Effect of transportation distance on the physiological condition and carcass traits of kampong chickens

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Abstract

This research aimed to investigate the effect of transportation distance on the physiological conditions and carcass traits of kampong chickens. Two hundred and twenty-five male kampong chickens were transported for distances of 30 km, 60 km, and 90 km, departing from three villages. Their physiological conditions were observed for up to 12 hours after having reached the final destination, and they were slaughtered after 45 minutes of lairage. The results showed that the transportation distance had a minor influence on the male kampong chickens' physiological conditions on arrival and on resulting carcass traits. Decreased oxygen consumption and metabolism rates were observable only eight hours after the rest period, without further effects on body temperature, tonic immobility, and blood triglyceride levels. There were no significant changes in live shrink, liveability, and carcass production from various transportation distances. However, a significant percentage increase in live shrink, accompanied by a significant decrease in visceral weight, was noted after transportation distances above 60 km. There was a significant decrease in the percentage of drumstick weight and a minor decrease in overall carcass quality, derived from bruising on the thighs. No significant changes were noted in graded carcass quality, meat water-holding capacity, pH, lactic acid, or water content. It was concluded that transportation distances up to 90 km were physiologically tolerable to kampong chickens, imposing minor negative impact on carcass traits.

Keywords: body temperature, carcass bruising, carcass grade, lactic acid, liveability, meat quality, metabolism rate, oxygen consumption, pH, tonic immobility, triglyceride, water-holding capacity
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Introduction

An estimated 100 million native chickens are consumed per year in Indonesia, although the actual supply of day-old kampong chickens reaches only 40% of such demand (Kontan–Agribisnis, 2017). This shortage results in big cities, such as Jakarta, being highly dependent on kampong chickens (that is, free-range chickens reared in villages) raised in native chicken production areas, such as the central Java Province. Demand for kampong chicken as food in Indonesia is driven by high household consumption plus catering at hotels, restaurants, and other food establishments, in which base production is still 100% fulfilled by village chicken production (Kontan–Agribisnis, 2017; Pusat Data dan Sistem Informasi–Kementrian Pertanian, 2017). The modes of transportation distribution of pure breed (non-crossbred) kampong chickens in Indonesia are unique. Kampong chickens are produced mostly by small-scale farms with semi-intensive and intensive breeding farms, and are collected and negotiated by local wholesale traders in various areas. For example, the main supply of kampong chicken for consumption in Jakarta originates from Solo Raya (central Java) and a small part comes from east Java, bordering with Solo. Chickens purchased from the wholesalers are stockpiled to be transported to Jakarta through the North Coast road from Semanggi Market, Solo, where the total time spent between transportation and lairage typically lasts 12–14 hours.

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Most kampong chickens being sold in the market range in bodyweight from 550 to 850 g/head (authors' observations). They are usually transported alive because of limited stockpiling space and scattered farm locations in the absence of a central slaughterhouse. The costs of transporting live chickens ultimately become cheaper than transporting processed carcasses or meat, when one considers factors such as seasonal variations in sale value, the geographical location of farms, necessary adaptations to livestock production plants, contract terms, the wholesale trading model, and endpoint consumer-specific preferences (Carlsson *et al.*, 2007).

Qi *et al.* (2017) and Chikwa (2019) observed that transportation leads to stress, health disturbances, and decreased overall wellbeing, performance, and quality of broiler chicken meat. Therefore, the final quality of processed chicken carcasses is determined not only by the processing conditions, but also by the chickens' quality of life preceding slaughter (that is, antemortem condition). The amount of stress caused by live transportation can be monitored from physiological condition, whereas the quality of carcasses can be assessed through product evaluation after production. To the best of the authors' knowledge, there are no published reports on the effects of transportation on kampong chicken products. USAID (2013) reported that no attempts had been made in Indonesia to estimate the margins of costs in this sector, because much of it cannot be quantified easily.

