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Influences of different transport durations on blood biochemical, meat quality, and meat yield of broiler chickens

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Abstract

The present study assessed the effects of different transport durations (0, 1, 2, and 3 hours) of broiler chickens on body weight loss, meat yield, meat quality, and blood metabolites. Seventy-two Cobb broilers aged 35 days, having an average body weight of 1.85±0.05 kg, were assigned to 4 treatments. Each treatment contained three replicates (replicate = 6 birds, treatment = 18 birds), and each replicate was transported in a single crate. The control birds were not transported, but the other three treatments were transported, in one truck, for durations of 1.0, 2.0 and 3.0 hours. The individual body weights were recorded before and after transport. The results indicated that there was no mortality recorded due to the transport treatments. The body weight loss of broilers transported for 1, 2 and 3 hours amounted to 1.52%, 1.61% and 1.65% of their pre-transport weights, respectively. The meat yield, in terms of dressing percentage, relative weights of the carcass, total pectoral muscle, and total leg muscle, was not affected by transport duration ($P > 0.05$). The water holding capacity and cooking loss of thigh and pectoral muscles, and the drip loss of pectoral muscle were not affected ($P > 0.05$) by the transport durations. However, the long transport durations (2 and 3 hours) tended to increase the drip loss of pectoral muscle and cooking loss of thigh muscle. The plasma total protein and globulin showed significant differences ($P < 0.05$) following an inconsistent trend among the treatments. Additionally, the tested transport durations did not show significant effects ($P > 0.05$) on hemoglobin, plasma glucose, uric acid, albumin, albumin/globulin ratio, triglycerides, lactic acid, and malondialdehyde. However, the long transportation (3 hours) relatively increased ($P > 0.05$) the triglycerides level in plasma, compared to the values of the other treatments. The birds transported for 1, 2, and 3 hours tended to have higher plasma malondialdehyde concentrations ($P > 0.05$) than the controls. The chemical analysis of pectoral muscle showed that the birds with the longest transport duration (3 hours) had lower water content ($P < 0.05$), higher dry matter, and ash content ($P < 0.05$) of pectoral muscle than the controls, and those transported for 1 and 2 hours showed intermediate values ($P > 0.05$). Finally, the crude fat content of pectoral muscle slightly decreased ($P > 0.05$) in a linear pattern with the increase in transport duration.

Keywords: broiler welfare, stress, meat quality, plasma analysis, meat composition.

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1. Introduction

Poultry producers, globally, seek to meet consumers' demands concerning poultry welfare and preferences for meat quality and safety. Pre-slaughter handling and transport of broiler chickens at marketing age between farm and processing units exposes birds to stress, and leads to negative effects on their welfare, meat yield, meat quality, and, in some cases, death of birds, which causes large economic losses in the poultry industry (Barbut, 2015; Gou *et al*., 2021). During transport to the slaughterhouse, broilers are exposed to many stress-inducing factors such as crating density, vehicle vibrations, speed, movement, microclimatic conditions, noise, transport time, transport distance, and the season of the year (Knowles and Broom, 1990; Mitchell and Kettlewell, 1998; Nicol and Scott, 1990). The transport stressors are categorized into mental, physical, and mixed factors; the physical stressors include catching, crating, and the environment conditions during transport, such as hot or cold temperatures, wind, vehicle vibration, and air flow, which cause physical injuries or, sometimes, death of birds. Mental stressors include fear, social mixing, exposure to pain, and deprivation from water and feed, leading to exhaustion of the normal antioxidant ability of the bird and exposing the cells to harmful free radicals (Jayaprakash *et al*., 2016). The ante-mortem stress on poultry increases the production and consumption of epinephrine and glucocorticoids (Arikan *et al*., 2017). Carlisle (1998) proposed that vibrations occurring on commercial broiler transporters can induce a several conspicuous physiological responses, which may contribute to transportation stress experienced by broiler chickens in transit to slaughter. Whyte *et al.* (2001) suggested that transport-induced stress may occur as a result of a combination of external factors such as crowding, motion, and temperature fluctuations together with deprivation from water and food. These stressors modify the normal physiological and biochemical status of the animal cells, altering their normal homeostasis, leading to reduced meat quality and quantity. Commercial meat-type chickens have difficulty with the dissipation of temperatures from their bodies, which increases body weight losses and mortalities. This often occurs when transporting broilers at marketing age from the farm to the slaughter house, particularly under high climatic temperatures and humidity conditions (Barbosa-Filho *et al*., 2014). Transport stress can negatively affect meat quality through consuming muscle glycogen reserves in broilers body during transport which initiates negative modifications in carcass meat pH, color, and water holding capacity. It has been reported that short shipments of broiler chickens lead to pale-soft-exudative meat, and long journeys display dark-firm dry-meat (Adzitey and Nurul, 2011; Droval *et al*., 2012). Simulation of the vibration and motion associated with the transport process for 2 h alters the secretion of hormones and the biochemical characteristic of blood, but with longer shipments (more than 4 h), birds appear to regain homeostatic equilibrium (Zheng *et al.*, 2020). In most regions around the

