Buletin Peternakan 45 (3): 170-176, August 2021

ISSTAP
Indonesian Society for Sustainable Tropical Animal Production

Bulletin of Animal Science

ISSN-0126-4400/E-ISSN-2407-876X Accredited: 36a/E/KPT/2016
http://buletinpeternakan.fapet.ugm.ac.id/

Doi: 10.21059/buletinpeternak.v45i3.64549

Performance and Quality of Broiler Meat During Transportation with Various Durations and $ZnSO_4$ level

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Article history
Submitted: 7 March 2021
Accepted: 16 June 2021

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ABSTRACT

Heat stress in the poor transportation systems will impact the oxidative stress, affecting the quality of chicken meat. The decrease in heat stress levels can be trigerred through antioxidants, one of which is $ZnSO_4$ antioxidants, before cutting. This study aimed to examine the reduction of post-transport stress on the performance of chickens, carcasses, and the physical and chemical qualities of broiler meat treated with $ZnSO_4$. The total broiler chickens transported were 324 roosters aged 4 weeks (with 3 replicates each). All of the transported chickens were treated with $ZnSO_4$ at doses of 0, 80, and 160 ppm for 7 days. Next, the chickens were transported with a travel time of 1, 2, and 3 hours. The breast meats were taken (filet) to be used as research samples. A factorial randomized block design was used as the research design and the data were analyzed using ANOVA (analysis of variance). The results showed that there was no correlation between travel time and the $ZnSO_4$ levels on broiler chicken performance (weight and carcass loss) and physicochemical quality of broiler meat (pH value, percentage of water lost, a_w, cooking loss, glycogen content and MDA). Longer travel time significantly reduced live weight, carcass percentage, pH value, glycogen content, while increasing the MDA levels. The addition of $ZnSO_4$ can significantly increase the pH value of breast meat, maintain high glycogen levels, increase carcass percentage, and inhibit MDA formation.

Keywords: Broiler, Meat quality, Performance, Transportation, $ZnSO_4$

Introduction

The process of transporting chickens from the farmer to the Poultry Slaughterhouse is an activity in the broiler pre-slaughter stage that must be considered. Poor pre-cut management can lead to stress. Stress is a condition of discomfort that can result in decreased immunity, weight loss and death in livestock (Astuti *et al*., 2014). The transportation of chickens managed by modern slaughterhouse refers to the Indonesian National Standard (SNI). Based on SNI 019-2044-2011 (BSN, 2011), the standard for transporting broilers is that the carriages are made of strong and durable construction materials equipped with insulators. The transport box should have a size that is suitable for the comfortable movement of livestock, with protective roof equipped with ventilators (inhaust and exhaust) (TAS, 2006). The transportation of chickens through traditional slaughterhouse standards does not refer to SNI whose management is far from the established standards such as insulators, shade, and unmeasured density.

The poor condition of the chicken transportation system can negatively impact on chicken productivity. The reduction in body weight of broilers during transportation is 3.09%-8.66%, depending on the transportation time (Marzuki *et al*., 2015). This aspect can potentially cause losses for farmers and consumers as well as affecting the quality of the meat. The duration of the transportation can affect the physical properties including pH, the percentage of lost water, and cooking loss (Purnama, 2013). Temperature an environmental factors that greatly affects meat quality (Wang *et al*., 2009). Zhang *et al*. (2012) reported that heat stress during transportation can lead to undesirable changes in meat quality. Heat stress can occur if environmental conditions such as temperature and humidity exceed 26°C and 60%, respectively;

resulting in a decrease in meat quality and an increase in malondialdehyde (MDA) content. The latter condition can lead to oxidative stress in the body (Azad *et al.*, 2010). In addition to MDA, another indicator in livestock experiencing heat stress is glycogen levels.

