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Original Article

Evaluation of the Factors Affecting the Mortality Rate in Poultry Transport via Panel Data Analysis

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ABSTRACT

In this study, we evaluated some of the factors that affect mortality rate during transport from broiler poultry houses to slaughterhouses by conducting panel data analysis. We analyzed the data obtained from 26,599 broiler farms transported to the slaughterhouse from contracted broiler farms in 11 provinces in Turkey. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were performed to evaluate whether the series forming the dataset were stationary. To analyze individual effects, parameters were estimated using fixed and random effects models. To decide which of the two models was valid, the Hausman test and fixed effects panel data analysis were performed. The fixed effects model explained 90.93% of the changes in the mortality rate through the independent variables. In the non-periodical fixed-effect panel data analysis, the mortality rate shows a significant ($p<0.01$) effect between the number of animals alive, number of animals dead, mean and total live weight at poultry farm exit, mean live weight at slaughterhouse arrival, and different variables. Our results showed that the estimation equations developed using model parameters to determine the mortality rate during transportation from different provinces could contribute to effective production planning.

INTRODUCTION

Animals, including farm animals, are transported for various purposes, such as selling (in animal markets) and food processing (slaughterhouses). During transport, animals experience stress, which can differ between species and individuals within a species. Broiler chickens are highly sensitive to stress (Guerrero-Legarreta, 2010). As broiler chickens are very commonly transported worldwide, the economic losses resulting from the risk of transportation are important (EFSA, 2004).

The effect of human and environmental factors on broiler chicken transport from the poultry farm to the slaughterhouse can significantly decrease production due to stress. These losses can occur while catching individuals, loading them into vehicles, transporting them, and waiting at the slaughterhouse (Warriss *et al.,* 1992; Nijdam *et al.,* 2004; Schwartzkopf-Genswein *et al.,* 2012; Vieira *et al.,* 2015; Vecerek *et al.,* 2016).

Broilers are rested before slaughtering to reduce stress levels caused by transport, but prolonged resting periods can increase stress due to hunger, thirst, and frequency of settlement, thus increasing the mortality rate (Nijdam *et al.,* 2004; Warris, 2010).

Some studies have shown that transportation distance and the time taken to transport broilers to the slaughterhouse at slaughter age significantly affect live weight loss. Longer transport times and distances can increase live weight loss in broilers (Ondrašovičová *et al.,* 2008; Oba *et al.,* 2009; Aral *et al.,* 2014).

The amount of waste and the losses incurred during transport from the poultry farm to the slaughterhouse is influenced by several factors, which include the mean body weight of the chicken (Nijdam *et al.,* 2004), the number of animals being transported (Aral *et al.,* 2014; Arıkan, 2017), the mortality rate (Lupo *et al.,* 2009), lairage time at the slaughterhouse (Vieira *et al.,* 2010; Lupo *et al.,* 2009; Pirompud *et al.,* 2022), and microclimate conditions (Santos *et al.,* 2020).

In this study, we conducted panel data analysis to assess the factors that increase mortality rate during the transport of broiler chickens from poultry farms to the slaughterhouse. These factors included the number of live animals being transported, the number of deaths during transport, the mean and total live weight at the exit from the poultry farm, the mean live weight upon arrival at the slaughterhouse, the difference in live weight between poultry farm exit and slaughterhouse arrival, and the lairage duration at the slaughterhouse.

MATERIALS AND METHODS

Dataset

We collected the data and transport records of 83,840,909 chickens that were transported to the slaughterhouse of a company. This involved 26,599 transports from contracted broiler farms in 11 provinces affiliated with an integrated poultry company operating in Turkey in 2022.

To examine the factors affecting mortality rate (MrRt), which was considered to be a dependent variable in this study, we analyzed several independent variables, including the number of animals transported from the poultry farm to the slaughterhouse (TNa), the number of live animals arriving at the slaughterhouse (LaNa), the number of dead animals in the slaughterhouse (ExNa), the mean live weight at poultry farm exit (MLWe), the total body weight at slaughterhouse arrival (TBW), the mean live weight of the hens upon arrival at the slaughterhouse (MLWa), the live weight difference (difference) between the poultry farm and slaughterhouse, and the lairage time in the slaughterhouse (LT). The data were analyzed using the EViews 8 Enterprise Edition software (EVIEWS, 2016).