world, broilers are often sold broken into parts. In contrast, broilers in Egypt are marketed alive, where the majority of consumers prefers buying whole life birds to ensure higher meat quality. Therefore, in Egypt, broilers at marketing age, which are often produced in farms belonging to the same governorate, need to be moved to city markets with shipment durations ranging from 0.5 up to 3 hours. The one shipment may have different stops at different market destinations. Transport durations for the live broilers are often (0.5 to 4 h) considered to be short (Dos Santos *et al*., 2017; Xing *et al*., 2015; Zhang *et al*., 2009). According to the Consortium of the Animal Transport Guides Project (2017), a long transport journey is one that exceeds 8 hours, starting from when the first animal of the consignment is moved. Gou *et al*. (2021) suggested that broilers at marketing age are commonly transported in short journeys, and long journeys are often used for moving the 1-day old chicks, which are commonly transported from central distributer hatcheries to grower farms (broiler chicks) or to rearing farms (laying hen chicks) at detached locations. In a recent study, Bulent *et al*. (2019) reported that transportation is a major component of the global commercial poultry industry, which often displays various levels of stress in meat-type chickens, even under optimal managerial conditions; it can cause negative effects ranging from slight disorders to death. This study, therefore, aimed to evaluate the effects of different transport durations (0, 1, 2, and 3 hours) under optimal recommended conditions on body weight loss, meat yield, meat quality and blood metabolites of broiler chickens at marketing age (35 days).

2. Materials and methods

2.1 Experimental design, birds, management, and transport conditions

Seventy-two (Cobb) broilers aged 35days, having an average body weight of 1.85±0.05 kg, were assigned to 4 treatments. Each treatment consisted of 3 replicates (6 birds/ replicate, 18 birds/treatment), and each replicate was transported in a single crate; each crate had the dimensions 74 × 55 × 27 cm (length × width × height), with crating density of 30 kg live BW/m2 according to the Land Transport of Poultry Standards and Guidelines (2011). The control birds were not transported, but birds of the other treatments were transported (in one truck) for durations of 1, 2 and 3 hours. All shipments occurred at 9:00 am on the fourth of November under conditions of Upper Egypt, *i.e*., 32°C temperatures and 55.5% relative humidity. The speed of transportation was 40-50 km/h (Zhang *et al*., 2017). Twelve hours before shipping, the feed was withdrawn, but water was available until transportation time. During transport in this study, water was not supplied; the Consortium of the Animal Transport Guides Project (2017) specified that pullets and broilers can be transported without feed and water for up to twelve hours, but feed and water should be provided for shipments longer than twelve hours. Loaded crates were

placed at random points on the truck surface to ensure exposing the treatment replicates to homogenous conditions and to simulate practical transport conditions. In practice, there are no obvious gaps among rows and layers. All birds went on the truck at the same time and crates were quickly removed after the designated transportation times then transportation continued to the next designated time.

2.2 Sampling

The body weight loss (BWL) was estimated for all individual birds involved in the study, as the difference between body weight before and after transport. The ratio of weight loss due to transportation was calculated by dividing the BWL by the initial weight before transportation. Two birds with body weight loss (BWL) ratio similar to that of their treatments were selected from each crate (replicate) for sampling (6 birds/treatment, 2/crate). The birds were slaughtered, bled, defeathered, and eviscerated to obtain carcass weight, dressing percentage, carcass cuts' weights, and internal organs' weights. The right and left pectoral and thigh muscles were dissected and weighed. The left pectoral samples and left thighs were used to measure meat quality. Blood samples were collected during bleeding of birds in 5-ml heparinized-evacuated tubes, which were then centrifuged at 3000 rpm for 15 minutes, and plasma samples were separated and held at −20°C until analysis.

