Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

e-ISSN: 1806-9061 2024 / v.26 / n.1 / 001-008

http://dx.doi.org/10.1590/1806-9061-2023-1890

Original Article

The Effect of Different Transportation Distances and the Application of Electrical Stimulation on Meat Quality in Broilers

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■Keywords

Broiler, electrical stimulation, meat quality, meat texture, transport distance.

Submitted: 08/December/2023
Approved: 15/March/2024

ABSTRACT

The aim of this study was to determine the meat quality characteristics of broilers that were brought to the slaughterhouse from different transport distances and received post-slaughter carcass electrical stimulation. For this purpose, broilers were transported to the slaughterhouse from different distances, from farms belonging to the same enterprise. Broilers coming from different distances were randomly divided into two subgroups after slaughter. Electrical stimulation was applied to one of the groups, on the pectoral muscle. After electrical stimulation, pH measurements of the carcasses were made in both groups in the first 15 minutes. The carcasses were then cut, and the breast and thigh meats were separated. Subsequently, these samples were kept at +4°C for 24 hours, and pH measurements, electrical conductivity, color parameters, cooking loss and texture profile analyses were made.

For the breast meat samples, it was determined that the difference in transport distance between the groups caused a difference in crude protein, crude fat, and crude ash values. It was detected that as the transport distance to the slaughterhouse increased, the protein and ash values decreased, while the fat value increased. pH15min was measured to be lower in breast meat samples taken from a closer distance to the farm. In thigh meat samples, the difference in transport distance was significant in crude fat and crude ash values. It was determined that the difference between the groups in the values obtained as a result of the electrical stimulation applied after slaughter were not significant, except for redness values of thigh meat.

INTRODUCTION

Pre-slaughter conditions for broilers are important for both animal welfare and meat quality. During pre-slaughter, chickens are submitted to stress factors such as feed and water withdrawal, catching, loading, unloading, design of transport trucks, transport load density, environmental conditions during transport, transportation duration, waiting period before slaughter, etc. (Schwartzkopf-Genswein *et al.,* 2012). These factors expose broilers to unfamiliar conditions such as heat stress, noise, crowding, adverse weather conditions, and vehicle speed (Benincasa *et al.,* 2020).

Hormonal and metabolic responses that occur in their bodies in response to these stress factors can disrupt body balance. The known effects of stress include animal deaths and deterioration in herd health. In addition, negative effects can be seen on both animal welfare and meat quality after slaughter (EFSA, 2011; Tougan *et al.,* 2013; Jacobs *et al.,* 2017; Teke *et al.,* 2019).

Stress caused by unfamiliar situations depletes the glycogen content of the muscles. Depending on the amount of lactic acid formed, pH decreases in the muscles can be observed (Dadgar *et al.,* 2010). At the same time, pH changes in the post-mortem period can affect the structure of muscle fibers and water holding capacity, tenderness, and color of meat (Santos *et al.,* 2017). In broilers, short-term stress intensity and duration can result in PSE (Pale Soft Exudative) meat, while long-term stress at high intensity can result in DFD (Dark Firm Dry) meat (Adzitey & Nurul, 2011).

Meat quality is important for both the consumer and the producers of meat products. Some properties used to determine meat quality are pH, colour (L*: brightness, a*: redness, b*: yellowness values), cooking loss, and shear force. Researchers have reported that transportation distance has an effect on the meat quality characteristics of broilers (Zhang *et al.,* 2009; Hussnain *et al.,* 2020).

Zhang *et al.* (2009) examined the effect of three different transportation distances to the slaughterhouse (without transportation, 45 min., 3 hours) on breast and leg meat, and reported that the b* value in breast meat was higher in animals transported to the slaughterhouse during 3 hours ($p<0.05$).

Hussnain *et al.* (2020) investigated the effects of transportation from four different distances (0, 80, 160 and 240 km) to the slaughterhouse during winter on meat quality and cooking loss. It was reported that pH15min, L* value, shear force, and raw meat cooking loss values were significantly higher in the breast meat of non-transported animals.

Hussnain *et al.* (2020) described that the lower pHu (<6) of meat resulted in higher lightness (high L*) due to increased light scattering, while higher pHu (>6) resulted in darker meat (lower L*), due to less light scattering.