Method

Panel data, which are defined as time series of cross-sections or cross-sectional data of the time series (Greene, 2003), can also be interpreted as the expression of cross-sectional observations of specific units, such as firms, countries, or households considering the dimension of time (Baltagi, 2001).

Panel regression models, in which datasets containing cross-section and time series combinations are used, include many methods such as one-way and two-way fixed effects and random effects models, dynamic panel analysis, and generalized least squares (LCC). In this study, one-way fixed effects and random effects models were used.

Panel Unit Root Test

To determine the stationarity of the variables, a panel unit root test was conducted using the method proposed by Im *et al.* (2003).

This test can be performed to calculate the mean test statistic of augmented Dickey-Fuller (ADF) tests for each unit in the panel (Saraçoğlu & Doğan, 2005).

For the panel unit root test, the model used was $\Delta yit = \alpha i + \beta i\ yi,t\text{-}1 + eit$,

Here, i = 1, ..., N and t = 1, ..., T,

were defined by Im *et al.* (2003). The null hypothesis (H0) was

$\beta i = 0$ for all i,

and the alternative hypothesis (H1) was $\beta i < 0$ for i = 1, 2, ..., N1 and $\beta i = 0$ for i = N1 + 1, N1 + 2, ..., N.

Accepting the null hypothesis indicates the presence of a panel unit root, while accepting the alternative hypothesis suggests the absence of a panel unit root. Im *et al.* (2003) tested the "no unit root" hypothesis using t-bar statistics.

One-Way Fixed Effects Model

To analyze the panel data, the variables were represented using two subscripts to indicate the time and cross-sectional dimensions. This differed in terms of the time series and cross-sectional data. The model $Y_{it} = \alpha_i + X'_{it}\beta + e_{it}$ is a fixed-effects model, where i is the cross-section index and t is the time index. The fixed-effects model can be estimated using the within-group estimator and the least squares with a dummy variable estimator (LSDV), which can satisfy the basic assumptions (Greene, 2003).

$$Y_{it} = \alpha_i + X'_{it}\beta + e_{it} \qquad (1)$$

i = 1, ………..N

t = 1,…………..T

$$E(e_{it}) = 0,\ Cov(e_{it}, e_{jt}) = 0,\ Var(e_{it}) = \sigma_e^2 \text{ ve } E(X_{it}, e_{it}) = 0$$

In the model, X_{it}, represents the vector of explanatory variables, Y_{it} represents the dependent variable, β represents the slope coefficients, e_{it} denotes the error term, and α_i represents the constant term unit effect. We analyzed the effect of time and units, assuming that the constant term did not change with time but could vary for each unit. The constant term did not change between units, but varied over time. To determine the coefficients of the model ($Y_{it} = \alpha_i + X'_{it} \beta + e_{it}$) using the within-group estimator, the mean values of the observations of each individual were subtracted from the observations of that individual. Then, using this transformed data, the least squares (LCC) method was used for estimation (Kennedy, 2006).

The model was analyzed based on two effects: the group effect, which assumes that the constant term does not change over time but can vary across units, and the time effect, which assumes that the constant term does not change across units, but can change over time.

An LCC estimator with a dummy variable for each unit can be used as an alternative method to account for the differences in constant terms. However, this method, also known as LSDV, might result in a reduction in the degree of freedom and the problem of multicollinearity, due to the use of many dummy variables (Kennedy, 2006). When using a dummy variable for each unit, the fixed effects model in equation (1) can be expressed as follows (Pazarlıoğlu & Gürler, 2007):

$$Y_{it} = \alpha_1 D_1 + \ldots + \alpha_N D_N + X'_{it} \beta + e_{it} \qquad (2)$$

Both models assume that the differences between units or times are due to differences in constant terms (Greene, 2003). Therefore, it is assumed that variable coefficients do not vary between units or times. To investigate the group effect, we assumed that the constant term did not change over time, but could vary between units. To investigate the time effect, the constant term was assumed to not change across units, but to potentially vary over time.