2.3 Biochemical indices in blood

The blood concentrations of hemoglobin, and plasma contents of glucose (GL), uric acid (UA), total protein (TP), albumin (ALB), triglycerides (TG), and lactic acid were measured colorimetrically using commercial kits purchased from (SPECTRUM, Egypt). The analyses were performed according to the manufacturer's instructions for each variable. Globulin was calculated as the difference between TP and Alb values.

2.4 Meat yield and internal organs

After the complete hemorrhage, the birds were defeathered and eviscerated. The relative weight of carcass and dressing percentage were calculated. Different organs (liver, heart, gizzards, and spleen) were weighed and expressed as a percentage of the live body weights. Breast muscle (%) and thigh muscle (%) were expressed as weight percentages of final BW.

2.5 Meat quality indices

2.5.1 Drip loss

About 30g samples of left pectoral muscle cut parallel to muscle fiber direction, with a constant shape, were used to measure drip loss (DL) during storage at 24-hour postmortem at 4°C, following the method described by Jiang

et al. (2007) and Abouelezz *et al*. (2019). After 24 hours of storing pectoral muscle samples at 4°C, any surface moisture was dried with filter paper. Subsequently, all samples were reweighed, and drip loss (%) was calculated according to the following equation:

$$\text{DL (\%)} = \frac{\text{initial weight of sample} - \text{final weight of sample}}{\text{initial weight of sample}} \times 100$$

2.5.2 Cooking loss

Duplicate samples from each bird (24 birds), approximately 40g each has the same thickness and size, were taken at 24-hour postmortem. The samples were then inserted into cooking bags and cooked in a water bath under 85°C until the central temperature of meat reached 72°C; the temperature was measured by inserting a thermometer into the fillets. The cooked samples were cooled to room temperature, dried with kitchen towels, and reweighed. The cooking loss (%) was calculated as:

[(initial weight of sample – final weight of sample) / (initial weight of sample)] × 100.

2.5.3. Water-holding capacity

Water-holding capacity (WHC) was determined based on the method of Hamm (1961). Samples were collected from the cranial side of the breast fillets, cut into 10.0g (±0.20g) cubes, and analyzed in duplicate. They were first carefully placed between two filter papers and then left under a 50.0g weight for 5 min. The samples were weighed, and WHC was determined from the exudate water weight using the formula:

100 – [(initial weight – final weight / initial weight) ×100].

2.6 Composition of the pectoral muscle

Frozen samples of the left pectoral muscle (6 per treatment, 2/crate) were dissected into small pieces. The dry matter, crude fat, and ash content in the breast muscle were analyzed in duplicate. Contents of dry matter, crude fat, and ash were measured according to the AOAC (2000). The dry matter was assayed by drying the breast muscle samples in a forced-air oven (method no. 934.01). To determine ash content, the dried samples were burned for 3 hours in a muffle furnace providing 550 °C (Method. 942.01). Ether extract content was determined (method no. 920.39) using a Goldfish Soxhlet fat extraction apparatus (Model. EV16, C. Gerhardt, Germany).

2.7 Statistical analysis

Each replicate (crate) (n=3) served as the experimental unit. The effects of transport durations (n=4) were examined for each variable using the GLM model when all data conform to normality and homogeneity (SAS Ver. 8.0.2, 2009; SAS Institute Inc., Cary, NC, USA). Duncan's multiple range tests were used to compare the means. Data are expressed as means ± SE for each treatment derived from the ANOVA.

3. Results

3.1 Body weight loss

The results in Table (1) showed that there was no mortality recorded due to the transport treatments. In addition, the results did not show significant effects on body weight loss of broilers transported for 1, 2 or 3 hours. However, a slight increase in BWL percentage was obtained with the increase in transport duration, which amounted to 1.52%, 1.61% and 1.65%, in the groups transported for 1, 2, and 3 hours, respectively.

