Changes in Physiological Condition of Broiler Chickens Sprayed with Water before Transportation

Sara U[1], Rahardja DP[2], Sonjaya H[2], Azhar M[1]

[1]*Politeknik Pembangunan Pertanian Gowa, Jl. Malino Km. 7 l. Malino No.KM.*
Romang Lompoa, Bontomarannu, Kabupaten Gowa, Sulawesi Selatan 92171
[2)] *Faculty of Animal Agriculture, Hasanuddin University*
Jln. Perintis Kemerdekaan, Makassar 90245-Indonesia
E-mail: urfianasara0801@gmail.com

(received 19-01-2022; revised 06-04-; accepted 11-06-2022)

ABSTRAK

Sara U, Raharja DP, Sonjaya H, Azhar M. 2022. Perubahan kondisi psikologi ayam broiler yang disemprot dengan air sebelum transportasi. JITV 27(2):93-99. DOI:http//:dx.doi.org/10.14334/jitv.v27i2.2996.

Pengangkutan menuju RPU (rumah potong unggas) merupakan rangkaian proses yang dapat menyebabkan tingginya tingkat stres pada ayam ras pedaging. Stres panas akan terus meningkat apabila jarak tempuh antara kandang dan rumah potong unggas sangat jauh yang menyebabkan perjalanan akan semakin lama. Salah satu solusi untuk mengatasi stres panas akibat pengangkutan adalah melakukan penyiraman beberapa menit sebelum perjalanan dimulai agar ayam ras pedaging tetap mampu mempertahankan kondisi homeostatisnya. Penelitian ini bertujuan untuk untuk mengetahui pengaruh metode penyiraman sebelum pengangkutan dengan jarak yang berbeda terhadap status hematologis, hormonal, serta kualitas daging ayam ras pedaging. Penelitian ini disusun berdasarkan Rancangan Acak Kelompok (RAK) pola faktorial. Sebanyak 54 ekor ayam ras pedaging strain Cobb umur 35 hari dibagi menjadi 2 perlakuan yakni; tanpa penyiraman (P0) dan penyiraman (P1). Ayam pada masing-masing perlakuan diangkut menuju rumah potong unggas dengan 2 jarak tempuh yang berbeda yakni; 30km (J1) dan 60km (J2), serta 1 perlakuan kontrol (tanpa pengangkutan) (J0). Penyiraman dilakukan sesaat sebelum proses pengangkutan. Hasil penelitian menunjukkan bahwa jarak tempuh pengangkutan meningkatkan nilai kekuningan (b*) daging bagian dada, dan menurunkan nilai kecerahan (L*), serta meningkatkan pH daging bagian paha ayam ras pedaging ($P<0.05$). Nilai hematokrit, kadar hemoglobin, dan konsentrasi hormon triiodotironin (T_3), komponen warna daging lainnya, serta pH daging bagian dada tidak mengalami perubahan signifikan, baik ditinjau dari penyiraman, jarak tempuh, maupun interaksi keduanya ($P>0.05$). Respon ayam ras pedaging terhadap penyiraman sebelum pengangkutan terlihat dari perubahan tingkat penyusutan berat badan. Selain itu, pengangkutan dengan jarak tempuh yang berbeda berpengaruh terhadap sifat fisik daging ayam ras pedaging

Kata Kunci: Jarak Tempuh, Kualitas Daging, Profil Fisiologis, Stres Pengangkutan, Penyiraman

ABSTRACT

Sara U, Raharja DP, Sonjaya H, Azhar M. 2022. Changes in physiological condition of broiler chickens sprayed with water before transportation. JITV 27(2):93-99. DOI:http//:dx.doi.org/10.14334/jitv.v27i2.2996.

