al.,* 2007; Elsayed, 2014), distance between the poultry farm and the processing plant (Nijdam*et al.,* 2004; Voslarova *et al.,* 2007; Ondrasovicova *et al.,* 2008; Sowinska *et al.,* 2013; Vecerek *et al.,* 2016), and transportation time (Bayliss & Hinton, 1990; Warriss *et al.,*1992; Nijdam *et al.,* 2004; Bianchi *et al.,* 2005) also influence production losses.

In Turkey, broiler slaughter age depends on the market demand for poultry products and on the production and sale policies established by the poultry companies. Broilers included in the slaughter program are generally caught and placed in transport crates by workers on the contracted poultry farms. The crates are then loaded into company-owned vehicles and transported to the processing plants by road. The birds are weighed on the vehicles at reception section at the entrance of the processing plant, and then shackled on the slaughter line after a lairage period, which depends on the slaughter order (Aral *et al.,* 2014).

This study aimed at determining the total volume of losses (g/broiler) due to live weight losses and mortality during the transportation of broilers from the farms to processing plants, and evaluating the impacts of season, transportation distance, and slaughter age on such losses.

MATERIAL AND METHODS

The study assessed a total of 26,270 transportation operations to processing plants of broiler enterprises contracted by a private company during the period of 2012-2013. The records of such transportation operations constitute the material of this study. The effects of season (autumn, winter, spring, and summer), transportation distance (short, ≤50 km; medium, 51-150 km, and long, ≥151 km) and broiler slaughter age (younger, 31-39 days; older, 40-46 days) on the total losses (live weight losses + mortality) occurring during transportation were evaluated by two-way analysis of variance (Generalized Linear Models – GLM: Least Squares Analysis). Seasonal average air temperatures recorded in the field study were 14.5, 4.8, 17.4, and 24.3 Celsius degree (°C) in the autumn, winter, spring, and summer, respectively. Mortality loss was calculated as the number of dead birds during the transport from poultry farms to slaughterhouse multiplied by the average slaughter weight of all broilers in the study, and expressed in grams. Mortality loss was then added to live weight loss to determine total loss related to transportation, which was calculated as: total loss (g/broiler) = mortality loss (g) + live weight loss (g). Average live weight (g), mortality rate (%), and average number of transported broilers were calculated for the periods before and after transportation. The statistical analyses were conducted using SPSS 14.01 software package. The model used in the analysis is shown in equation [1];

$$y = \mu + \alpha i + \beta j + \delta k + (\alpha\beta)ij + (\alpha\delta)ik + (\beta\delta)jk + \varepsilon \quad [1]$$

where:

y: Total loss (g/broiler); μ: general mean; αi: effect of season (i: spring, summer, autumn, winter); βj: effect of transportation distance (j: 50 km or less, 51-150 km, 151 km and above); δk: effect of slaughter age (k: 31-39 days, 40-46 days); $(\alpha\beta)ij$: season × transportation distance interaction; $(\alpha\delta)ik$: season × slaughter age interaction; $(\beta\delta)jk$: transportation distance × slaughter age interaction; and ε: random error. For characteristics where the variation among groups was found to be significant, Tukey's multiple comparison test was employed to determine from which group and/or groups the variation stemmed.

RESULTS

The findings obtained from the analysis of the data acquired in this study are given in the tables and figures below.

Table 1 shows the seasonal distribution of all transportation operations between poultry farms and processing plants and of the number of animals transported throughout the year.

As can be seen in Table 1, 82.77 million broilers in total were transported to the processing plants, at an

Table 1 – Seasonal distribution of transportation operations examined in the study and total number of broilers transported.

Season	Number of transportation operations	Rate (%)	Total number of broilers transported (millions)	Rate (%)	Average number of broilers transported
Spring	6544	24.9	20.39	24.6	3117
Summer	7428	28.3	23.47	28.4	3161
Autumn	6761	25.7	21.77	26.3	3220
Winter	5537	21.1	17.12	20.7	3092
Total	26270	100.0	82.77	100.0	3150

average density of 3,150 broilers/transportation. The transportation operations and the total number of broilers transported were found to be the highest in summer and the lowest in winter.

The results relating to live weight, mortality during transportation, and average number of live broilers calculated for the periods before and after transportation are given in Table 2 below.

Table 2 – Live weight, average number of broilers before and after transportation, and mortality rate during transportation.