Stressors experienced by chickens during transportation include sudden shocks and displacement and changes in temperature, and relative humidity, which are linked to physiological and behavioural alterations (Debut *et al.*, 2005). Reported physiological alterations include increased blood corticosterone and creatinine kinase, altered blood pH, and elevated levels of bicarbonate in breast muscle correlated with lactic acid accumulation and glycolysis. Heat stress also affects O_2 consumption and CO_2 production, measured per $kg^{0.75}$ (McKee *et al.*, 1997) and the concentration of Ca^{2+} and Na^{+} ions. Heat stress induces glycaemia and glycolysis in thigh muscles, which can ultimately adversely affect carcass quality (Mitchell & Sandercock, 1995; McKee *et al.*, 1997; Yalçin *et al.*, 2004; Debut *et al.*, 2005; Arikan *et al.*, 2017).

Live shrink of broiler chicken during transportation is reported to vary from 0.18–0.60% of bodyweight for each hour of the first 5–6 hours after feed withdrawal, increasing by approximately 0.30% per additional hour (Taylor *et al.*, 2001; Nijdam *et al.*, 2006; Fernandez *et al.*, 2011). The difference in live shrink is up to 14 g higher when the broiler chicken is harvested in accordance with market standards of age and weight and within 15 hours of feed as compared with the weight at 12 hours before slaughter. The live shrink of the male broiler is substantially higher than that of the female broiler (Savenije *et al.*, 2002; Nijdam *et al.*, 2005; Northcutt & Buhr, 2010), which is more sensitive to temperature changes to the body core. Males also presented a greater decrease in meat quality compared with females (Dadgar *et al.*, 2011). Changes in poultry meat quality because of heat stress occur after a rapid decrease in muscle pH during and after slaughter from metabolic conversion of glycogen reserves to lactic acid, which is particularly intense in muscles under high temperature. A combination of high muscle temperature and low pH could lead to denaturation of sarcoplasmic protein, reducing the water-holding capacity (WHC) of muscles (Zaboli *et al.*, 2019).

Furthermore, Nijdam *et al.* (2004) stated that severe bruising would not only decrease carcass quality grade, but would lead to a market rejection of that entire carcass. Thus, rough handling in transportation, changes in environmental temperature, the density in crate storage, lairage, and modes of stunning and slaughter are causes of stress and changes in chickens' muscle metabolism that will have a negative impact on final broiler chicken carcass quality. Heat and other typical stressors during transportation reduce post-slaughter poultry meat quality by intensifying glycolysis and the accumulation of lactic acid, leading to a reduction in pH (Doktor & Połtowicz, 2009; Wang *et al.*, 2017). Breed, body size, and weight may influence the development of pathologies, affecting poultry meat tissue. Fast-growing broiler muscle differs from that of slow-growing chicken in terms of minerals and metabolic enzymes, producing broiler breast muscle of a poorer colour quality (Sandercock *et al.*, 2009). The present research was conducted to investigate the impacts of various transportation distances on the physiological conditions and final carcass quality of kampong chickens.

Materials and Methods

Two hundred and twenty-five, nine-week-old male kampong chickens weighing 691.6 ± 51.0 g were subject to three transportation distances, namely (A) 30 km (duration ~1 h), (B) 60 km (~2 h), and (C) 90 km (~3.5 h). Crate dimensions and animal density were adjusted proportionally across treatment groups to ideal conditions for broiler transportation: cages (cm) were 95.5 (l) × 57 (w) × 32.5 (h), carrying 8.5 kg (Chikwa *et al.*, 2019). Feed was withdrawn 6 h prior to transportation, which is considered ideal. Average temperature and humidity were recorded, representing overall ambient conditions during transportation (Table 1). Transportation of the three treatments started at the same time and was kept a maximum standard speed of 60 km/hour, and the lairage period on arrival preceding slaughter was standardized to 45 min.