Transportation to the slaughterhouse is a series of processes that can cause high levels of stress in broilers. Heat stress will increase if the distance between the farm and the slaughterhouse is far. One of the solutions to overcome heat stress due to transportation is to do watering a few minutes before the transportation so that the broilers are still able to maintain their homeostatic conditions. This study aims to determine the effect of watering methods before transportation with different distances on the haematological, hormonal, and quality status of broiler chickens. This study was arranged based on a factorial randomized block design (RAK). A total of 54 broilers of the Cobb strain aged 35 days were divided into 2 treatments, namely; without watering (P0) and watering (P1). Chickens in each treatment were transported to the poultry slaughterhouse with 2 different distances; 30km (J1) and 60km (J2), as well as 1 control treatment (without transport) (J0). Watering is done just before the transportation process. The results showed that the transportation distance increased the yellowness value (b*) of the breast meat, decreased the brightness value (L*), and increased the pH of the broiler thigh meat ($P<0.05$). Hematocrit values, hemoglobin levels, and concentrations of the hormone triiodothyronine (T3), other meat color components, as well as the pH of the breast meat, did not change significantly, both in terms of watering, distance traveled, and the interaction between the two ($P>0.05$). The solution of water spraying before transportation on different distances could not restore the hematology and hormonal status, as well as the meat quality of the broiler. However, the decline in meat quality was shown in transported broilers.

Key Words: Distances, Meat Quality, Physiological Profile, Transportation Stress, Water Spraying

INTRODUCTION

Transportation is one of the processes in a series of pre-slaughter management on broilers. During transport, broilers are very susceptible to stress caused by several factors: shock, vibration, vehicle speed changing, ambient temperature, noise, high density, dehydration, and lack of food (Zheng et al. 2020). Changes in environmental temperature are a potential stressor during transportation, especially in tropical climates. Thermal stress causes changes in metabolism or physiological processes, which finally decrease meat quality (Xing et al. 2019).

Under stressful conditions, broilers will try to reduce metabolism in their body by declining the concentration of triiodothyronine (T3). Still, it happens temporarily because homeostasis processes in the body require a lot of energy. In this condition, metabolism will increase, even exceeding the normal level. Triiodothyronine does not play a role in this process anymore, but corticosterone. High metabolism requires glucose and oxygen in an amount more. Further, it will cause changes in haematological status and produce undesirable changes in meat quality.

Changes in haematological status will affect the body balance of broilers. Explained that chickens' well-being is supported by the balance of the physiological condition of blood, due to the critical roles of blood in absorbing and transporting nutrients, metabolic waste, hormones, and enzymes. Mainly, stress is caused by high ambient temperatures may change haematological profiles in broilers. Previous research was conducted by Hassan & Reddy (2012) found an increase of hematocrit value on 42-d-old broilers which were experiencing heat stress for 2 hours, however, haemoglobin concentration did not change. A previous study by Bergoug et al. (2013) found that there was no effect of transportation on the hematocrit value of 1-day-old chicks. A study conducted by Ulupi et al. (2018) found no change in the hematocrit value and haemoglobin concentration in broilers both before and after the transportation.

Meat quality decreased due to disruption of physiological processes during stress is a substantial loss. Several studies have proved that heat stress during transport changes meat quality, both in terms of colour, and pH of meat (Aleme & Bekele 2021; Zhang et al. 2012). Indeed, changes in meat color and pH refer to the formation of PSE meat (pale, soft, exudative), or DFD meat (dark, firm, dry), which indicates a decline in meat quality.

The solutions for reducing stress during transportation are the primary interest. The keys can be applied by supplementation vitamins, minerals, or changing environmental temperature by using a cooler on a truck. In this research, the solution was the application of water spraying just before transportation. Additionally, this inexpensive solution with an easy method can be applied by farmers and distributors of broilers. Some previous researchers who used water spraying before transportation could minimise extreme loss of meat quality of broilers (Jiang et al. 2015; Tamzil et al. 2018). However, no study that focused on physiological conditions, and especially haematological status due to the implementation of water spraying before transportation, and its relationship with meat quality. Thus, this study aimed to investigate the effect of water spraying before transport of different distances to the status of broiler's haematological, hormonal, and meat quality.