Hussnain *et al.* (2020) noted that longer transportation distances cause depletion of glycogen reserves, high ultimate pH, and darker meat. In addition, it was stated that the cooking loss value was the lowest in the group transported for 240 km (farthest transport distance), and the shearing force decreased with the increase in the transport distance.

Consumers want products for sale to be of high quality. Quality in meat products also starts with pre-slaughter practices, and continues with slaughter and post-processing (Sofor, 2014).

Electrical stimulation (ES) can be applied to the carcass to improve meat quality characteristics after slaughter. This application accelerates post-mortem biochemical changes in the muscles, and the final pH normally reached in 15-20 hours in unstimulated muscles can be reached in 4 hours as a result of stimulation. It achieves this effect by initiating post-mortem glycolysis, which causes pH depletion due to the decrease in muscle glycogen. This process is conducted to improve sensory properties. It is a valuable application in the meat industry, since by softening the meat it facilitates its processing and use (Adeyemi & Sazili 2014; Polidori & Vincenzetti 2017; Ali *et al.,* 2021).

In the literature review, it was seen that studies on the distance from the farm to the slaughterhouse, the electrical stimulation applied after slaughter, and the effects of these factors on the texture development of meat are limited. Therefore, this study aims to examine how broiler meat quality changes according to transport distances from the farm to the slaughterhouse and the ES treatment applied post-slaughter.

MATERIALS AND METHODS

In this study, broilers (42 days, Ross-308) brought to the slaughterhouse from different distances (70 km and 250 km) were selected. 24700 broilers from 70 km and 34500 from 250 km were transported to the slaughterhouse. The dimensions of the plastic crates used to transport the animals were 1100X1125X200 mm. Feed was withdrawn 8 h before, and birds were allowed to drink water until flocks were loading. The catching and loading of animals was done manually. The average speed of the vehicles during transportation was 50km/h. The ambient temperature (15 °C) and humidity value (60%) during the transportation of both flocks were similar.

Sample Preparation

A total of 24 broilers, 6 from each group (far distance (ES; Non-ES) and close distance (ES; Non-ES)), were randomly chosen and slaughtered on the same day. Male and female animals were used together. After the animals were hanging in stirrups, they were sent to slaughter in a very short time. After electrical stunning and slaughter of the animals, ES was applied to the upper pectoral muscle at 71 volts for 30 seconds (Low voltage electrical stimulation, Al-Hilphy *et al.,* 2020). Breast and thigh meats of the groups to be used in the study were placed in plastic bags. The samples to be analysed chemically were kept at -18°C until analysis, while samples for other analyses were kept at +4 °C for 24 hours. Chemical analyses were made in the lower right part of the breast samples; colour and pH analyses were performed in the upper right part; and cooking loss, electrical conductivity, and texture analyses were performed in the left part. Chemical analyses and pH measurements were measured on the right thigh; while color, cooking loss, and electrical conductivity were measured on the left thigh.

Chemical Composition

Dry matter, moisture, crude protein, crude fat and crude ash analyzes were performed in samples taken from breast and thigh meat (AOAC, 1990). 5 g samples taken for moisture analysis were dried in a drying oven (UNB400 Memmert Ltd., Germany) at 103 °C for 3 hours, and the weight difference was measured before and after the drying process. The Kjeldahl method (VAPOdest45S, Gerhardt, Germany) was used for crude protein analysis. Crude fat analysis was measured by petroleum ether extraction using the Soxhlet method (SOX416, Gerhardt, Germany). Crude ash content was measured by heating the sample (3 g) in an oven (Carbolite ELF11/6B, Carbolite UK-Germany) at 550°C for 6 hours.

Cooking Loss

In order to determine cooking loss, 5 g samples were taken from breast and thigh meats placed in a polyethylene bags and tightly tied. After the samples were kept in an 80 °C water bath (until the internal temperature reached 72˚C), they cooled at room temperature and the difference between the first weighing and the last weighing was calculated (Honikel, 1998).

pH measurement

Meat pH was determined using an electronic pH meter (Thermo Scientific Orion Star A211, Beverly, MA, USA) at pH15min and pH24h. pH measurements were made after ES application. pH measurements were performed by direct insertion of the probe into the breast muscle. Each sample was measured 3 times, and their average pH value was considered the final result. Before starting the analysis, the pH meter was calibrated (pH buffers were used in pH meter calibration).