To determine the difference between the units in the fixed effects model, a group significance test was performed. The following F statistic was evaluated under the null hypothesis that the constant term did not change between units (Greene, 2003):

$$F_{(N-1,NT-N-K)} = \frac{(R^2_{LSDV} - R^2_{Pooled})/(N-1)}{(1-R^2_{LSDV})/(NT-N-K)} \qquad (3)$$

In the F statistic (3), represents the coefficient of determination of the LSDV model, and represents the coefficient of determination obtained from estimating the panel data with EKK. T represents the number of observations for each unit, N represents the number of units (groups), and K represents the number of explanatory variables. When the computed F statistic is greater than the table value, the null hypothesis is rejected, indicating the presence of a group effect or a difference between units.

The same test statistic can be used to determine the difference over time. In this case, the LSDV model with a time-varying constant term was used, and the null hypothesis stated that the constant term did not vary with time.

One-Way Random Effects Model

An alternative model to consider is the random effects model. When individual effects are not related to explanatory variables and the constant terms of the units are randomly distributed across units, the model should be structured accordingly (Greene, 2003).

In random effects models, the variations associated with cross-sections and/or time are included as a component of the error term in the model. The advantage of random effects models over fixed effects models is the elimination of the loss of degrees of freedom (Baltagi, 2001).

In this study, we used a one-way random effects model, which assumed that the difference between the cross-sections was a component of the error terms in the model. The model was estimated with i representing the cross-sections and t representing the time, as shown in equation (4):

$$Y_{it} = \alpha + X'_{it}\beta + (\mu_i + v_{it})$$
$$i = 1, \ldots\ldots N \qquad t = 1, \ldots\ldots T$$
$$E(u_i) = (v_{it}) = 0,\ Cov(u_t, v_{jt}) = \sigma_{u,v},\ Var(u_i) = \sigma^2_u \text{ ve } E(X_{it}, u_t) = 0 \qquad (4)$$

In this model, X_{it} represents the vector of explanatory variables, Y_{it} represents the dependent variable, β represents the vector of variable coefficients, and α represents the constant term. The error terms in the model are assumed to be independently and identically distributed with zero variance. The error term μ_i represents unobservable random differences between the units and v_{it} represents the remaining errors. The individual error terms μ_i, which express the cross-sectional effect, are not related to each other, and v_{it} is not related to the panel error term. By combining these two error terms, a model can be obtained, assuming that the data follows a normal distribution.

$$Y_{it} = \alpha_i + X'_{it} \beta + e_{it} \qquad (5)$$

$$e_{it} = \mu_i + v_{it}, \qquad (6)$$

The error terms in this model consist of two components, and the error term variance (6) does not exhibit constant variance and zero covariance properties. Thus, the LCC estimator cannot be applied to this model, since the error terms lack the desired properties. Instead, methods such as appropriate versions of the Generalized Least Squares (GLS) method can be used. To apply the GLS method to these models, the error term and variance components must be known. In this study, the variance components were determined using the methods described by Swamy & Arora (1972) and Wallace & Hussain (1969). Swamy & Arora (1972) recommended obtaining variance components from within-group and between-group regression models (Baltagi, 2001). In this study, we estimated the unit effect using the Swamy & Arora (1972) method, and the time effect using the Wallace & Hussain (1969) method.

Hausman Test

The fixed effects model is commonly used in panel data analysis with desirable statistical properties. However, if the random effects model is more effective than the fixed effects model, it should be used instead. Therefore, it is necessary to determine which of the two models is more effective, since both are consistent but may differ in effectiveness. Several studies have used this effectiveness test, known as the Hausman test, which fits the Chi-squared distribution with k degrees of freedom, to determine which model is more effective between the fixed effects model and the random effects model (Baltagi, 2001).

The null hypothesis states that the coefficients obtained from the random effects model and those obtained from the fixed effects model are not different. The rejection of the null hypothesis indicates that the random effects model is more effective than the fixed effects model.

RESULTS

The details of the parameters used in the study are presented in Table 1.

The mean mortality rate was found to be 0.57%, and the mean live weight loss due to transport was 0.30 kg (C/A-B)-D) (Table 1). The total waste amount was calculated as the sum of the decrease in production amount due to live weight loss and deaths during transport. The values calculated for mean live weight loss, mortality loss, and total waste due to transport are presented in Table 2.