MATERIALS AND METHODS

This research was carried out at the Poultry Production Laboratory, Livestock Physiology Laboratory, and Animal Products Technology Laboratory, Faculty of Animal Husbandry, Hasanuddin University, as well as Pathology Laboratory, Makassar Health Laboratory Center.

Materials

The materials used include; 54 Cobb strain broilers aged 35 days, disposable syringe volume 3 ml, non-additive vacuum tube, tube containing EDTA K3 volume 3 ml, wax, 70% alcohol, hydrochloric acid (HCL), aquades, label paper, plastic clip, cotton swab, microcapillary hematocrit, and ELFA Triiodothyronine kit. The tools used include: pickup trucks, chicken baskets, electric scales, clinical thermometers, maximum-minimum thermometers, pipettes, microtubes, tube and microtube racks, knives, scissors, tweezers, and surgical boards, haemoglobinometer Sahli, general purpose centrifuge, specialty centrifuge, microhematocrit reading instrument, colorimeter, and pH meter.

Methods

The method used in this research includes research design, watering process, conditions in the transportation process, data collection and data analysis.

Research design

This study was arranged based on a 2x3 factorial randomized block design (RBD) with 3 transport groups (replicates), and each consisted of 3 sub replications, so that there were 54 experimental units. Two factors used in this study are; the first factor (I) is watering, which P0 is No Watering and P1 is Watering. The second factor (II) is the distance traveled with J0 is 0 km, J1 is 30 km, and J2 is 60 km.

Watering process

The watering process based on the method of Jiang et al. (2015) and Wang et al. (2016) with some modifications. Chickens are watered using 4 sprinklers which are sprayed on both the right and left sides of the pick-up truck. The sprinkler used Nozzle Kit 8, with settings in *shower mode*. The water temperature is 27°C and at an ambient temperature of ±30°C. Watering occurred for 30 seconds after the chickens are loaded onto a pick-up truck before the transport process.

Transportation process

The vehicle used to transport broilers from the cage to the poultry slaughterhouse is a pick-up type car. The baskets used are made of latticed plastic (0.78 x 0.58 x 0.28 m). Each basket can accommodate about 9-10 chickens. The minimum and maximum temperatures of the environment around the chickens are measured during the journey. Chickens are divided into 2 groups, namely; transportation distances of 30 km and 60 km. When arriving at the slaughterhouse, the chickens are weighed and rested for a short time (10-15 minutes) before slaughtering (Vieira et al. 2013). The series of handling processes before up to the time of the slaughtering process for broilers can be seen in Figure 1.

Data collection

The process of taking blood samples in broilers is carried out after transportation. Blood samples were taken from each chicken from each experimental unit through the brachial vein using a syringe. Blood is accommodated in two different tubes, namely; vacuum tube containing EDTA K3 anticoagulant, and non-additive vacuum tube. The blood sample in the EDTA K3 vacuum tube was used to test the parameters of the hematocrit value and hemoglobin levels, while the blood sample in the non-additive vacuum tube was centrifuged to obtain a serum sample which was used to test the Triiodothyronine hormone concentration parameter. After postmortem for 15 minutes, all the pectoralis major muscles (chest muscles) and gastrocnemius muscles (thigh muscles) were sampled to determine meat quality. Muscle samples were stored in plastic clips for later use for testing the color and pH parameters of the meat. Measuring meat color using a Minolta CR400 A colorimeter consisting of; L* (brightness), a* (redness) and b* (yellowish) (CIELAB color system) on the surface of the chest and thigh muscles.

Data analysis

The data obtained were analyzed using the Analysis of Variance (ANOVA) to test the diversity of the data and if there was a significant effect, continued with Duncan's Multiple Range Test (DMRT) at a 95% confidence level.