3.2 Meat yield, carcass cuts, and relative weights of internal organs

The results in Table (2) showed that there were significant differences in the relative weights of the liver, thigh muscle, the drumstick ($P<0.05$) among the treatments but followed an inconsistent trend. The relative weight of the thigh in the group transported for 2 hours was higher than that of those transported for 1 hour.

Table (1): Effect of transport duration on body weight loss of broiler chickens (mean±SE).

Variables	Transport duration (hour)			
	0	1 h	2 h	3 h
Initial BW (g)	1830.22±16.59	1885.89±14.83	1882.06±12.44	1878.89±13.06
Final BW (g)	1830.22±16.59	1857.17±14.61	1851.83±12.39	1847.72±13.56
BW loss (g)	0.00	28.72±1.53	30.22±1.99	31±1.95
BWL (%)	0	1.52±0.08	1.61±0.11	1.65±0.11
mortality	0.00	0.00	0.00	0.00

1h= 1 hour transportation; 2h= 2 hours transportation; 3h=3 hours transportation.

The relative weight of drumstick in the broilers transported for 3 hours was significantly low compared to the other treatments. The relative weight of the liver in the birds transported for 2 hours was similar to the control, but was significantly lower than that of those transported for 1 and 3 hours. Additionally, the transport duration did not show significant effects ($P > 0.05$) on relative weights of the eviscerated carcass, dressing weight, total breast muscle, total leg muscle, heart, gizzard, and spleen.

Table (2): Effect of transport duration on meat yield, carcass cuts, and relative weights of internal organs of broilers aged 35 days (mean±SE).

Variables (%)[1]	Transport duration (hour)			
	0	1 h	2 h	3 h
Eviscerated carcass	70.55±0.96	71.31±0.42	71.93±0.26	70.08±0.54
Total breast muscle[2]	30.93±0.41	30.69±0.43	30.60±0.59	29.72±0.49
Total leg Muscle[2]	28.85±0.76	28.56±0.49	29.97±0.32	28.88±0.71
Thigh	9.93±0.39^{ab}	9.61±0.25^{b}	10.71±0.17^{a}	10.44±0.20^{ab}
Drumstick	4.41±0.08^{a}	4.45±0.09^{a}	4.42±0.05^{a}	4.05±0.10^{b}
Liver	2.00±0.08^{ab}	2.13±0.11^{a}	1.80±0.06^{b}	2.09±0.06^{a}
Heart	0.49±0.02	0.69±0.16	0.51±0.02	0.47±0.09
Gizzard	1.75±0.15	1.36±0.25	1.66±0.16	1.69±0.13
Spleen	0.10±0.01	0.17±0.09	0.07±0.01	0.13±0.01
Dressing percentage	74.79±0.94	75.63±0.44	75.91±0.16	74.33±0.53

^{a,b} Means with different superscripts within the same row are significantly different ($p < 0.05$). 1h= 1 hour transportation; 2h= 2 hours transportation; 3h=3 hours transportation. [1] Expressed as % of live BW. [2] non-deboned.

3.3 Meat quality

The meat quality indices of broilers transported for different durations are shown in Table (3). The results indicated that the water holding capacity and cooking loss of thigh and pectoral muscles, and the drip loss of pectoral muscle were not affected (P>0.05) by the transport durations. However, the long transport durations (2 and 3 hours) tended to increase the drip loss of pectoral muscle and cooking loss of thigh muscle.

Table (3): Effect of transport duration on meat quality of broilers aged 35 days (mean±SE).

Variables (%)	Transport duration (hour)			
	0	1 h	2 h	3 h
Pectoral muscle				
Water holding capacity	69.53±0.21	69.08±0.19	68.98±0.47	69.04±0.19
Cooking loss	25.71±1.92	28.99±2.56	25.10±2.90	25.40±2.82
Drip loss	1.69±0.21	1.92±0.27	2.26±0.32	2.07±0.11
Thigh muscle				
Water holding capacity	68.84±0.27	69.35±0.19	68.85±0.24	69.27±0.24
Cooking loss	27.09±3.28	27.75±4.11	32.63±1.13	34.30±1.92

1h= 1 hour transportation; 2h= 2 hours transportation; 3h=3 hours transportation.