Table 1 – The details of the parameters used in the study.

Parameter	Abbreviation	Mean	Std. deviation	Min	Max
A-Number of Transported Animals (n)	TNa	3151.44	1187.53	134.00	7463.00
B-Number of Dead Animals (n)	ExNa	17.96	1187.51	0.00	745.00
(A-B) Number of Live Animals (n)	LaNa	3133.48	1181.22	134.00	7418.00
(B/A*100) Mortality Rate (%)	MrRt	0.57	0.86	0.00	27.56
C-Total Live Weight at Poultry Farm Exit (kg)	TBW	8018.04	3055.28	348.94	16709.11
(C/A-B) Mean Body Weight (kg)	MLWe	2.56	0.27	1.85	2.87
D-Mean Body Weight at Slaughterhouse Arrival (kg)	MLWa	2.26	0.31	1.20	2.86
(C/A-B)-D*(A-B) Difference (kg)	Difference	940.04	672.79	0.44	6032.21
Lairage Time (minutes)	LT	325.96	219.39	0.00	1438.00

Table 2 – Mean live weight loss, mortality, and total waste due to transport.

Total Losses (kg/broiler)	Mean Number of Animals (n)	Mean Weight (kg)	Total Loss (kg)	Percentage (%)
Live weight loss	3133.48 ±1181.22	0.30	940.044	95.37
Mortality loss	17.96 ±1187.51	2.56	45.977	4.62
Total	3151.44 ±1187.53	-	986.021	100

As shown in Table 2, 95.37% of the total transport waste was attributed to the reduction in the live weight of broiler chickens (including excretion), while 4.62% was due to the loss of production caused by deaths.

We performed the Extended Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to assess unit root (stationarity) in the dataset. The results of the unit root tests are presented in Table 3.

The panel data was stationary, as determined by the ADF and PP tests ($p<0.05$) (Table 3), and satisfied one of the requirements for panel data analysis.

In the panel data analysis, the parameters were estimated using fixed effects and random effects models to evaluate individual effects. The Hausman test was performed to determine the statistically valid

Table 3 – The ADF and PP unit root test results of the variables in the Newey-West and Bartlett kernel panel data.

1st Degree Differences taken			*p*	Cross-sections	Obs
Number of Lives	ADF	703.317	0.0001	11	4007
	PP	910.710	0.0001	11	4015
Number of Dead	ADF	602.189	0.0001	11	3997
	PP	1182.96	0.0001	11	4015
Number of Animals Transported	ADF	703.063	0.0001	11	4007
	PP	910.136	0.0001	11	4015
Mortality Rate	ADF	615.821	0.0001	11	3989
	PP	1023.75	0.0001	11	4013
Average Live Weight Exiting the Poultry farm	ADF	414.327	0.0001	11	4015
	PP	418.568	0.0001	11	4015
Total Live Weight Exiting the Poultry farm	ADF	749.348	0.0001	11	4011
	PP	882.818	0.0001	11	4015
Slaughterhouse Arrival Average Live Weight	ADF	488.606	0.0001	11	4012
	PP	535.437	0.0001	11	4015
Difference	ADF	675.881	0.0001	11	4008
	PP	950.951	0.0001	11	4015
Lairage Time	ADF	828.882	0.0001	11	4008
	PP	1120.86	0.0001	11	4015

ADF: Augmented Dickey-Fuller unit root test

PP: Phillips-Perron unit root test

model between the two, and the results are presented in Table 4.

Table 4 – Panel data analysis of the relationship between mortality rate and the independent variables-Hausman Test.

Test Summary		SD	p
Hausman Test	93.445	7	0.001

The null hypothesis based on the Hausman test is a "random effects model" and the alternative hypothesis is a "fixed effects model". The significance level (Probe) value was compared to the table value (α) (Table 3). As the Probe value was found to be 0.001 (i.e., $p<0.050$), the null hypothesis was rejected, indicating that a fixed-effects model was necessary for the panel data analysis. The estimation results obtained from the fixed-effects model are presented in Table 5.