An effort to overcome oxidative stress due to heat stress in broiler chickens is through antioxidants before slaughtering. Antioxidants play a role in changing the form of free radicals into safe bonds so that they can stop the lipid peroxide process (Powell, 2000). Antioxidants can come from vitamins, methionine, minerals, and other micronutrients. Zinc is an essential mineral that is important for poultry and acts as an antioxidant (Vinus and Sheoran, 2017). Based on these results, it is necessary to conduct research on the physical and chemical qualities of broiler breast meat that experienced transportation stress with different travel times.

Materials and Methods

Location and time

The present research was conducted from May to June 2019 at the Poultry Field Laboratory of the Department of Animal Production Science and Technology (IPTP) of the Faculty of Animal Science, IPB. The physical and chemical quality testing of meat were carried out at the Large Ruminant Laboratory, the Laboratory of Animal Products Technology, Department of IPTP, Faculty of Animal Science, IPB, Laboratory of Nutritional Biochemistry, Faculty of Human Ecology, IPB, and the Laboratory of Physiology and Pharmacology, Faculty of Veterinary Medicine, IPB.

Materials

The materials used in this study included 324 male broilers of the Cobb strain aged 4 weeks with an average weight of 1.9 kg, commercial feed, and $ZnSO_4$. Materials needed for testing the physical and chemical quality of meat involved breast meat, buffer solution, several types of salt (BaCl2, Mg(NO3)2, NaCl, and KCl), phosphate buffer solution, centrifuge supernatant solution (Gerhardrt-soxtherm 416), acid chloride, 0.9 g/dL NaCl solution, chloroform, 5% TCA, heparin, and distilled water.

Tools

The tools used in this study included pickup trucks (APV, Japan), chicken transport baskets (Rabbit Container, Indonesia), digital thermohygrometer (HTC-1, China), digital scales (DNG, Japan), digital pH meter (Hanna Instrument USA), stopwatch (Casio HS, Japan), cooling box (Lion Star, Indonesia), and ice gel (Maslaha Ulta, Indonesia). The tools used for testing the physical and chemical quality are pH meter (Mark 903, Indonesia), aw meter (Hygropalm 23-AW, Indonesia), planimeter (Topcon KP90 N, Japan), thermometer (Alla France, France), pan (Global eagle, Indonesia), stove (Rinnai, Japan), blender/mortar (Mortar, Indonesia,) 100 ml beaker (Pyrex, Japan), 10 ml measuring flask (Pyrex, Japan), butchner funnel (Funnel, Indonesia), ice bath (Memmert, Germany), erlenmeyer (Pyrex, Japan), centrifuge (Biocen, Indonesia), and butchner filter (Whatman, UK).

Research procedure

Livestock maintenance. A total of 324 male broiler chickens tested were divided into 3 groups based on different transportation times, namely 1, 2, and 3 hours. Each transportation time was divided into 3 small groups based on the level of $ZnSO_4$ administration, namely 0, 80, and 160 ppm. Each small group contained 12 chickens placed in a cage measuring 1 x 1.5 m^2. $ZnSO_4$ was given through drinking water for 7 days in the morning, 1 hour after feeding. During the administration of $ZnSO_4$ solution, the feeding pattern did not change. After the $ZnSO_4$ solution was used up, the animals were given ordinary drinking water ad libitum.

Loading. Before being put into the transport basket, the weight of each chicken was measured (initial weight). Then, 12 chickens were put into a transport basket measuring 0.85 x 0.65 x 0.35 m3. The baskets are placed on the pickup truck in parallel. The digital thermohygrometer is located in the center of the truck.

Transportation and unloading. The basket is placed on the pickup truck in a parallel position. Transportation is carried out with travel times of 1 hour, 2 hours, and 3 hours at a constant speed of 40 km/hour. Transportation starts at 2.00 WIB (early morning). The route was the same for each treatment, where one round of the route is carried out for 1 hour. Thus, the travel time of 2 and 3 hours passed the route 2 and 3 times, respectively. Transportation is done 3 times in 3 days. Arriving at the slaughterhouse, the transport basket was lowered. The chickens were rested for 30 minutes and given drinking water ad libitum, then their weights were measured.