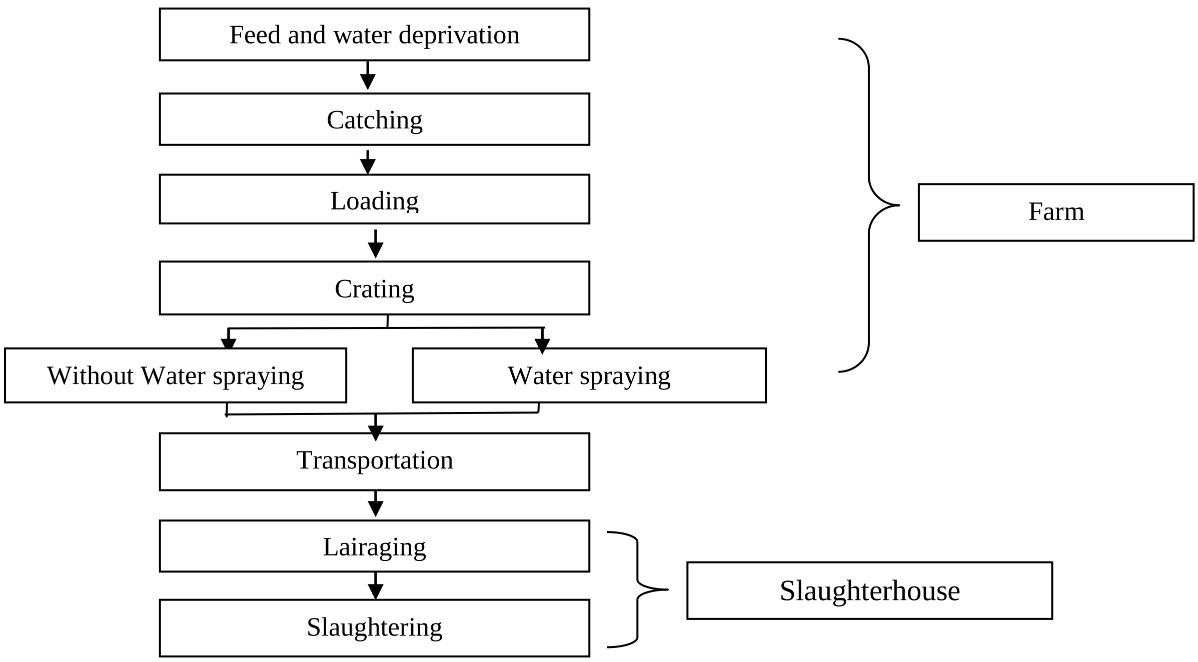

Figure 1. Flow chart of broilers handling sequence

RESULTS AND DISCUSSION

The haematological and hormonal status of broiler watered before transportation at different distances is shown in Table 1. Hematocrit values, hemoglobin concentration, and triiodothyronine levels did not change significantly, because of water spraying, distance, or their interaction (P>0.05).

There was no significant effect of water spraying, distances, and their interaction on the hematocrit values of broilers. These results indicated that both water spraying and different distances had not changed the number of blood cells in broilers. These results were obtained in a previous study by Adeyemi et al. (2015) who reported that feed deprivation time did not affect hematocrit values of broilers. Another study by Tamzil et al (2018) which applied water spraying before transportation, did not find any change in the hematocrit value. Although hematocrit values in this study did not differ, these values were lower than the normal standard. Broiler's normal hematocrit values range from 30 to 50% (Tamzil et al. 2013). Several factors affected low hematocrit values; erythropoiesis decline, increasing water consumption, hemodilution, and others (Tamzil et al. 2014). Besides, water spraying before transportation applied in this study also did not affect hematocrit values. A previous study by Yadav et al (2016) who investigated misting and wallowing in buffaloes found that under heat stress conditions, untreated buffalo would experience hemodilution more quickly, so the hematocrit value was lower than watered or wallowed buffalo.