Table 1 Average ambient conditions during three transportation distances for kampong chickens

Ambient conditions	**Transportation distance**		
	30 km	60 km	90 km
Temperature (°C)	31.0	31.3	32.2
Humidity (%)	67.7	66.7	67.8

The physiological conditions of chickens were observed every four hours up to 12 h after transportation, and they were slaughtered after 45 min of lairage, after which carcass processing was carried out immediately. The physiological parameters included oxygen consumption, metabolism rate, body temperature, tonic immobility, and blood triglyceride level. Carcass traits were assessed using net weight, percentage difference and carcass grade, weights of giblet and viscera, overall aspect, WHC, and pH and lactic acid content in the meat of male kampong chickens. Body temperature, O_2 consumption, metabolism rate, and tonic immobility were measured upon arrival, and at 4 h, 8 h, and 12 h after arrival. These observations were based on the maximum chicken transportation duration and lairage period at the slaughterhouse without feed, but water was available *ad libitum*. Oxygen consumption and metabolism rates were measured with a Warburg apparatus, a device for measuring gas pressure at constant volume and temperature. Detected pressure changes were used to estimate the amount of respiratory gas production or absorption based on the closed indirect calorimetric method employed by Isroli *et al.* (2004). Body temperature was measured with an Omron® digital thermometer. Blood samples for measuring triglycerides were collected on arrival, The triglyceride content of blood serum was tested with the enzymatic colorimetric test with a GPO-PAP reagent kit using a UV-Visible spectrophotometer.

Live shrink was estimated antemortem to produce an overview of the processed chickens' conditions while living, and the liveability rate during transportation process was also recorded. Carcass net production was calculated based on absolute carcass weight, and removed parts, such as giblets and viscera, were weighed, and the percentage of the full carcass was estimated from live weight. Carcass quality was assessed visually by grading carcasses using USDA standard score classifications (USDA, 2018). The scoring was based on 6 out of 10 criteria, which depict chicken conditions freshly before processing. Overall aspects consisted of the body constitution, including flesh and fat covering, presence of loose or broken bones, and bruises. The carcass grade value was converted into score values for statistical analysis, where scores were A = 1, B = 2, and C = 3. Bruised areas were measured manually with a transparent, millimetre-graded block placed on the four largest carcass cut parts, namely breast, wing, back, and thighs (consisting of drumstick and higher thigh); these measurements were then converted into scores, including the number and area of all bruises. Any carcasses lacking bruises were scored 9, carcasses presenting bruises on one body part or with a maximum bruised area of 1 cm^2 were scored 6, while carcasses presenting bruises on more than one body part or total bruised area >1 cm^2 were scored 3. All described procedures were approved by the Research Ethics Committee of Diponegoro University, Indonesia, Decree No. 57-06 / A–3 / KEP–FPP and were carried out in accordance with the guidelines for ethical handling of animals for use in research.

The pH of the muscle meat in wings, chest, thighs, and back was measured with the Hanna Instrument HI98107 pHep pH tester. Lactic acid was estimated as total acid using the titration method (TTA, titrated total acid), as in Sultana *et al.* (2020). The WHC was measured using the Hamm pressing method; meat water content was measured using the AOAC method, as used in Amin *et al.* (2014). Statistical analysis of variance was performed using JMP® 13.0.0 for Win10, and tested with Duncan's multiple range test to detect significant differences in the effect of treatment on the data (P <0.05).

Results and Discussion

The observed physiological conditions in transported male kampong chickens are presented in Table 2. Transportation travel distance did not affect body temperature, tonic immobility, or blood triglycerides levels significantly, but reduced oxygen consumption and the metabolism rates of male kampong chicken after a resting period of eight hours, where a significant difference was detected in transportation distances greater than 60 km.

The physiological condition of birds may be affected by transportation stress, depending on their capacity to accommodate such stressors, including their relative constitution (conformity index) of meat and body muscle, weight, growth rate, and sex (Cockram & Dulal, 2018). This research employed young male kampong chickens weighing 691.6 ± 51.0 g. Young, male, kampong chickens present a lower index of conformity of meat or body muscle, weight, and slower growth potential than do broiler chickens. Therefore, transportation distances up to 90 km generally had no significant stressor effects and were physiologically tolerable, as illustrated by non-significant effects on body temperature, tonic immobility, and blood triglycerides.