Slaughtering. Broiler slaughtering is carried out in a halal manner according to the standards of CAC/GL 24-1997 (BSN, 2009), namely by cutting the neck including the carotid artery, jugular vein, trachea, and esophagus. After slaughtering, the chicken is hung for 2 minutes to get rid of the blood. Furthermore, the chicken is dipped for 45-90 seconds in warm water at a temperature of 55-60ºC to easily remove the feathers using a tool. The non-carcass parts of the clean broiler (unfeathered), including the head, neck, entrails and legs, were removed. Two broilers were used from each treatment (travel time and the addition of $ZnSO_4$). The age of broilers when they started being reared was 4 weeks and 7 days. After rearing they were 5 weeks old, so the broilers were slaughtered at the age of 5 weeks. The average weight of a slaughtered chicken was 1.9 kg.

Observed variables

Climatic conditions. The climatic conditions measured during transportation included temperature (°C) and humidity (H). Temperature and humidity are measured on the outside of the basket (ambient temperature and humidity) and in the center of the basket. Temperature and humidity were recorded at departure (2.00 a.m.), in the middle of the trip (every 30 minutes, then averaged), and at the arrival (3.00, 4.00, and 5.00 a.m.).

Percentage of weight los in broiler chickens. The percentage of weight loss in broilers after being transported is seen from the initial weight before loading and the final weight after being unloaded, with the following formula:

$$\text{Percentage of decrement (\%)} = \frac{initial\ weight\ (g) - final\ weight\ (g)}{initial\ weight\ (g)} \times 100\ \%$$

Carcass percentage. Carcasses were obtained by removing the internal organs, cutting off the legs and head, then calculating through the formula by Sun *et al.* (2008):

$$\text{Carcass percentage (\%)} = \frac{carcass\ weight\ (g)}{live\ weight\ (g)} \times 100\ \%$$

pH values. The pH of meat was measured using the AOAC method (2005) with a digital pH meter. The pH measurement was carried out 6 hours after cutting.

Percentage of water lost. The percentage of water lost used the Hamm method (1977). The broiler breast, weighing 0.3 g, was used. The sample was placed on filter paper between two steel plates. Then, the sample was placed under a weight of 35 kg for 5 minutes. The area of the outer circle (wet area) minus the area of the inner circle, measurements using a planimeter, resulted in the value of MgH_2O. The percentage of water holding capacity is obtained based on the percentage between the wet area and the total area.

$$\text{Wet ares} = \frac{outer\ circle - inner\ circle}{100}$$

$$MgH_2O = \frac{wet\ area\ (cm2)}{0.0948} - 8.0$$

$$\text{\% lost water} = \frac{MgH2O}{0.3\ g} \times 100\%$$

a_w values. The values of aw (water activity) were measured using an aw meter. Prior to testing, the sample was ground first. The measurement of the aw values is done by inserting the sample into the container that is on the aw meter, then the sample is allowed to stand for approximately 15 minutes, the constant aw value is recorded (Salejda *et al*., 2014).

Glycogen levels. Glycogen levels were measured using the Folin Wu method. Determination of glucose levels in meat extract includes several steps. First, several tubes were prepared for blanks, standards, and samples (extraction solution). Each tube was added with 2 ml of alkaline copper reagent (folin wu), mixed until homogeneous, heated in boiling water for 8 minutes, then cooled in a beaker containing cold water for approximately 3 minutes (until cold). Second, all tubes were added with 2 ml of phosphomolybdic acid, mixed until homogeneous, and allowed to stand for 3 minutes to dissolve Cu2O. Third, the solution is put into a measuring flask up to 25 ml. Rinse the test tube with distilled water, the solution in the measuring flask is up to 25 ml. Next, the absorbance is read at a wavelength of 490 nm.