Haemoglobin concentration was also not different in this study. Ulupi et al. (2018) reported that there was no change in the blood haemoglobin concentration of broilers after transportation. In this research, the stress of distances could not cause excessive product of glucocorticoid, thus water and sodium chloride reabsorption in kidney and caecum were still in normal condition, and hemodilution had not happened. Furthermore, stress during transportation was also unable to reduce the production of erythrocytes, thus erythropoietin could not stimulate erythropoiesis. The water spraying method applied in this research did not alter hemoglobin concentration. These results indicated that water sprayed broilers or not were still able to maintain haemoglobin concentration in their body. The study conducted on Murrah buffalo showed no change in haemoglobin concentration, both with water spraying or not (Yadav et al. 2016).

The triiodothyronine levels which were not different in this study were consistent with the finding of Hussnain et al. (2020) on broilers who experienced transportation and feed deprivation. Recent research on buffalo also showed that the cooling method or different seasons did not change triiodothyronine levels (Kumar et al. 2019; (Yadav et al. 2016). However, another study found a decrease in triiodothyronine concentrations after chickens underwent 2 and 4 hours transportation and feed restriction (Azis et al. 2012; Zheng et al. 2020). Change in triiodothyronine levels on transported broilers Changes in triiodothyronine levels was affected by deiodinase type III activity. Deiodinase type III was an enzyme that catalysed the deiodinase of thyroid hormones and had an essential role in controlling the bioavailability of hormones (Ciavardelli et al. 2014). Triiodothyronine levels in this research indicated that stress-caused transportation had not been able to increase the activity of deiodinase type III in broilers.

Table 1. Hematocrit values, haemoglobin concentrations, and triiodothyronine levels of broilers were watered before transportation at different distances

Parameters	Water Spraying	Distances			Mean
		J0	J1	J2	
Hematocrit Values (%)	P0	24.39±5.74	25.11±1.83	28.55±2.26	26.01±3.75
	P1	26.05±2.05	27.22±2.99	22.67±6.43	25.31±4.22
Mean		25.22±3.96	26.16±2.50	25.61±5.38	
Hemoglobin Concentration (gdL-1)	P0	8.29±1.82	7.86±1.44	8.58±1.12	8.24±1.33
	P1	8.82±0.60	8.41±0.99	7.89±1.67	8.37±1.09
Mean		8.56±1.25	8.14±1.15	8.24±1.33	
Levels Triiodothyronine (T3) (ng/mL)	P0	1.23±0.31	0.52±0.31	0.39±0.13	0.71±0.45
	P1	1.93±0.69	1.11±1.14	0.63±0.47	1.22±0.86
Mean		1.58±0.60	0.81±0.76	0.51 ± 0.31	

[a-b] Means within a column with superscripts are significantly different (P<0.05); P0= Without water spraying, P1= Water spraying; J0= 0 km (without transportation), J1= Transportation distance of 30 km, J2= Transportation distance of 60 km

Table 2. Meat color and pH values of broiler watered before transportation at different distances.