Dawson & Whittow (2000) and Damane *et al.*, (2018) showed how body surface influences body temperature. For example, birds with larger bodies have a much lower surface ratio than birds with small bodies, which face greater body temperature variations. Thus, body size, feather density, ambient conditions, and acclimatization are key drivers in determining the lowest and highest tolerable temperatures of birds. Thus, the body temperature of male kampong chickens on arrival (0 hour of rest) was not significantly different from that of any chicken's normal temperature under usual conditions. The adult chicken's normal body temperature ranges from 41–41.5 °C (Zhou *et al.*,1997; Luthra, 2017), in agreement with the present study.

The lack of significant effects on tonic immobility suggested that transportation distances of up to 90 km are not substantially stressful to male kampong chickens. In Indonesia, kampong chickens are traditionally raised in a free-range cage, and this is expected to contribute to their tolerance of transportation stress. Scott *et al.* (1998) also observed that chickens raised a free-range cage showed lower signs of fear and a shorter duration of tonic immobility than chickens raised inside cages, when transported for over 60 km or for longer than one hour. In the current research, the degree of fear was also estimated by tonic immobility. The authors inferred that their mode of raising was the main reason that tonic immobility was not affected significantly.

Table 2 Effects of transportation distance on the physiological conditions of male kampong chickens

Parameter	Observation	Transportation distance treatment			P-value
		30 km	60 km	90 km	
Body temperature (°C)	0 h of rest	41.92 ± 0.15	41.73 ± 0.15	41.57 ± 0.12	0.23
	4 h of rest	41.51 ± 0.12	41.33 ± 0.07	41.32 ± 0.14	0.28
	8 h of rest	40.64 ± 0.12	40.71 ± 0.10	40.79 ± 0.16	0.64
	12 h of rest	40.27 ± 0.24	40.87 ± 0.29	40.70 ± 0.37	0.29
Oxygen consumption (l/chicken/day)	0 h of rest	8.12 ± 0.99	11.22 ± 1.64	8.86 ± 1.59	0.40
	4 h of rest	9.42 ± 1.25	8.73 ± 1.22	9.21 ± 1.88	0.75
	8 h of rest	22.22 ± 1.36[a]	14.15 ± 2.31[b]	13.59 ± 2.45[b]	<0.00
	12 h of rest	15.00 ± 1.26	13.64 ± 1.44	13.95 ± 1.54	0.19
Metabolic rate (kcal/kg$^{0.66}$ day^{-1})	0 h of rest	61.79 ± 9.12	63.48 ± 9.61	57.77 ± 8.70	0.90
	4 h of rest	64.06 ± 9.18	72.61 ± 8.39	77.49 ± 8.63	0.57
	8 h of rest	156.18 ± 12.26[a]	98.29 ± 14.37[b]	102.35 ± 10.86[b]	<0.00
	12 h of rest	82.34 ± 9.77	93.71 ± 8.43	99.68 ± 8.71	0.46
Tonic Immobility (seconds)	0 h of rest	431.00 ± 18.36	310.10 ± 17.98	382.40 ± 20.11	0.38
	4 h of rest	255.60 ± 70.58	367.00 ± 66.40	248.10 ± 52.20	0.13
	8 h of rest	314.00 ± 63.86	229.20 ± 66.91	374.90 ± 56.61	0.37
	12 h of rest	327.10 ± 70.71	184.30 ± 57.74	386.20 ± 59.76	0.10
Blood triglyceride (mg/dl)		622.39 ± 35.15	571.85 ± 31.44	501.13 ± 31.44	0.10

Different superscript letters on the same line indicate a significant difference (P <0.05)