MDA levels. The measurement of the MDA used the method of Capeyron *et al*. (2002). Broiler chicken breast that has been stored in a freezer at -20°C is thawed first at room temperature. A total of 1.25 g of meat samples were chopped (in cold conditions), then put into a beaker added with 2.5 mL of phosphate buffer containing 11.5 g L-1 potassium chloride in cold conditions pH 7.4 (stored at 5°C). The solution was centrifuged at 4000 rpm for 10 minutes. A total of 1 mL of the clear supernatant was taken and then added with 4 mL of a mixture of 0.25 N cold hydrochloric acid (2.23 mL of concentrated hydrochloric acid per 100 mL) containing 15% trichloroacetic acid, 0.38% thiobarbituric acid and 0.5% butylate hydroxytoluene. The MDA was then calculated with following the formula:

$$\text{MDA (µmol g}^{-1}) = \frac{A\ \mu\frac{\text{mol}}{\text{g}} 50\ \mu\text{L X } 7.5\ \text{ml}}{1.25\ g\ (bb)}$$

Data analysis

The experimental design used was a factorial randomized block design with two factors. The first treatment factor was travel time which consisted of three levels, namely 1 hour, 2 hours, and 3 hours. The second treatment factor was the provision of $ZnSO_4$ minerals at 0 ppm, 80 ppm, and 160 ppm. The linear model used according to Mattjik and Sumertajaya (2002) is as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \rho_k + \varepsilon_{ijk}$$

Yij : Observation value of the i-th and j-th treatment
µ : The average general mean of the observations
αi : Effect of treatment on the i-th travel time (1 hour, 2 hours, 3 hours)
βj : Effects of treatment on the j-th $ZnSO_4$ mineral level (0 ppm, 80 ppm, 160 ppm)
αβij : Effect of interaction on the i-th travel time with the j-th $ZnSO_4$ mineral level
ρk : Effect of the k-th group (1, 2, 3)
εijk : Effect of treatment error on the i-th travel time (1 hour, 2 hours, 3 hours), the j-th $ZnSO_4$ mineral levels (0 ppm, 80 ppm, 160 ppm), and the k-th group (1, 2, 3)

The data from the observations of the performance and physical and chemical quality of broiler meat were analyzed through ANOVA (analysis of variance) using the SAS program.

Results and Discussion

Environmental temperature and humidity and basket

The ambient temperature at the beginning of the trip was around 24.40ºC with an average humidity of 85%, if added up, the result was 160.92. During the trip, the average temperature reached 24.96ºC with an average humidity of 82%, amounting to 158.93. At the end of the trip, the average temperature increased to 25.51ºC with a humidity of 78.22% at 156.14. The temperature in the transportation basket at the beginning of the trip was around 26.79ºC with an average humidity of 78%, if added up the result was 158.22, so it was not included in the category of heat stress. During the trip, the average temperature reached 31.55ºC with an average humidity of 74.52%. If the total result was 163.31, this value already indicated heat stress.

At the end of the trip, the average temperature increased to 31.93ºC with a humidity of 74%. If the total result was 163.53, then the broiler chickens in the transport basket were already experiencing heat stress (Leeson and Summers, 2001). During transportation, the transportation basket used measuring 0.85 x 0.65 x 0.35 m3 was filled with 12 chickens with an average live weight of 1.9 kg/chikens. If calculated, the density of the transport basket will be 41.45 kgm-2. According to Petracci *et al*. (2005), the density of the transport basket was divided into 3, namely low density (<55 kg m^2), medium density (55-67 kg m^{-2}), and high density (>67 kg m^{-2}). Thus, the density of the transport basket in this study was still relatively low.

Broiler chicken performance

Percentage of body weight loss. The performance of broiler is seen from the percentage of shrinkage after the chickens have been transported. Weight loss of broilers during transportation can be seen in Table 1. The results of the analysis of variance showed that there was no interaction between travel time and the addition of $ZnSO_4$ on body weight loss. The level of $ZnSO_4$ was not significantly different from the reduction in body weight of broilers. Body weight loss was significantly different ($P<0.05$) in the travel time treatment. Body weight loss was seen after 3 hours, which was 3.68%. This result showed that the length of travel time is directly proportional to the reduction in body weight of livestock (Nangoy, 2012). Basket density has an important role in the ability of broilers to cope with body temperature as homeothermic animals to weather changes during transportation (Delezie *et al*., 2007). The density of the basket must be adjusted to the total weight and age of the chickens being transported as well as the environmental conditions at the time of transportation.