Parameters	Water Spraying		Distances			Mean
			J0	J1	J2	
				Breast		
	P0	*L**	46.76±2.08	47.36±0.80	43.47±2.52	45.86±2.47
		*a**	3.51±1.55	3.01±1.43	3.30±0.60	3.27±1.11
Meat Color		*b**	2.41±0.53	4.26±0.56	2.96±0.89	3.21±1.01
	P1	*L**	43.55±5.14	46.58±1.57	48.24±0.37	46.12±3.38
		*a**	3.81±1.22	2.02±1.03	3.26±0.69	3.03±1.18
		*b**	2.24±0.90	3.21±0.47	3.75±1.16	3.07±1.01
		*L**	45.15±3.92	46.97±1.97	45.85±3.06	
Mean		*a**	3.66±1.26[a]	2.51±1.24[b]	3.28±0.57[ab]	
		*b**	2.33±0.67[a]	3.74±0.74[b]	3.35±1.02[b]	
				Thigh		
	P0	*L**	52.10±2.93	49.43±1.26	48.02±1.59	49.85±2.53
		*a**	5.70±1.07	4.64±0.78	5.95±0.61	5.43±0.94
		*b**	3.52±0.43	4.50±0.79	3.08±1.29	3.70±1.00
	P1	*L**	51.29±1.53	49.37±1.34	49.43±1.35	50.03±1.54
		*a**	6.03±1.51	4.45±1.70	5.50±1.86	5.32±1.62
		*b**	3.52±0.07	3.15±0.54	3.74±0.74	3.47±0.53
		*L**	51.69±2.13[a]	49.40±1.16[b]	48.72±1.53[b]	
Mean		*a**	5.86±1.18	4.54±1.19	5.72±1.26	
		*b**	3.53±0.27	3.82±0.96	3.41±1.01	
				Breast		
Meat pH	P0		6.63±0.06	6.70±0.25	6.85±0.03	6.73±0.16
	P1		6.67±0.23	6.72±0.13	6.72±0.93	6.70±0.14
Mean			6.65±0.15	6.71±0.18	6.79±0.94	
				Thigh		
	P0		6.77±0.03	6.99±0.12	6.97±0.11	6.91±0.12
	P1		6.76±0.25	6.89±0.12	6.79±0.08	6.82±0.16
Mean			6.77±0.16[a]	6.94±0.12[b]	6.88±0.11[ab]	

[a-b] Means within a column with superscripts are significantly different (P<0.05); P0 = Without water spraying, P1= Water spraying; J0= 0 km (without transportation), J1= Transportation distance of 30 km, J2= Transportation distance of 60 km

Table 2 shows the meat quality of broiler watered before transportation at different distances. Significant differences were seen in the b* values (yellowness) of breast meat, and L* values (lightness) of thigh meat on transported broiler (P<0.05). b* values of breast meat showed an increase, whereas L* values of thigh meat decreased on transported broiler. However, water spraying treatment and interaction between water spraying and distances did not affect significantly color values. Moreover, the other color values had no significant effect, both in terms of water spraying, distances, and the interaction of these two factors (P>0.05). The significant difference in pH values was shown in thigh meat. pH values of thigh meat were increased after transportation (P<0.05). But, no significant effect in pH values of breast meat could be observed in this experiment (P>0.05).

Previous studies that found an increase in b* values on breast meat had also been observed by Tang et al. (2013) and Hu et al. (2020). In addition, L* values decreased after transportation was an early indication of the formation of DFD (dark, firm, dry) meat. These results corroborated the findings of Brossi et al. (2018), who reported a decrease in L* values in broilers under Acute Heat Stress (AHS) conditions. Decreasing of L* values due to glycogen depletion, as a result, intracellular water increased in broiler meats. Hence, the meat's surface was too dry, and dense, and the ability of meats to absorb the light, was so high. Eventually, the meats look dark (Mir et al. 2016). The application of water spraying in this experiment did not show a significant difference in all meat colours, breast, and thigh meat. These results indicated that broilers could maintain meat quality though not completely.

In contradiction to these results, previous studies reported a decrease in pH value, either on breast or thigh meats (Tang et al. 2013; Zhang et al. 2012). Furthermore, there was no significant effect of all treatments on the pH values of chest meats. These findings were also obtained by Yalçin & Güler (2012), both on long or short distances. Additionally, Kim et al. (2017) found that heat stress change the pH values of thigh meat of broilers. There was very little evidence clarifying an increase in pH values of meat after transportation, but the results of this study were in line with a decrease in L* values (lightness) of thigh meats described previously. The increase of glycogen utilisation is because of energy requirements during stress (Yalçin & Güler, 2012). Commonly, lactic acid which was a by-product of glycogen had a role in decreasing pH values of 7.0 to 5.7 in the rigour mortise phase, yet the poor glycogen levels in meats due to stress resulted from an increase in pH values of meat. High meat pH caused a lower denaturation of myoglobin, and aerobic metabolism increased on the surface of the meat. Furthermore, meat's WHC (water holding capacity) increased, thus its shape became too dense, dark, and dry because the water was suspended in the meats (Mir et al. 2017; Wideman et al. 2016).