Krannen *et al.* (2000) showed that the high growth rate of broiler chickens, in combination with inadequate oxygenation, made them highly sensitive to hypoxia. Furthermore, Watt *et al.* (2011) reported that other stressors, such as high animal density inside crates or fluctuations in ambient temperature during transport, can affect body heat of broiler chickens. Oxygen consumption and metabolic rates in this research were not different on arrival, but a decrease was observed from 8 h after transportation (P <0.05). This effect is expected to be related to the gluconeogenesis associated with the depletion of energy reserves in chickens being transported for longer distances. This is in accordance with statements by Delezie *et al.*, 2007, who noted that extended fasting in broilers prior to transportation led to a decrease in serum triglycerides, uric acid, and triiodothyronine, signalling a negative energy balance, which stimulated gluconeogenesis. Although the tested chickens had access to water *ad libitum*, feed was withdrawn for up to 12 hours after transportation. The authors' previous research on broiler chickens has shown that gluconeogenesis starts from six hours of transportation, that is, at ~180 km, or at ~8 h after feed withdrawal, when a significant decrease in serum triglycerides is observed with a non-significantly different glucose concentration (Purwadi *et al.*, 2018).

Zhang *et al.* (2009) reported that broiler chickens that were withdrawn from feeding just before transportation started to convert glycogen reserves in the liver into circulating glucose within 45 min of transportation, and that their glycogen reserves expired after 3 h of traveling, when lipolysis began. In the present study, although the authors could not detect a decrease in blood triglycerides (P >0.05), the duration of feed withdrawal during transportation reached 7, 8, and 9 h; decreased O_2 consumption and metabolic rates after resting 8 h can indicate limited energy reserves, which are depleted during longer distance journeys. Feed withdrawal during transportation has a significant effect on plasma hormonal and metabolite concentrations. For instance, Nijdam *et al.* (2005), Fernandez *et al.* (2011), and Purwadi *et al.* (2018) showed a decrease in triiodothyronine, diglycerides, triglycerides, and fat released during cooking, which are indicative of lipolysis. These alterations are expected to contribute substantially to decreasing oxygen consumption and metabolism rates, as, in principle, heat-stressed, fasting chickens will lower their metabolism, slowing down glucose utilization by up to 37.5%, oxygen consumption, and CO_2 production (Belo *et al.* 1976; McKee *et al.,* 1997). Changes in oxygen consumption might be caused by heat-stress-induced electrolyte transport imbalance (Akbarian *et al.*, 2016).

The effects of transportation distance on antemortem condition and carcass production are presented in Table 3. An increase in live shrink (P <0.05) was noted in male kampong chickens transported for 60 km, but no further increase was reported at 90 km. Estimated absolute body live shrink followed the same trend (P <0.06). There were no effects of travel distance on chicken liveability and carcass production, bodyweight, or carcass percentage (P >0.05). However, longer distances affected the net percentage of drumstick (P <0.05). A decrease in carcass quality was observed from their thighs (Table 4), where increased bruising resulted from transportation for 60 km (P <0.05). However, there was no greater increase in bruise area from the longer journey of 90 km. Other parameters of carcass quality, i.e., number of bruises, carcass quality grades, WHC, pH, lactic acid, and water contents, were not substantially affected by transportation.

Table 3 Effects of transportation distance on live shrink and carcass production from male kampong chickens