3.4 Blood measurements

The results presented in Table (4) indicated that the plasma total protein and globulin showed significant differences (P<0.05) following an inconsistent trend among the treatments. Additionally, the tested transport durations did not show significant effects (P>0.05) on hemoglobin, plasma glucose, uric acid, albumin, albumin/globulin ratio, triglycerides, lactic acid, and malondialdehyde. However, the long transportation (3 hours) relatively increased (P>0.05) the triglycerides level in plasma compared to the values of the other treatments, and the birds transported for 1, 2, and 3 hours tended to have higher plasma malondialdehyde concentrations (P>0.05) than the controls.

Table (4): Effect of transport duration on blood measurements of broiler chickens aged 35 days (mean±SE).

Variables	Transport durations (hour)			
	0	1 h	2 h	3 h
Hemoglobin (g/dl)	14.49±0.42	13.98±0.22	15.05±0.17	14.85±0.50
Glucose (mg/dl)	131.50±9.20	131.70±8.48	147.50±4.13	138.67±5.32
Uric acid (mg/dl)	4.92±0.62	4.73±0.56	4.13±0.36	4.32±0.85
Total protein (g/dl)	$3.40±0.12^{b}$	$3.97±0.25^{ab}$	$3.76±0.21^{b}$	$4.67±0.34^{a}$
Albumin (g/dl)	2.42±0.05	2.44±0.10	2.65±0.09	2.65±0.21
Globulin (g/dl)	$0.98±0.14^{b}$	$1.53±0.29^{ab}$	$1.11±0.21^{b}$	$2.02±0.36^{a}$
Albumin/globulin	2.80±0.50	1.97±0.45	2.80±0.48	1.61±0.38
Triglycerides (mg/dl)	54.13±7.51	55.25±2.02	55.48±4.98	58.58±6.19
Lactic acid (mg/dl)	82.07±2.99	82.63±2.70	83.17±2.99	84.12±2.48
Malondialdehyde (nmol/ml)	16.35±1.98	17.05±3.03	17.34±2.79	18.75±1.96

^{a,b} Means with different superscripts within the same row are significantly different (p<0.05). 1h= 1 hour transportation, 2h= 2 hours transportation, 3h=3 hours transportation.

3.5 Chemical analysis of pectoral muscle

The chemical analysis of pectoral muscle is shown in Table 5. The results showed that the birds of the longest transport duration (3 hours) had lower water content (P<0.05), higher dry matter, and ash content (P < 0.05) of pectoral muscle than the controls, and those transported for 1 and 2 hours showed intermediate values (P>0.05). Finally, the crude fat content of pectoral muscle slightly decreased in a linear pattern with the increase in transport duration (P>0.05).

Table (5): Effect of transport duration on chemical analysis of pectoral muscle of broiler chickens aged 35 days (mean±SE).

Variables (%)	Transport duration (hour)			
	0	1 h	2 h	3 h
Moisture	72.91±0.27[a]	69.80±1.57[ab]	68.16±1.16[ab]	67.63±0.61[b]
Ash	3.93±0.20[b]	4.07±0.23[ab]	4.21±0.19[ab]	4.39±0.17 [a]
Crude fat	17.74±0.60	17.27±0.56	17±0.93	16.56±0.78
Dry matter	27.09±0.27[b]	30.20 ±1.57[ab]	31.84±1.16[ab]	32.37 ±0.61[a]

[a,b] Means with different superscripts within the same row are significantly different (p < 0.05). 1h= 1 hour transportation, 2h= 2 hours transportation, 3h=3 hours transportation.