Meat colour

L* (brightness), a* (redness) and b* (yellowness) values were measured with a Chroma meter (Konica Minolta, CR- 400, Japan) 24 hours after slaughter in the breast (M. pectoralis major) and thigh meat (M. iliotibialis lateralis).

Electrical conductivity measurement

To measure electrical conductivity, approximately 10 g samples were taken from both breast meat and thigh meat. These samples were ground in a blender. 100 ml of distilled water was added and homogenized. The electrical conductivity of samples was determined using a conductivity meter (Orion Star A222, Thermo Scientific, Korea) (Saelin *et al.,* 2017).

Measurement of Texture Characteristics

The hardness, springiness, adhesiveness and chewiness of raw chicken breast samples were measured using a texture analyzer (CT3 Texture Analyzer; BrookfieldEngineering Labs Inc., Middleborough, MA, USA) according to the method described by Masoumi *et al.* (2022) with some modifications. A TA44 probe was used for the analysis. The speed of the pre-test, the test speed and the speed of the post-test were respectively 2, 1 and 1 mm / s. Sample dimensions were 5 cm diameter and 2 cm thickness.

Statistical analysis

The collected data were analysed using the two-way analysis of variance (ANOVA) technique under a completely randomized design. The ANOVA test was applied after examining the collected data for normal distribution and homogeneity of variance. The means were considered significant at a P value of 0.05. The sample size used in the study was determined with the G Power 3.1 power analysis software (Faul *et al.,* 2007). The statistical analysis was performed using the SPSS Statistics 23.0 software (IBM SPSS Statistics, Armonk, NY) packet program.

RESULTS

The results of chemical analysis and cooking loss in breast meat of transport distance and ES application are given in Table 1. It was determined that the crude protein and crude ash values were higher ($p<0.05$; $p<0.01$) and the crude fat value was lower ($p<0.05$) in the breast meat of chickens transported from a closer distance. The interaction of transport distance and ES were determined to be significant for the crude protein value ($p<0.05$). In this interaction, it was determined that the protein value was higher in the group that came from further away and also received ES.

Table 1 – Effect of transport (T) and electrical stimulation (ES) on the chemical composition and cooking loss of breast muscles of broilers slaughtered at 42 days of age.

Transport distance	ES	n	Dry matter (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude ash (%)	Cooking loss (%)
Close		12	26.27	73.72	23.40^{b}	1,26^{b}	1.31^{a}	15.61
Far		12	26.50	73.41	22.88^{a}	1,81^{a}	1.22^{b}	14.15
ES		12	26.37	73.53	23.18	1.56	1.26	15.72
Non-ES		12	26.40	73.60	23.11	1.51	1.27	14.05
Close	ES	6	26.11	73.83	23.19	1.39	1.28	16.11
	Non-ES	6	26.38	73.61	23.62	1.13	1.34	15.12
Far	ES	6	26.59	73.24	23.17	1.72	1.23	15.32
	Non-ES	6	26.41	73.58	22.60	1.89	1.21	12.98
p values								
T			0.46	0.24	*	*	**	0.20
ES			0.94	0.81	0.76	0.81	0.53	0.15
Interaction			0.51	0.28	*	0.30	0.16	0.55

Values are shown as mean. *: $p<0.05$, **: $p<0.01$. a, b: Between transport distances, values with the different superscript significantly differ.

When the chemical analysis results of the thigh meat samples were examined, it was determined that the crude fat values were lower ($p<0.001$) and the crude ash values were higher ($p<0.05$) in broilers brought from less distance (Table 2). Transport distance did not make any difference between the groups in terms of moisture, crude protein, and cooking loss values. Although crude protein and crude ash values were measured to be lower in ES applied groups, there was no difference between the groups ($p>0.05$). Transport distance and ES interaction significantly affected only crude fat values ($p<0.01$). In this interaction, it was determined that crude fat values were lower in the group coming from a smaller distance, and also in the group where ES was applied, and in the group coming from a larger distance, and not in the group where ES was not applied.