CONCLUSION

Transported & watered broiler had no difference in haematological status compared to no transported broilers. This indicates that watering could maintain the haematological status of broilers. However, transportation could not maintain the meat quality, because there are some changes in the color of the thigh and breast meat that lead to the pale, soft, and exudative condition.

REFERENCES

Aleme M, Bekele G, 2021. Effect of Handling Cattle During Transport and Marketing on Quality of Beef. J Fisheries Livest Prod. 9. DOI:10.4172/2332-2608.1000305.

Azis A, Maritim U, Ali R. 2012. Thyroid hormone and blood metabolites concentrations of broiler chickens subjected to feeding time restriction thyroid hormone and blood metabolites concentrations of broiler chickens. Med Pet. 35:32-37. DOI:10.5398/medpet.2012.35.1.32.

Bergoug H, Guinebretière M, Tong Q, Roulston, N., Romanini CEB, Exadaktylos V, Berckmans D, garain P, Demmer TGM, MCGonnel IM, Bahr C, Burel C, Eterradossi N, Michel V. 2013. Effect of transportation duration of 1-day-old chicks on postplacement production performances and pododermatitis of broilers up to slaughter age. Poult Sci. 92:3300–3309. DOI:10.3382/ps.2013-03118.

Brossi C, Montes-Villanueva N, Rios-Mera J, Delgado E, Menten J, Contreras-Castillo C. 2018. Acute heat stress detrimental effects transpose high mortality rate and affecting broiler breast meat quality. Scientia Agropecuaria. 9: 305–311. DOI:10.17268/sci.agropecu.2018.03.01.

Ciavardelli D, Bellomo M, Crescimanno C, Vella V. 2014. Type 3 deiodinase: Role in cancer growth, stemness, and metabolism. Front. Endocrinol. 5:215. DOI:10.3389/fendo.2014.00215.

Hassan AM, Reddy PG. 2012. Early age thermal conditioning improves broiler chick's response to acute heat stress at marketing age. American J Animd Vet Sci. *7:* 1–6.

Hu H, Chen L, Dai S, Li J, Bai X. 2020. Effect of glutamine on antioxidant capacity and lipid peroxidation in the breast muscle of heat-stressed broilers via antioxidant genes and HSP70 pathway. Animals. 10:204. DOI:10.3390/ani10030404.

Hussnain F, Mahmud A, Mehmood S, Jaspal MH. 2020. Effect of broiler crating density and transportation distance on preslaughter losses and physiological response during the winter season in Punjab, Pakistan. Revista Brasileira de Ciencia Avicola. 22:1–10. DOI:10.1590/1806-9061-2019-1169

Jiang NN, Xing T, Wang P, Xie C, Xu X L. 2015. Effects of water-misting sprays with forced ventilation after transport during summer on meat quality, stress parameters, glycolytic potential and microstructures of muscle in broilers. AJAS. 28:1767–1773. DOI:10.5713/ajas.15.0152

Kim HW, Kim JH, Yan F, Cheng HW, Kim, YHB. 2017. Effects of heat stress and probiotic supplementation on protein functionality and oxidative stability of ground chicken leg meat during display storage. J Sci Food Agric. 97:5343–5351. DOI:10.1002/jsfa.8423

Kumar B, Sahoo AK, Ray PK, Chandran PC, Taraphder S, Das AK, Batabyal S, Dayal, S. 2019. Evaluation of environmental heat stress on physical and hormonal parameters in murrah buffalo. J Anim Healt Prod. 7:, 21–24. DOI:10.17582/journal.jahp/2019/7.1.21.24.