In addition to the travel time factor, body weight loss also occurs because the metabolic system in broiler chickens continues without feeding and drinking during transportation. Feed stored in the digestive tract will be completely absorbed and excreted in the form of feces and urine during the transport process. Chickens metabolize so that the energy needed is still fulfilled by overhauling the energy stored in body tissues. The main energy used for muscle contraction comes from glucose and fatty acids in the blood. Energy reserves (glycogen) in the form of intramuscular carbohydrates (muscle glycogen) and extra muscular carbohydrates (liver glycogen) will be overhauled when muscles run out of the main energy source (Suryadi *et al*., 2011). Another factor affecting body weight loss during transportation is temperature. The shrinkage percentage will be higher at high ambient temperatures (Chen *et al*., 1983). The percentage of shrinkage in this study was still high (3.48%) when compared to the results of Warris (2000)'s study which reported that chickens transported

Table 1. Percentage of body weight loss, carcass performance, pH values, percentage of water lost and water activity (a_w) with various durations and $ZnSO_4$ levels

Observed variables	Transport time (hour)	Levels $ZnSO_4$ (ppm)			Average
		0	80	160	
Percentage of body weight loss	1	3.39±0.25	3.36±0.12	3.27±0.20	3.34±0.19[b]
	2	3.50±0.18	3.43±0.32	3.30±0.15	3.41±0.22[b]
	3	3.79±0.19	3.72±0.32	3.52±0.36	3.68±0.29[a]
	Average	3.56±0.20	3.50±0.25	3.36±0.24	3.48±0.23
Carcass performance	1	69.82±0.39	70.38±1.57	71.64±2.84	70.61±1.60[a]
	2	68.15±0.77	68.96±1.03	71.09±1.49	69.40±1.09[b]
	3	67.40±1.60	68.78±0.95	70.27±2.49	68.81±1.68[b]
	Average	68.45±0.92[b]	69.37±1.18[b]	71.00±2.27[a]	69.61±1.46
pH values	1	5.71±0.02	5.74±0.02	5.76±0.02	5.74±0.02[a]
	2	5.70±0.03	5.73±0.02	5.74±0.02	5.72±0.02[b]
	3	5.69±0.02	5.72±0.02	5.73±0.03	5.71±0.02[b]
	Average	5.70±0.02[c]	5.73±0.02[b]	5.74±0.02[a]	5.73±0.02
Percentage of water lost	1	32.43±0.08	32.71±0.00	32.60±0.16	32.58±0.08
	2	31.58±0.64	32.66±0.40	31.18±0.24	31.81±0.43
	3	32.38±0.16	31.92±0.81	32.83±0.16	32.37±0.38
	Average	32.38±0.16	31.92±0.81	32.83±0.16	32.37±0.38
Water activity (a_w)	1	0.88±0.01	0.84±0.01	0.86±0.00	0.86±0.02
	2	0.86±0.01	0.85±0.01	0.86±0.00	0.86±0.00
	3	0.85±0.01	0.85±0.01	0.86±0.01	0.85±0.00
	Average	0.86±0.01	0.84±0.00	0.86±0.00	0.85±0.01

[ab] Different letters on the same row indicates statistical difference ($P<0.05$) among treatments

without being fed (and no drinks) experienced a decrease in body weight of 0.2%-0.3% per hour.