Parameter	Before Transportation	After Transportation	Difference	*p* value
	$\bar{X} \pm S_{\bar{x}}$	$\bar{X} \pm S_{\bar{x}}$	$\bar{X} \pm S_{\bar{x}}$	Probability
Live weight (kg)	2556 ± 0.002	2256 ± 0.002	0.299 ± 0.001*	<0.001
Number of broilers	3150.8 ± 7.324	3133.03 ±7.728	17.76 ± 0.172*	<0.001
Mortality (%)		0.565 ± 0.005		

$\bar{X} \pm S_{\bar{x}}$: Mean ± Standard error; *: Statistically significant by the paired-sample T Test)

Average live weight loss, mortality loss, and total loss associated with transportation are given in Table 3.

Table 3 – Average live weight loss, mortality, and total loss.

Total Losses (g/broiler)	$\bar{X} \pm S$	Percentage*
Live weight loss	285.33 ± 179.71	92.30
Mortality loss	14.41 ± 21.19	7.70
Total loss	299.74 ± 181.26	100

$\bar{X} \pm S$: Mean ± Standard deviation; *: Percentage of total loss

It was found that 92.3% of the total loss associated with transportation was due to broiler live weight loss (including excreta), and 7.7% to mortality (Table 3).

In the model used for the two-way analysis of variance, total amount of loss is the dependent variable, whereas season, distance, and slaughter age are independent variables. Table 4 shows the sources of variance used in the analyses.

Table 4 – Sources of variance in ANOVA.

Sources of Variance	Sum of Squares	SD	Mean of Squares	F value	*p* value
Corrected model	93704777.6	17	5512045.7	188.1	<0.001
Constant	898566555.7	1	898566555.7	30661.4	<0.001
Season	25162415.9	3	8387472.0	286.2	<0.001
Transportation distance	9063010.8	2	4531505.4	154.6	<0.001
Slaughter age	5081288.8	1	5081288.8	173.4	<0.001
Season × Transportation distance	4251428.9	6	708571.5	24.2	<0.001
Season × Slaughter age	606226.5	3	202075.5	6.9	<0.001
Transportation distance × Slaughter age	489711.7	2	244855.9	8.4	<0.001
Error	769344088.9	26252	29306.1		
Total	3223254215.9	26270			
Corrected model	863048866.5	26269			

DF: Degree of Freedom; R^2 (Coefficient of Determination): 0.109

The null hypothesis (H_0) was that the effect of season, distance, and slaughter age on total loss was not significant (the common slope is zero). The null hypothesis that the common slope is zero was rejected since F = 188.1 and $p<0.001$. All variables were closely associated with the total amount of loss ($p<0.001$). The effect of season, distance, and slaughter age on total losses was significant. Furthermore, the interactions season x distance, season x slaughter age, and distance x slaughter age were also statistically significant ($p<0.001$).

Total losses (g/broiler) at the different slaughter ages (31-39 days and 40-46 days) and distance ranges (short, medium and long) were compared within season, and the results obtained are given in Table 5 below.

Table 5 – Descriptive statistics and multiple comparisons of total losses (g/broiler) as affected by season, slaughter age, and transportation distance.

Season	Slaughter Age Groups	Transportation Distance (km)					
		Short (≤50 km)		Medium (51-150 km)		Long (≥151 km)	
		N	$\bar{X} \pm S_{\bar{x}}$	N	$\bar{X} \pm S_{\bar{x}}$	N	$\bar{X} \pm S_{\bar{x}}$
Spring	Younger (31-39 d)	675	164.29 ± 3.89^{a,A,*}	818	229.76 ± 4.94^{b,A,*}	131	230.95 ± 14.92^{b,A,*}
	Older (40-46 d)	1086	202.45 ± 4.24$^{a,X,\#}$	3314	251.73 ± 2.83$^{b,X,\#}$	520	284.13 ± 7.09$^{c,X,\#}$
Summer	Younger (31-39 d)	607	299.08 ± 5.25^{a,B,*}	1053	303.20 ± 4.69^{a,B,*}	161	336.55 ± 12.12^{b,B,*}
	Older (40-46 d)	1182	310.35 ± 4.99^{a,Y,*}	3755	359.09 ± 3.21$^{b,Y,\#}$	670	383.23 ± 7.37$^{c,Y,\#}$
Autumn	Younger (31-39 d)	780	289.17 ± 4.80^{a,B,*}	787	302.83 ± 5.49^{b,B,*}	104	304.92 ± 13.38^{b,B,*}
	Older (40-46 d)	1019	337.62 ± 5.38$^{a,Y,\#}$	3408	367.86 ± 3.53$^{b,Y,\#}$	663	378.01 ± 6.71$^{c,Y,\#}$
Winter	Younger (31-39 d)	592	211.43 ± 5.28^{a,C,*}	783	229.81 ± 5.05^{b,A,*}	111	326.05 ± 12.72^{c,B,*}
	Older (40-46 d)	883	222.23 ± 4.79^{a,Z,*}	2551	274.36 ± 3.41$^{b,Z,\#}$	617	380.71 ± 8.34$^{c,Y,\#}$
General		6824	259.40 ± 1.90^{a}	16469	307.35 ± 1.45^{b}	2 977	350.14 ± 3.39^{c}