Mir NA, Rafiq A, Kumar F, Singh V, Shukla V. 2017. Determinants of broiler chicken meat quality and factors affecting them: a review. Journal of Food

Science and Technology. Springer. 54:2997-3009. DOI :10.1007/s13197-017-2789-z

Adeyemi OA. Njoku CP, Odunbaku OM, Sogunle OM, Egbeyale LT. 2015. Response of broiler chickens to quantitative feed restriction with or without ascorbic acid supplementation. Irianian J Appl Anim Sci. 5:393-401.

Tamzil MH, Noor RR, Hardjosworo PS, Manalu W, Sumantri C. 2013. Acute heat stress responses of three lines of chickens with different heat shock protein (HSP)-70 genotypes. Int J Poult Sci. 12:264–272.

Tamzil MH, Noor RR, Hardjosworo PS, Manalu W, Sumantri C. 2014. Hematological Response of Chickens with Different Heat Shock Protein 70 Genotypes to Acute Heat Stress. Int J Poult Sci. 13:14–20.

Tamzil MH, Indarsih B, Sukatha JIN. 2018. Water spraying prior to transportation reduces transportation stress and maintain the meat quality of broiler chickens. Pakistan J Nutr. 17:550–556. DOI:10.3923/pjn.2018.550.556.

Tang S, Yu J, Zhang M, Bao E. 2013. Effects of different heat stress periods on various blood and meat quality parameters in young arbor Acer broiler chickens. Canadian J Anim Sci. 93:453–460. DOI:10.4141/CJAS 2013-041.

Ulupi N, Aryani SS, Evni FT, Nugraha R. 2018. Effects of transportation duration on broiler chicken physiology and performance factors. Int J Poult Sci. 17:197–204. DOI:10.3923/ijps.2018.197.204.

Vieira FMC, Silva IJO, Filho JADB, Vieira AMC. 2013. Reducing pre-slaughter losses of broilers: Crating density effects under different lairage periods at slaughterhouse. J Anim Behav Biometeorology. 1:1–6. DOI:10.14269/2318-1265.v01n01a01.

Wang P, Zhao Y, Jiang N, Li K., Xing T, Chen L, Wang X, Tang Y, Xu X. 2016. Effects of water-misting spray combined with forced ventilation on heat induced meat gelation in broiler after summer transport. Poult Sci. 95:2441–2448. DOI:10.3382/ps/pew203.

Wideman N, O'Bryan CA, Crandall PG. 2016. Factors affecting poultry meat colour and consumer preferences - A review. World's Poult Sci J. https://doi.org/10.1017/S0043933916000015

Xing T, Gao F, Tume RK., Zhou G, Xu X. 2019. Stress effects on meat quality: a mechanistic perspective. CRFSFS. DOI:10.1111/1541-4337.12417.

Yadav B, Pandey V, Yadav S, Singh Y, Kumar V, Sirohi, R. 2016. Effect of misting and wallowing cooling systems on milk yield, blood and physiological variables during heat stress in lactating Murrah buffalo. J Anim Sci Technol. 58. DOI:10.1186/s40781-015-0082-0.

Yalçin S, Güler HC. 2012. Interaction of transport distance and body weight on preslaughter stress and breast meat quality of broilers. British Poult Sci. 53:175–182. DOI:10.1080/00071668.2012.677805.

Zhang ZY, Jia GQ, Zuo JJ, Zhang Y, Lei J, Ren L, Feng DY. 2012. Effects of constant and cyclic heat stress on muscle metabolism and meat quality of broiler breast fillet and thigh meat. Poult Sci. 91:2931–2937. DOI:10.3382/ps.2012-02255.

Zheng A, Lin S, Pirzado SA, Chen Z, Chang W, Cai H, Liu G. 2020. Stress associated with simulated transport, changes serum biochemistry, postmortem muscle metabolism, and meat quality of broilers. Anim. 10:1–12. DOI:10.3390/ani10081442