Parameter		City distance treatment			*P*-value
		A	B	C	
Antemortem	Live shrink (g)	18.08 ± 0.96	21.57 ± 0.98	21.12 ± 0.96	0.06
	Live shrink (%)	2.57 ± 0.13[b]	3.08 ± 0.12[a]	3.11 ± 0.15[a]	0.03
	Liveability (%)	99.53 ± 0.002	99.53 ± 0.002	99.11 ± 0.003	0.77
Carcass, Giblets, and Viscera	Carcass (g)	400.33 ± 8.33	392.33 ± 12.84	390.87 ± 10.05	0.73
	Carcass (%)	59.74 ± 0.75	60.07 ± 1.35	59.67 ± 1.16	0.96
	Breast (g)	88.40 ± 2.20	87.60 ± 3.05	95.90 ± 3.18	0.09
	Breast (%)	13.51 ± 0.34	13.22 ± 0.41	14.06 ± 0.59	0.43
	Thigh (g)	68.30 ± 1.74	66.80 ± 1.87	70.90 ± 1.66	0.27
	Thigh (%)	10.43 ± 0.23	10.06 ± 0.14	10.36 ± 0.22	0.39
	Drumstick (g)	77.50 ± 1.48	74.50 ± 3.43	72.70 ± 1.90	0.38
	Drumstick (%)	11.85 ± 0.24[a]	11.18 ± 0.31[ab]	10.62 ± 0.20[b]	0.01
	Giblets (g)	22.00 ± 1.08	21.80 ± 0.82	22.50 ± 0.94	0.84
	Giblets (%)	3.25 ± 0.15	3.36 ± 0.14	3.44 ± 0.14	0.67
	Viscera (g)	76.62 ± 6.13[a]	73.32 ± 4.87[a]	58.07 ± 5.59[b]	0.02
	Viscera (%)	14.90 ± 0.81	15.00 ± 0.87	13.74 ± 0.76	0.48

Different superscripts on the same line indicate a significant difference (P <0.05)

Longer travel distances associated with feed withdrawal substantially affected live shrink, resulting in greater weight loss before slaughter. In the current study, male kampong chickens had been fasting for 6 h before traveling, thus chickens subjected to the three treatments fasted for 7, 8, or 9 h. Longer feed withdrawal resulted in higher live weight loss. Live shrink percentage in chickens transported for 60 km was 3.08%. Accordingly, Taylor *et al.* (2001), Northcutt & Buhr (2010), and Chikwa *et al.* (2019) reported varied mean weight losses in broiler chickens and turkeys within 5–24 h of feed withdrawal, ranging from 0.2–0.6% live weight loss for every hour, resulting in 1.6–4.8% after eight hours of feed withdrawal. This increment in live shrink percentage was expected as a result of the longer fasting during longer journeys at high average temperatures (Table 1). Taylor *et al.* (2001) and Cockram & Dulal (2018) showed that longer fasting, lairage periods, and higher ambient temperatures increased live shrink and mortality of broilers. During the first 6 h of feed withdrawal, the live shrink occurs mostly because of excretion, and losses beyond six hours are mainly from moisture and nutrients leaving body tissues, contributing to a decrease in carcass production.

The data revealed a substantial reduction in visceral weight, after the live shrink percentage, without affecting overall carcass production. This was in accord with studies by Warris *et al.* (2004) and Chikwa (2019), who reported that the increase in weight loss that occurs in broilers 4–6 hours after feed withdrawal occurs mainly from the emptying of the digestive tract by defecation. Under such conditions, weight loss occurs without affecting carcass production. Weight loss from expulsion of gut contents peaks in eight to 12 hours of fasting. The authors suspected that the significant decrease in drumstick weight percentage was because of a reduction in drumstick size. Zhang *et al.* (2009) reported that longer transport duration could result in increased release of plasma cortisol and glucopenia, contracting muscle fibres (thus affecting muscle size, area, and density), and even stimulation of glycolysis and lipolysis. Increased lipolysis may have contributed to the drumstick weight percentage loss. Weng *et al.* (2022) stated that slower-growing broilers have thicker muscle fibres, possibly promoting firmer, more oxidation-prone fibres, which would display more redness and intramuscular fat. Kampong chickens in the current study have a slower growth rate than broilers. Despite a decrease in thigh weight, the breast part of chicken carcasses has greater commercial value, such that a discrete loss generally does not affect total carcass production substantially.