Table 2 – Effect of transport (T) and electrical stimulation (ES) on the chemical composition and cooking loss of thigh muscles of broilers slaughtered at 42 days of age.

Transport distance	ES	n	Dry matter (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude ash (%)	Cooking loss (%)
Close		12	23.58	76.41	20.34	1.63^{a}	1.08^{b}	10.83
Far		12	24.24	75.76	20.24	2.44^{b}	1.06^{a}	10.92
ES		12	23.79	76.20	20.17	2.06	1.06	10.92
Non-Es		12	24.03	75.96	20.41	2.01	1.08	10.84
Close	ES	6	23.30	76.69	20.17	1.49	1.07	10.82
	Non-ES	6	23.87	76.12	20.51	1.78	1.10	10.84
Far	ES	6	24.29	75.71	20.16	2.63	1.05	11.01
	Non-ES	6	24.19	75.80	20.32	2.25	1.07	10.83
p values								
T			0.052	0.052	0.71	***	*	0.94
ES			0.49	0.49	0.35	0.69	0.08	0.95
Interaction			0.30	0.30	0.73	**	0.94	0.94

Values are shown as mean. *: $p<0.05$, **: $p<0.01$, ***: $p<0.001$. a, b: Between transport distances, values with the different superscript significantly differ.

pH, conductivity, and colour values of breast meat of different transport distance and ES application are given in Table 3. It was determined that the difference in the transport distance affected the pH15min value of breast meat. While pH15min was measured to be lower ($p<0.05$) in samples taken from chickens coming from a smaller distance to the farm, pH24h was determined to be lower ($p>0.05$) in samples taken from animals coming from a smaller distance. It was determined that both different tranport distances and ES application did not make a difference between the groups in electrical conductivity values.

It was determined that L* value was higher in breast meats of chickens transported from a smaller distance. However, this difference was not statistically significant ($p>0.05$). ES application did not cause a significant difference in terms of electrical conductivity and colour values in breast meat samples ($p>0.05$). The interactions between transport distance and electrical stimulation were measured in electrical conductivity ($p<0.05$) and L* value ($p<0.05$). In this interaction, it was determined that EC and L values were higher in the group that came from afar and also did not receive ES.

Table 3 – Effect of transport (T) and electrical stimulation (ES) on the ph, electrical conductivity (EC) and color of breast muscles of broilers slaughtered at 42 days of age.

Transport distance	ES	n	pH15min	pH24h	EC24 (mS x cm–1)	L*	a*	b*
Close		12	6.26[a]	6.11	1021.89	56.96	1.51	10.67
Far		12	6.41[b]	6.28	1002.80	55.09	2.39	11.69
ES		12	6.33	6.12	998.64	55.26	1.92	11.07
Non-ES		12	6.34	6.27	1026.05	56.79	1.98	11.29
Close	ES	6	6.29	6.08	1045.57	58.09	1.41	10.79
	Non-ES	6	6.22	6.14	998.20	55.84	1.60	10.55
Far	ES	6	6.37	6.16	951.70	52.44	2.43	11.34
	Non-ES	6	6.46	6.40	1053.90	57.75	2.35	12.03
p values								
T			*	0.06	0.52	0.19	0.07	0.11
ES			0.84	0.11	0.36	0.28	0.90	0.71
Interaction			0.25	0.31	*	*	0.78	0.45

Values are shown as mean. *: $p<0.05$. a, b: Between transport distances, values with the different superscript significantly differ.

In the study, it was determined that pH24 (6.73) values were lower and L*, a* and b* values were higher in broiler thigh meat samples transported from a smaller distance (Table 4). While pH15min, a* and b* values were measured to be lower in the thigh meat samples of ES-treated groups, it was determined that the difference between the groups in the a* value was statistically significant ($p<0.05$).

Table 4 – Effect of transport (T) and electrical stimulation (ES) on ph, electrical conductivity (EC) and color of thigh muscles of broilers slaughtered at 42 days of age.