a,b,c: The difference among transportation distance groups that bear different letters in the same row is statistically significant.

A,B,C: The difference between the groups of slaughter age of Group 1 that bear different letters in the same column is statistically significant.

X,Y,Z: The difference between the groups of slaughter age of Group 2 that bear different letters in the same column is statistically significant.

*,#: The difference between the groups of slaughter ages, namely, Group 1 and Group 2 that bear different symbols for each season is statistically significant.

As shown in Table 5, the total losses were 259.40 g/broiler for short transportation distance, 307.35 g/broiler for medium distance, and 350.14 g/broiler for long distance, indicating that total losses increases with distance, and this increase was statistically significant (Fig. 1).

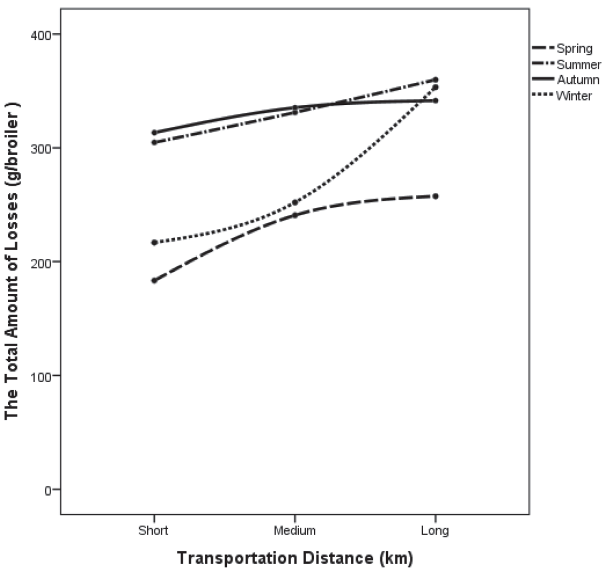

Figure 1 – Change in total losses in each seasonas a function of transportation distance.

The total loss of broilers slaughtered at a younger age (31-39 days) was lower those slaughtered at an older age (40-46 days), independently of season or transportation distance.

Relative to season, the highest losses were observed during summer, which, however were not statistically different from those calculated during autumn. Total losses were lower during spring, followed by winter. However, total losses during long-distance transportations during winter increased considerably and reached a level equal to the amount of loss during summer (Fig. 2).

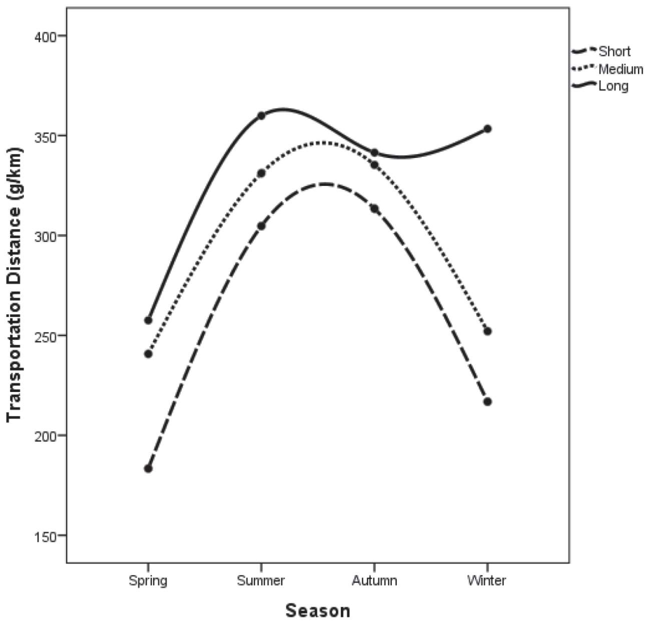

Figure 2 – Change in total losses due to transportation distance as a function of season.