Carcass performance. The performance of broiler chickens can be seen from the percentage of carcass. The percentage values of broiler carcasses in this study are presented in Table 1. The results of the analysis of variance showed that there was no interaction between travel time and the addition of $ZnSO_4$. Travel time was significantly different ($P<0.05$) with carcass percentage. The largest percentage of carcass was seen in the travel time of 1 hour (70.61%). The addition of $ZnSO_4$ also had a significant effect ($P<0.05$) on the carcass percentage. The largest carcass percentage was seen in the addition of 160 ppm $ZnSO_4$, which was 71.00%. The higher the addition of $ZnSO_4$, the higher the carcass percentage. If in the reduction of live weight the role of $ZnSO_4$ has not been seen, then its role has been seen explicitly displayed in this study. The percentage of carcasses in this study ranged from 68.45% to 71.00%. This carcass percentage is still considered normal. According to Lesson *et al*. (1996) the percentage of broiler carcasses at a slaughter age of 5 weeks ranged from 69.3 to 73%.

One of the factors affecting the percentage of broiler carcasses is live weight (Wahju, 2004). In this study, it can be seen that higher live weight loss of broiler chickens has an impact on the lower carcass percentage. In the transportation process, chickens are susceptible to stress such as rough handling during transportation, travel conditions, and the absence of feed and water (Nangoy, 2012).

Physical quality of broiler breast meat

pH values. The pH value of broiler meat can be seen in Table 1. The results of statistical tests showed that there was no interaction between the addition of $ZnSO_4$ and travel time. The results of the analysis of variance showed that the administration of $ZnSO_4$ significantly affected the pH values. The higher the $ZnSO_4$ level, the higher the pH values. When viewed from the travel time, the results of the analysis of variance showed that the pH value with a travel time of 1 hour was significantly different from the value of a 2 and 3 hours trips. Longer travel time will also lower the pH value. The pH value is influenced by heat stress factors (Zhang *et al*., 2012). As a result of heat stress, namely high temperatures will produce higher lactic acid due to the reshuffle of muscle glycogen reserves. The breakdown of glycogen into lactic acid during rigor mortis occurs for 6-8 hours with a normal pH between 5.7-5.8 (Zhuang and Savage, 2012), and 5.2-6.6 (Lengkey *et al*., 2013). In this study, the average pH value was 5.69-5.76. Thus, the pH value of broiler breast meat obtained during the study was still considered normal.

Percentage of water lost. Examination of the physical quality of broiler meat also includes the percentage of water lost. The value of the percentage of lost water can be seen in Table 1. The results of the analysis of variance showed that there was no interaction between the length of travel time and the addition of $ZnSO_4$. The travel time and the addition of $ZnSO_4$ were not significantly different from the percentage of water lost. The percentage of water lost in this study ranged from 31.81% to 32.83%, which was still in the normal range of 25%-38% (Suradi, 2006).

Water activity (aw). Water activity (aw) is the amount of free water used for the growth of micro-organisms. The aw value is tested because it can determine the damage to food (Winarno, 1992). The aw value of broiler breast meat can be seen in Table 1. The results of the analysis of variance showed that there was no interaction between the length of travel time and the addition of $ZnSO_4$. There was no significant difference in the treatment of travel time and the addition of $ZnSO_4$.

The average aw value obtained in the study ranged from 0.84 to 0.86. The aw value at postmortem will decrease because longer postmortem will cause the tendons to shrink, releasing water and resulting in the availability of free water in the meat (Lawrie, 1985). The aw value in fresh meat is around 0.990, where spoilage is easy to occur due to the presence of various growing micro-organisms. Some foodstuffs can be poisoned by Staphylococcus aureus at the optimum aw value which is around 0.995 (Lawrie, 1985). Some micro-organisms have a minimum aw value in order to grow well, including bacteria (0.90), yeast (0.80-0.90), and mold (0.6-0.7) (Winarno, 1992).