Transport distance	ES	n	pH15min	pH24h	EC24 (mS x cm⁻¹)	L*	a*	b*
Close		12	6.47	6.73	874.55	49.71	13.57	11.78
Far		12	6.46	6.80	847.05	48.09	12.25	10.46
ES		12	6.40	6.77	883.31	49.18	11.88[x]	10.89
Non-ES		12	6.53	6.76	838.30	48.63	13.95[y]	11.36
Close	ES	6	6.42	6.75	858.39	49.74	12.37	11.38
	Non-ES	6	6.52	6.72	890.71	49.68	14.78	12.18
Far	ES	6	6.38	6.79	908.22	48.61	11.39	10.39
	Non-ES	6	6.55	6.80	785.89	47.58	13.12	10.54
p values								
T			0.94	0.55	0.56	0.22	0.14	0.06
ES			0.23	0.90	0.34	0.67	*	0.48
Interaction			0.78	0.82	0.11	0.71	0.69	0.63

Values are shown as mean. *: $p<0.05$. x, y: Between electrical conductivity, values with the different superscript significantly differ.

The results of the texture analysis in the study are given in Table 5. In the breast meat of chickens transported from a longer distance, the hardness value is higher (11.73-10.18), the adhesiveness value lower (1.40-1.44), the springiness value higher (7.70-7.14) and the chewiness value lower (16.46-17.13) measured.

DISCUSSION

The aim of this study was to examine the effects on broiler meat quality of different transport distances to the slaughterhouse and ES treatments applied post-slaughter.

In recent years, it has been observed that consumers prefer chicken piece products such as fillets, tenderloins, thigh meat, and drumstick meat. Consumers expect these products to have certain quality characteristics when purchasing them. When it comes to the quality of poultry meat, different factors are examined, such as water holding capacity, shear force, drip loss, cooking loss, pH, shelf life, collagen content, protein solubility, and fat binding power (Allen *et al.*, 1998).

Baeza *et al.* (2022) reported that among the factors affecting the chemical composition of chicken meat, factors such as animal species, nutrition, age, genotype, production systems were effective.

Table 5 – Effect of transport (T) and electrical stimulation (ES) on the texture analysis of breast muscles of broilers slaughtered at 42 days of age.

Transport distance	ES	n	Hardness (N)	Adhesiveness (mJ)	Springiness (mm)	Chewiness (mJ)
Close		12	10.18	1.44	7.14	17.13
Far		12	11.73	1.40	7.70	16.46
ES		12	10.06	1.42	7.46	14.76
Non-ES		12	11.85	1.42	7.38	18.83
Close	ES	6	8.74	1.43	7.35	13.49
	Non-ES	6	11.61	1.46	6.93	20.77
Far	ES	6	11.37	1.42	7.57	16.03
	Non-ES	6	12.09	1.37	7.84	16.88
p values						
T			0.11	0.88	0.09	0.77
ES			0.07	0.98	0.80	0.09
Interaction			0.27	0.90	0.29	0.17

Values are shown as means. Level of significance of the effects of transport time, electrical stimulation and interaction: $p<0.05$.

Sowinska *et al.* (2013) reported that the protein content of the meat increased as the transporting distance increased. It has been stated that this increase may be caused by the genetic structure of broilers and post-slaughter applications. In the same study, it was stated that the distance difference did not change fat and water compositions. In the current study, it was determined that both crude protein and crude ash values were higher and the crude fat content was lower in the breast meat of chickens brought from a smaller distance. Low fat and high ash content were measured in thigh meat. In another study, it was noted that the protein content was especially affected by slaughter age, while the fat content was affected by the animal species and nutritional factors (Baeza *et al.,* 2022). Since the type of animals and nutritional factors were the same in the groups from which the samples were taken in the current study, the effect of different transport distances and road conditions may be considered the factors that may affect the chemical composition of the meat.

In their study investigating the effects of different transport distances (with simulation model) on broiler meat quality, Yetişir *et al.* (2019) stated that cooking loss value was not affected by differences in transporting distances. Moreover, it was reported that the cooking loss of breast meat was lower than those of thigh and drumstick meats. In the current study, neither different transport distances nor electrical stimulation had any effects on these parameters.