As shown in Table 5, the R^2 value was 0.9093, indicating that the independent variables used in the model explained 90.93% of the changes in the mortality rate. Additionally, the F statistic showed that the model was significant.

The non-periodical fixed-effects panel data analysis showed a significant ($p<0.01$) effect between the number of living animals, number of dead animals, mean live weight at poultry farm exit, total live weight at poultry farm exit, mean live weight at slaughterhouse arrival, and a difference in the mortality rate.

Table 5 – Fixed-effects panel data analysis of the relationship between mortality rate and several independent variables.

Variable	Coefficient	SD Error	t-Statistic	Prob.
C	1.912589	0.169170	11.30574	0.0001*
LaNa	-0.000562	4.59E-05	-12.25104	0.0001*
ExNa	0.028679	0.000168	170.4798	0.0001*
MLWe	0.714321	0.116937	6.108583	0.0001*
TBW	0.000167	1.84E-05	9.058152	0.0001*
MLWa	-1.293321	0.107442	-12.03736	0.0001*
DIFFERENCE	-0.000351	3.41E-05	-10.29251	0.0001*
LT	3.54E-05	3.24E-05	1.093408	0.2743
Fixed Effects (Cross)				
_ANKARA--C	0.147702			
_BARTIN--C	-0.037904			
_BILECIK--C	-0.115445			
_BOLU--C	-0.070789			
_CANKIRI--C	0.061917			
_DUZCE--C	0.011552			
_ESKISEHIR--C	0.002062			
_KARABUK--C	0.000183			
_KOCAELI--C	-0.034677			
_SAKARYA--C	0.021603			
_ZONGULDAK--C	0.013801			
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.909338	Mean dependent present		0.831970
Adjusted R-squared	0.908953	SD dependent present		1.327961
S.E. of regression	0.400699	Akaike info criterion		1.013249
Sum squared resid	643.3622	Schwarz criterion		1.041424
Log likelihood	-2021.163	Hannan-Quinn criter.		1.023233
F-statistic	2364.116	Durbin-Watson stat		1.330879
Prob. (F-statistic)	0.000001			

*$p<0.01$

The results of the number of transports and distances from poultry farms to slaughterhouses by province are presented in Table 6.

Table 6 – The transportation distance from the poultry farm to the slaughterhouse by provinces.

Province	Number of Transports (n)	Average Distance (km)	Std. D	Min	Max
Ankara	1.611	149,50	51,95	69,7	243
Bartın	725	157,93	51,70	138	172
Bilecik	26	195,11	50,88	190	197
Bolu	11.567	46,50	52,15	1,9	156
Çankırı	132	208,15	51,63	106	221
Düzce	5.366	76,19	52,12	30,4	179
Eskişehir	167	186,68	51,23	155	276
Karabük	553	138,93	52,22	106	163
Kocaeli	634	189,56	51,72	134	214
Sakarya	1.029	143,05	51,65	90,9	210
Zonguldak	4.789	123,94	52,16	44,8	200

As shown in Table 6, Bolu had the highest number of transports due to its proximity to the slaughterhouse, while Çankırı & Bilecik had the lowest number of transport as they were far from the slaughterhouse.

The independent variables included in the model explained 90.93% of the changes in the mortality rate. The estimation equations for estimating the mortality rate during transport from the poultry to the slaughterhouse in 11 provinces (Ankara, Bartın, Bilecik, Bolu, Çankırı, Düzce, Eskişehir, Karabük, Kocaeli, Sakarya, and Zonguldak), based on the model parameters, are presented in Table 7.

Table 7 – Equations for estimating the mortality rate by provinces.

$$\hat{y}_{ankara} = 0.15 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{bartın} = -0.03 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{bilecik} = -0.11 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{bolu} = -0.07 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{çankırı} = 0.06 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{düzce} = 0.01 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{eskişehir} = 0.002 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{karabük} = 0.0001 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{kocaeli} = -0.03 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{sakarya} = 0.02 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$$\hat{y}_{zonguldak} = 0.013 + 1.92 - 0.0006 * x_1 + 0.029 * x_2 + 0.71 * x_3 + 0.0001 * x_4 - 1.29 * x_5 - 0.0003 * x_6 + 3.54 * x_7$$

$x_1 = CASA, x_2 = EXCA, x_3 = KOC, x_4 = KTC, x_5 = KVOC, x_6 = FARK, x_7 = BS$

DISCUSSION

The transport of chickens from the broiler house to the poultry slaughterhouse incurs in financial losses, as it decreases live weight and increases the mortality rate. These losses negatively affect integrated companies aiming for high-quality, high-capacity, and sustainable production (Aral *et al.,* 2014).