4. Discussion

Previous research findings indicated that the transport stress showed various negative effects ranging from slight discomfort, increased body weight loss, and reduced meat quality, to elevated mortality of birds. This, as mentioned in the introduction, deteriorates the distinct meat attributes anticipated by consumers and reduces the expected profits from poultry enterprises. In the present study, no deaths were recorded due to transporting broiler chickens at marketing age for up to 3 hours. Similar results were reported by Gou *et al*. (2021) with medium-weight broiler chickens transported for 0, 0.5, 1, 2 and 3 hours (< 100 km). Some studies indicated that mortality of broilers is positively correlated with journey length, i.e. transport duration (Bayliss and Hinton, 1990; Warriss *et al*., 1999). For instance, Vecerek *et al*. (2006) found that short transportation of broilers (< 50 km) led to 0.15% mortality and long transportation journeys (> 300 km) led to 0.86%. The body weight loss resulting from transportation of birds and animals affects the final meat yield. In the present study, the body weight loss was estimated, 28.7 g, 30.22 g, 1.65 g, which represented 1.52%, 1.61% and 1.65% of the live weight of broilers transported for 1, 2 and 3 hours, respectively. Our results are comparable to those reported by Gou et al., 2021, who found that Chinese indigenous chickens (2 kg) transported for 0.5 to 3 hours lost around 12.4 to 40.5 g. Higher BWL values were reported by Karaman (2009), where the light broilers (< 2 kg) transported for 1, 2, and 3 h, lost 40, 57, and 90 g after transport, respectively. Body weight loss also is dependent on broiler body weight, the latter author found that medium (2-2.5

kg) and heavy birds (> 2.5 kg) showed greater BWL values, which reached up to 140 g/bird. In another study with growing turkeys (2.5 kg), the BWL was found to be 259, 307, and 350 g when transported for three distances (≤ 50 km, 51-150 km, and ≥ 151 km), respectively; this indicates that the BWL is affected by transport distance and type of poultry (Arikan *et al*., 2017). The long transportation journeys, *i.e*., > 240 km, are associated with significantly reduced carcass and breast meat yield (Hussnain *et al*., 2020). Indeed, the total BWL occurring during the transportation is attributable to losses from the body itself and part due to excreta. Taylor *et al*. (2001) reported that BWL from body estimated 4.2% plus 1.8% came from excreta loss. Gou *et al*. (2021) suggested that the loss due to excreta is mainly dependent on the duration of feed removal before transport. In our study, feed was removed 10 hours before shipping of birds; therefore, the BWL due to excreta can be excluded here, which also may explain the relatively reduced BWL values compared to the findings of previous studies. Besides, the transport durations tested in the present study did not show adverse effects on meat yield, in terms of dressing percentage, relative weights of carcass, total breast muscle, and total leg muscle. Our results agreed with those reported by Gou *et al*. (2021) who found that transport duration of 0.5, 1, 2 and 3 hours did not affect relative weights of breast muscle, leg muscle, or abdominal fat. The BWL obtained here, therefore, is non-carcass parts of the body, it possibly can be attributed to dehydration. This explanation could be supported by the differences obtained in the chemical composition of pectoral muscle in this study (Table 5), where the dry matter and ash content (%) increased and moisture content (%) decreased in the transported birds. Oba *et al*. (2009) and Gou *et al*. (2021) removed the feed 10 hours before transportation of broilers, and attributed the BWL to exposure to dehydration during transportation rather than coming from excreta origin. The transport conditions of this study, including pre-handling, water and feed removal, and crating density, comply with the recommendations of the Consortium of the Animal Transport Guides Project (2017) for optimal animal transportation. Therefore, the feed was withdrawn 12 hours before transport, which reduces the part of BWL attributed to excreta. However, in practical transport, some producers do not follow these recommendations and keep offering feed for birds until transportation time, and use higher crating densities which may increase BWL and stress due to transportation. According to Bulent *et al*. (2019), transportation can cause negative effects on birds even under optimal managerial conditions. This study, therefore, tried to estimate these effects of transport stress under normal conditions. Transportation of broilers for up to 3 hours in the present study did not show significant adverse effects on blood