The pH is an important factor affecting many other factors related to the quality of meat, such as texture, water holding capacity, colour, and shelf life. Depending on the amount of glycogen in the muscles after slaughter, the conversion of glycogen to lactic acid and the final pH of the meat occur in the post-slaughter period. If the pH is high, the meat has more water-binding capacity and a darker colour is observed (Mir *et al.,* 2017). In the current study, pH15min value was lower in breast meat of broilers coming from a smaller distance. In this study, it was determined that neither the transportation distance nor the ES application made any difference between the groups in terms of pH24h, electrical conductivity, L*, a* and b* values in breast meat. For thigh meat samples, transportation distance did not cause any difference between the groups in the examined meat quality values. ES application made a difference only in a* value, and the thigh meats of chickens coming from a smaller distance were measured to be redder. This difference may be due to the fact that ES application keeps the pH24h value of the meat lower, and this may be reflected in the color elements (such as myoglobin and hem value of the meat).

Sowinska *et al.* (2013) reported that pH15min and pH24h values did not make a significant difference between the groups in their studies with broilers submitted to different transport distances to the slaughterhouse. In the same study, the difference in colour lightness was significant 24 hours after slaughter, especially in the meat of broilers coming from the distances of 200 and 300 km. The b* value was found to be the highest in animals brought from 300 km, and the lowest in those transported from a distance of 200 km. It was reported that there was no difference between groups in the a* value. Similarly, in the current study, the transport distances to the slaughterhouse did not cause differences between the groups, in both breast and thigh meat pH15min and pH24h values.

Contrary to this study, Sahir *et. al.* (2013) reported that the effect of different transport times (1 and 4 hours) to the slaughterhouse on the first and final pH of breast meat was significant. They stated that the pH of breast meat decreased 8 hours after slaughter and then stabilized. It has also been reported that the final pH was higher if the transport time was longer. Zheng *et al.* (2020) found no difference in pH45min and pH24h measurements in breast and thigh meat in broilers that were transported for 2 hours. It was reported that these values decreased in the 4-hour transportation, and that this event may cause PSE-like or spoiled meat.

Yalcin & Güler (2012) reported that transportation time does not make any difference in the initial pH measurement of breast meat for chickens transported from different distances to the slaughterhouse, considering transportation times of 90, 155, and 220 minutes. It has been reported that an increase in the transport distance increases the redness of the meat and has no effect on the yellow color. In the current study, it was determined that the transported distance did not create significant color differences in both breast and thigh meat.

Meat texture is one of the most important factors in consumers' choice of meat, and pre- and post-slaughter processes are important in texture development. The chemical changes that occur in the structure of the muscles after death, and the healthy transformation of the muscle into meat shape textures (Zheng *et al.,* 2020). In this study, transport distance and ES application did not lead to a difference between the groups in terms of texture characteristics. Similarly, Dos Santos *et al.* (2017) stated that differences in the transport distances did not have a significant effect on the shear force of the meat.

Unlike this study, Yetişir *et al.* (2019) stated that as the transport distance increased (0, 80, 160, 240, 320 km), the hardness of chicken meat increased, and the drumstick and thigh meats were crispier than breast meat. In another study, it was stated that pH15min, L*, and shear force were significantly higher in the breast meat of chickens that were not transported before slaughter, as compared to those that were transported (Hussnain *et al.,* 2020).

CONCLUSION

In conclusion, this study has determined that while the difference in transportation distance caused a difference in some chemical values of breast and leg meat, ES application did not cause a difference between the groups, except for redness values of thigh meat. In general, the similarities between the groups may be due to the resting procedures applied pre-slaughter, the similar regional temperature values during transportation, and the consequently glycogen reserves in the muscles being less affected.

ACKNOWLEDGMENTS

The author is thankful to Sen Pilic Food Industry Inc. for providing the necessary facilities to complete this study.

CONFLICT OF INTEREST

The author declares no conflicts of interest.

ETHICAL STATEMENT

Experimental procedures were approved by the Osmaniye Korkut Ata University Ethics Committee (2023/4/5).

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