Table 6 shows ANOVA estimations of the parameters transportation season (spring, summer, autumn, winter-reference), transportation distance (short distance, medium distance, long distance-reference) and slaughter age (Group 1 and Group 2-reference).

Total losses were highest in winter and summer, and lowest in spring. Total losses in the spring were 97.22 g lower and in the summer 5.16 g higher relative to those calculated for the winter (reference season). It was established that total losses increased as transportation distance from the poultry farms to the processing plants increased. Total losses were 106.55 units lower at medium distance and 153.79 units lower at short distance compared with long distance of transportation. In addition, total losses of broilers slaughtered at a younger age (31-39 days age) due to transportation were 48.83 units lower than those slaughtered at an older age (40-46 days age).

Table 6 – ANOVA parameter estimations.

Parameters		B	T value	*p* value	95% confidence interval for B value
Season	Constant term	379.82	58.34	<0.001	367.06, 392.58
	Spring	-97.22	-10.42	<0.001	-115.51, -78.93
	Summer	5.16	0.58	0.557	-12.05, 22.37
	Autumn	-1.54	-0.17	0.863	-19.03,15.94
	Winter (Reference)				
Distance of Transportation	Short	-153.79	-18.92	<0.001	-69.73, -137.87
	Medium	-106.55	-14.86	<0.001	-120.61, -92.50
	Long (Reference)				
Age of Slaughter	Group-1 (31-39 days)	-48.82	-5.1	<0.001	-67.59, -30.06
	Group-2 (40-46 days) (Reference)				

B: Slope of the trend line of the independent variable

DISCUSSION

In studies on broiler transportation, the main factors affecting the mortality rate and live weight loss during transportation between the farms and the processing plants are catching method (Ekstrand, 1998; Knierim & Gokce, 2003), transportation distance (Nijdam *et al.,* 2004; Vecerek *et al.,* 2006; Voslarova *et al.,* 2007; Ondrasovicova *et al.,* 2008; Sowinska *et al.,* 2013), time of transportation (Bayliss & Hinton, 1990; Warriss *et al.,* 1992; Nijdam *et al.,* 2004; Bianchi *et al.,* 2005; Luptakova *et al.,* 2012), lairage time at the reception area (Bayliss & Hinton, 1990; Nijdam*et al.,* 2004, Vieira *et al.,* 2010), transportation duration (Bayliss & Hinton, 1990), crate stocking density (Bayliss & Hinton, 1990; Chauvin *et al.,* 2011), seasonal conditions (Vecerek *et al.,* 2006; Petracci *et al.,* 2006; Voslarova *et al.,* 2007; Drain *et al.,* 2007; Elsayed, 2014), daily average temperature (Warriss *et al.,* 2005; Elsayed, 2014), and weather conditions (Chauvin *et al.,* 2011).

The present study was conducted to evaluate the effects of season, transportation distance, and slaughter age on total loss (live weight loss and mortality) of broilers transported from the farms to the processing plant. Average live weight loss and mortality rate during all transportation operations throughout the year were 0.285 kg and 0.565%, respectively. A study conducted in the USA reported that the calculated 4.2% average loss during the transportation of broilers was due to live weight loss and 1.8% originated from excreta (Taylor *et al.,* 2001).