Studies conducted in various countries have reported different mortality rates associated with the transport of broilers. For example, the mortality rate was reported to be 0.35% in Italy (Petracci *et al.,* 2006), 0.37% in the Czech Republic (Vecerek *et al.,* 2016), and 0.41% and 0.46% in the Netherlands (Nijdam *et al.,* 2004). The European Union (EU) has set the maximum recommended mortality rate at 0.5% (European Commission, 2005), while the USA reported a mortality rate of 0.68% (Ritz, 2005). In Turkey, studies have reported mortality rates of around 0.56%, which is between the values reported in the EU and the USA (Arikan *et al.,* 2017). In this study, the mean mortality rate was found to be 0.57%, which was similar to the previously reported mortality rate in Turkey.

Lairage time, which is the period between the arrival of broiler chicks at the holding area in the slaughterhouse and their slaughter, helps animals adapt to their new environment, reduces thermal and physiological stress, and contributes to the welfare of broilers, thus improving meat quality (Hoffman & Lambrechts, 2011). The recommended maximum waiting period is 1 h, although it might be extended to 2 h under favorable conditions (Warris *et al.,* 1999). Exceeding this period, for example, by 4 h, significantly increases the mortality rate, as observed in previous studies (Bayliss & Hinton, 1990). In this study, we found no significant relationship between lairage time and mortality rate; our findings differed from those of other studies (Bayliss & Hinton, 1990; Warris *et al.,* 1999).

This discrepancy might be due to the slaughtering strategy of slaughterhouses, which prioritize herds with a low slaughter age rather than implementing a fixed waiting period in the holding area. The minimum lairage time recorded in our study was 0 min, indicating that some herds were immediately slaughtered upon arrival at the slaughterhouse.

In a study conducted in Poland in the winter, the effect of different transport distances on broiler mortality rates was examined. The mortality rates were 1.41% for a distance of 100 km, 2.65% for 200 km, and 2.36% for 300 km, compared to the control group that was not transported (Sowinska *et al.,* 2013). Another study in Brazil analyzed 13,937 transport operations and reported a mean mortality rate of 0.33% for distances between 24–242 km, with the highest rate (0.42%) being recorded during the summer (Vieira *et al.,* 2015). A study in the Czech Republic recorded a mean mortality rate of 0.247% during transport, with rates of 0.146% and 0.862% for enterprises within 50 km and over 300 km away, respectively (Vecerek *et al.,* 2006). In our study, the shortest and longest transport distances were 1.9 km and 276 km, with mortality rates of 0.45% and 1.72%, respectively.

We found a significant relationship between broiler mortality rates during transport from poultry to slaughterhouses and most variables, but not with lairage time (Table 5). The equations presented in Table 7 for each province can be used to identify critical control points that affect animal mortality and minimize losses during transport; thus, they can help reduce the mortality rate.

These equations were determined to estimate mortality rates during transport for each province, and can also be used in effective production planning for broiler integration and optimization of slaughterhouse capacity.

CONCLUSION

The mortality and live weight loss of broilers during transport from poultry farms to slaughterhouses were found to be affected by various factors, including geographical, climatic, and seasonal conditions; as well as production, slaughter, and transportation-related factors, such as transportation infrastructure, distance, time, and vehicles. Future econometric studies, paired with regular records on the factors affecting the mortality rate in poultry integrations, will reduce the mortality rate during poultry transfers.

In conclusion, studies like this should be conducted in different regions and provinces to optimize the costs of transportation, minimize mortality rates and live weight losses, optimize lairage times, select the shortest possible distances, and consider environmental and climatic conditions. Companies should consider these factors during the production planning stage.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest in this study.

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