hemoglobin or most plasma variables, including glucose, uric acid, triglycerides, lactic acid contents, and malondialdehyde. Similarly, transporting Chinese broilers for durations similar to those of our study, Gou *et al*. (2021) did not find significant effects on plasma glucose levels or pectoral muscle contents of malondialdehyde and lactic acid, which go in line with our findings. However, they found that plasma contents of cortisol, corticosterone and ACTH, as well as glutathione peroxidase activity increased with the increase in duration of transport. The tested transport durations (up to 3 hours) in our study did not affect glucose content in plasma, which agreed with the findings reported by Vosmerova *et al*. (2010), as broilers transported for 10, 70 and 130 km did not show difference in plasma glucose content, but the plasma glucose concentration decreased after 130 km of transport distance compared with their controls (non-transported). The results of some previous studies indicated that plasma glucose levels were reduced with transport durations longer than those tested here (Suchy *et al*., 2007; Vosmerova *et al*., 2010). Suchy *et al*. (2007) found that plasma glucose of pheasants decreased after a 4-hour transport compared with the non-transported controls. Findings of other studies indicated no significant effect on plasma glucose due to transport (Delezie *et al*., 2007; Ondrašovičová *et al*., 2008). Some authors suggested that handling (catching and crating) of broilers is more stressful than the transport process per se (Gou *et al*., 2021; Vosmerova *et al*., 2010; Zhang *et al*., 2009). These authors recorded elevated levels/activities of stress biomarkers such as ACTH, corticosterone, and glutathione peroxidase, before transport or at the beginning of transport for 0.5 hour or 45 minutes, but not after transportation for 1, 2, and 3 hours or more. These results, therefore, suggests that most changes occur during handling and crating of birds due to exposure to high stress or fear, which is followed by subsequent adaptation. This can explain the absence of significant differences in blood criteria studied here among the birds transported for different durations (1, 2 and 3 hours). Similarly, the results of Vosmerova *et al*. (2010) indicated that corticosterone concentration increased significantly before transport (i.e., after catching and crating the broilers) and decreased with transport distance (10, 70, and 130 km). Long transport journeys, *i.e*., > 240 km, increased plasma catalase activity and uric acid content; the increased uric acid level is associated with increased protein catabolism due to exposure to stress (Hussnain *et al.*, 2020), but plasma uric acid levels did not differ here due to transport treatments. Concerning the effects of transportation stress on meat quality indices, the results of Gou *et al*. (2021) indicated that drip loss of pectoral muscle increased linearly with the increase in transport duration (from 0, 0.5, 1, 2, to 3 hours). In our study, the broiler chickens transported for 2 and 3

hours showed relatively higher (P>0.05) drip loss values (2.26% and 2.07%) than those transported for 1 hour and the non-transported controls (1.69% and 1.92%). Additionally, the cooking loss (%) of thigh muscle followed the same pattern of drip loss, which amounted to 32.63% and 34.3% in broilers transported for 2 and 3 hours, versus 27.1% and 27.75% in broilers transported for 1 hour and the non-transported controls. Similar results were reported by Owens and Sams (2000) who found that meat quality of turkeys transported for three hours was not negatively affected, in terms of drip loss and cooking loss of the fillets, as compared with the non-transported controls. The increased drip loss and reduced water holding capacity of postmortem meat are attributable to protein denaturation in muscles, which is dependent on low pH scores (more acidic meat tissues). There is a negative correlation between pH values and carcass loss, that is the increase in pH leads to decreased carcass loss (Caldara *et al*., 2012; Zhang and Barbut, 2005), as low pH (more acidic meat) increases muscle protein denaturation, and subsequently decreases the water holding capacity and increases cooking loss and drip loss at the muscle surface. Generally, Wheeler *et al*. (1997) suggested that there is a difficulty in comparing indices of meat quality among different researches, due to following different methodology. In a like manner, Gou *et al*. (2021) noted the same conclusion which implies the reason behind contradictory finding on the effect of transport on meat quality of previous studies. The present results demonstrated minor negative effects of transport duration on broilers meat quality. A similar conclusion was reported by Dos Santos *et al*. (2017).

5. Conclusion

In conclusion, the tested transport durations from 1 to 3 hours under recommended managerial conditions tended to increase body weight loss, drip loss of pectoral muscle, cooking loss of thigh muscle, as well as plasma lactic acid, malondialdehyde, and triglycerides, particularly with the increase in transport duration. Additionally, the longest transport duration (3 hours) significantly decreased moisture content and increased dry matter and ash percentages in pectoral muscle versus the non-transported birds, the same tended to occur with those transported for 1 and 2 hours. The followed transport conditions here showed high adequacy for transporting commercial broilers at marketing age. For future research, it is recommendable investigating transport conditions following practical practices applied by broiler producers and distributors in Egypt, including crating density, truck speed, and removal time of feed and water.

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