Transportation distance significantly affected total losses, with average total transportation losses of 259.40 g when broilers were transported for a short distance, 307.35 g for medium distance, and 350.14 g for long distance. These results are in agreement with several other reports. An experimental study conducted in Slovakia in 2008 reported that transportation of 6- to 7-week-oldbroilers from two different farms 30 km and 120 km distant from the processing plant resulted in a live weight loss of 100 and 306 g per broiler, respectively (Ondrasovicova *et al.,* 2008). In a study conducted in Turkey in May 2012, six transportation durations were evaluated (Group 1: 0-120 minutes, Group 2: 121-240 minutes, Group 3: 241-360 minutes, Group 4: 361-480 minutes, Group 5: 481-600 minutes and Group 6: 600 minutes or longer above). Mortality rates of 0.29, 0.38, 0.40, 0.43, 0.42, and 0.46%, respectively, and average live weight losses of 4.33, 4.95, 5.55, 5.73, 6.02, and 6.63%, respectively, were obtained (Aral *et al.,* 2014). A study investigating the effect of different transportation distances of broilers to processing plants in Poland (0, 100, 200, and 300 km) reported that 1.41% live weight loss when broilers were transported for a distance of 100 km compared to not transported broilers, 2.65% between 200 and 100 km, and 2.36% between 300 and 20 km (Sowinska *et al.,* 2013). The mortality rate during 432 transportation operations from 55 poultry farms to 2 processing plants at distances ranging from 15 to 134 km in Jordan in 1993-1994 was 0.40% on average, and increased with transportation distance, with the highest mortality rate recorded in August (Alshawabkeh & Tabbaa, 1997). In a study conducted in Italy, the mortality rate and transportation time of broilers between 38 to 55 days of age of 321 flocks were examined in 3 groups (Group 1: <3.5 hours, Group 2: 3.5-5 hours, Group 3: >5 hours). The mortality rates were 0.24%, 0.41% and 0.45%, respectively, and live weight losses were 1.27%, 1.87% and 2.09%, respectively (Bianchi *et al.,* 2005). A study in Egypt examined the effect of transportation distance on mortality rate of broilers transported for 15, 50, and 150 km, and reported mortality rates of 0.14, 0.25, and 0.86%, respectively (Elsayed, 1998). In study conducted in Czech Republic, the mortality rate of broilers transported for not more than 50 km to the processing plant was 0.146%, whereas, when transported for more than 300 km, 0.862% mortality was recorded (Vecerek *et al.,* 2006).

Various studies report that climate and seasonal conditions have a significant effect on mortality rate (Petracci *et al.,* 2006; Chauvin *et al.,* 2011). A study on 13937 transportation operations in Brazil in 2006 indicated that the average mortality rate for transportation distances ranging from 24 km to 242 km was 0.33%, with the highest mortality rate recorded during summer (0.42%) (Vieira *et al.,* 2014).

The highest total loss in the present study was recorded in the summer. However, total loss significantly increased when broilers were transported for long distances during winter, reaching a similar level of that recorded during the summer. Vieira *et al.* (2015) observed that the highest level of pre-slaughter losses occurred during hottest periods and emphasized the importance of environmental control during pre-slaughter lairage of broiler chickens in their research conducted in Brazil.

In a study conducted in the Czech Republic by Vecerek *et al.* (2016), transport-related mortality rate ranged between 0.31% and 0.72% in all broiler transports. The effects of season and transport distance on mortality were statistically significant (p<0.001) and the highest mortality occurred during the winter months (0.55%) and for transportation distances longer than 300 km (0.72%).

The results of the present study are consistent with reports of the Czech Republic and Egypt, which indicated that the effect of season on mortality rate is the highest in summer (June, July and August) and winter (December, January and February), and that mortality rate increases at very high and very low temperatures (Vecerek *et al.,* 2006; Elsayed, 2014). A study conducted in Brazil reports the mortality rates during pre-slaughter operations to be 0.42% in summer, 0.39% in spring, 0.28% in winter and 0.23% in autumn (Vieira *et al.,* 2011).

When evaluating the effect of slaughter age, lower total losses were determined in broilers slaughtered at a younger age (31-39 days) than that in those slaughtered at an older age (40-46 days), independently of season and transportation distance. In the study of Moran & Bilgili (1995), after 6 hours of active transportation and 4 hours of waiting time prior to slaughter, average live weight losses of 39- and 53-day-old broilers were 5.8% and 6.2%, respectively.

In addition to geographical, climatic and seasonal aspects, many other factors affect broiler mortality and live weight losses during transportation in the broiler industry, including production, slaughter and transportation conditions, transportation infrastructure, and transportation vehicles.

In conclusion, according to the results of this study, transportation operations should be carried out for short distances, taking into the economically optimal slaughter age and in such a manner as to ensure minimum level of impact of environmental and climatic conditions on the birds. These factors should be taken into consideration in production planning. Further studies in different regions and companies should be carried out to further corroborate these recommendations.

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