Chemical quality of broiler breast meat

Glycogen levels. Glycogen is the stored form of carbohydrates in the body. The structure of glycogen consists of glucose units in the form of branched chains so that they are more easily broken down to be used as an energy source (Almatsier, 2001). The percentage of glycogen in the test results is shown in Table 2. There is no interaction between the length of travel time and the addition of $ZnSO_4$. In the table, it can be seen that the glycogen levels in the treatment time were significantly different ($P<0.05$), the largest percentage of glycogen was found in the 1 hour travel time, which was 0.19%. The percentage of glycogen was significant at 1 and 3 hours of travel time. The addition of $ZnSO_4$ was also significantly different ($P<0.05$), the highest glycogen level was found in the addition of 160 ppm $ZnSO_4$, which was 0.24%. The higher the $ZnSO_4$ level, the higher the glycogen value. The average glycogen obtained in this study ranged from 0.07% to 0.24%. Aksit *et al*. (2006) stated that chickens reared at 34ºC had 0.076% glycogen in the breast meat. The average obtained in this study is lower than the glycogen content of broiler chicken under normal conditions, which is around 0.5%-1.3% of muscle weight (Forrest *et al*., 1975).

Malondialdehyde (MDA) levels. Malondialdehyde (MDA) is one of the indicators often associated with lipid peroxidation in

Table 2. Glycogen levels and Malondialdehyde (MDA) with various durations and ZnSO4 levels

Observed variables	Transport time (hour)	Levels ZnSO4 (ppm)			Average
		0	80	160	
Glycogen	1	0.08±0.01	0.24±0.00	0.25±0.00	0.19±0.00[a]
	2	0.07±0.00	0.23±0.00	0.24±0.01	0.18±0.00[ab]
	3	0.06±0.00	0.22±0.05	0.23±0.00	0.17±0.02[b]
	Average	0.07±0.00[c]	0.23±0.02[b]	0.24±0.03[a]	0.18±0.02
MDA	1	0.15±0.02	0.03±0.01	0.03±0.01	0.07±0.01[b]
	2	0.15±0.00	0.05±0.01	0.05±0.02	0.09±0.01[a]
	3	0.16±0.02	0.05±0.01	0.05±0.00	0.09±0.01[a]
	Average	0.15±0.02[a]	0.05±0.01[b]	0.04±0.01[b]	0.08±0.01

[ab] Different letters on the same row indicates statistical difference (P<0.05) among treatments

oxidative stress (Sahin *et al*., 2008). MDA levels of broiler breast meat after transportation can be seen in Table 2. It can be seen that there is no interaction between the addition of $ZnSO_4$ and the length of travel time. The addition of $ZnSO_4$ significantly affected the MDA value. The MDA value of broiler chicken that was given $ZnSO_4$ at the 80 ppm level was 0.05 mol g^{-1} and 0.04 mol g-1 at the 160 ppm. This result shows that the administration of $ZnSO_4$ at 80 ppm has overcome heat stress during transportation. MDA at both levels had lower values when compared to the 0 ppm $ZnSO_4$ level (0.15 mol g^{-1}). This difference is caused by the functioning of the zinc mineral contained in $ZnSO_4$ as an antioxidant that can counteract free radicals (Kakhki *et al*., 2016). Antioxidants play a role in preventing lipid peroxidation because they can stabilize free radicals so they are not harmful to the body. Also, the addition of zinc can reduce MDA levels in broilers experiencing heat stress (Kurkcu, 2010). The higher the level of zinc administration, the lower the MDA level (Sahin *et al*., 2005).

Looking at the travel time, the MDA value at 1 hour looks significantly different when compared those of 2 and 3 hours. Higher values of MDA indicate the presence of free radicals as a result of the length of heat stress treatment during transportation. The average MDA values obtained in this study ranged from 0.04 to 0.15 mol g^{-1}. This value is still lower than that of the research by Harsini *et al*. (2012), stating that broiler meat in the finisher phase (42-49 days) reared under heat stress (temperature up to 37ºC) had an MDA of 2.16 mol g^{-1}.

Conclusions

Longer travel time significantly reduced live weight, carcass percentage, pH value, glycogen content, while increasing MDA levels. The addition of high $ZnSO_4$ levels significantly increased the pH value, keeping glycogen levels and carcass percentage high, and inhibiting the formation of MDA.

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