Table 4 Effect of transportation distance on carcass quality of male kampong chickens

Parameter		City distance treatment			*P*-value
		A	B	C	
Amount of carcass bruises and area score	Total amount of bruises	5.73 ± 0.83	6.20 ± 0.80	7.20 ± 0.49	0.22
	Total bruised area (cm^2)	6.60 ± 0.88	6.73 ± 0.84	7.60 ± 0.54	0.51
	number of bruises on wings	8.20 ± 0.55	8.80 ± 0.20	8.53 ± 0.47	0.58
	Bruised wing area (cm^2)	8.00 ± 0.68	8.93 ± 0.07	8.60 ± 0.40	0.35
	Number of bruises on breast	8.13 ± 0.61	8.27 ± 0.52	8.53 ± 0.32	0.72
	Bruised breast area (cm^2)	8.27 ± 0.52	8.20 ± 0.55	8.73 ± 0.18	0.60
	Number of bruises on thighs	7.07 ± 0.78	8.13 ± 0.52	7.87 ± 0.43	0.30
	Bruised thighs area (cm^2)	7.07 ± 0.85^b	8.73 ± 0.15^a	8.53 ± 0.19^a	0.04
	Number of bruises on back	8.27 ± 0.40	8.13 ± 0.61	8.53 ± 0.32	0.66
	Bruised back area (cm^2)	8.40 ± 0.32	7.93 ± 0.73	8.60 ± 0.29	0.37
Carcass grade score		2.07 ± 0.22	2.20 ± 0.24	2.27 ± 0.19	0.55
Water-holding capacity	Thighs	51.42 ± 1.26	47.85 ± 2.06	48.81 ± 1.47	0.32
Meat pH	Wings	6.11 ± 0.12	6.26 ± 0.14	5.96 ± 0.09	0.22
	Breast	6.04 ± 0.12	6.11 ± 0.13	5.98 ± 0.13	0.66
	Thighs	6.34 ± 0.16	6.29 ± 0.14	6.12 ± 0.14	0.55
	Back	5.87 ± 0.08	6.08 ± 0.12	6.16 ± 0.09	0.15
Meat lactic acid	Wings	0.097 ± 0.02	0.134 ± 0.02	0.121 ± 0.02	0.35
	Breast	0.096 ± 0.02	0.140 ± 0.02	0.098 ± 0.01	0.06
	Thighs	0.103 ± 0.01	0.118 ± 0.02	0.093 ± 0.01	0.33
	Back	0.090 ± 0.02	0.094 ± 0.02	0.092 ± 0.01	0.50
Meat water content	Wings	73.04 ± 1.07	71.14 ± 1.21	72.69 ± 1.53	0.55
	Breast	71.69 ± 1.28	71.46 ± 0.81	70.47 ± 0.68	0.64
	Thighs	72.41 ± 0.96	70.61 ± 0.88	70.57 ± 0.48	0.20
	Back	71.70 ± 1.21	70.79 ± 1.26	71.87 ± 0.62	0.73

Different superscripts on the same line indicate a significant difference ($P < 0.05$)

At the cellular level, longer stress periods during transportation might lead to size reduction and contraction of breast (type IIa muscle fibres) and thigh muscles (type I, IIa, and IIb muscle fibres) because of the conversion of reserve glycogen to circulating glucose and the initiation of lipolysis (Zhang *et al.*, 2009). This process decreases the live weight of chickens transported for longer distances but did not affect carcass weight and meat quality substantially. Arikan *et al.* (2017) stated that stress from transportation distances over 150 km increased creatine kinase activity, disturbed ionic homeostasis (K^+, Ca^{2+}, Mg^{2+}) and inhibited ATPase (Na^+-K^+-ATPase, Ca^{2+}-ATPase, Mg^{2+}-ATPase, and Ca^{2+}-Mg^{2+}-ATPase). The increased ATP use and decreased gene expression at a subunit of a heart ATPase signals how transportation stress affects ionic homeostasis through ATP modulation, finally decreasing bodyweight. Zaboli *et al.* (2019) showed that the accumulation of lactic acid (leading to a lower meat pH and WHC) was indicative of oxidative stress as a result of environmental factors. However, Ismail *et al.* (2019) stated that shorter periods of stress of 10–60 min had no substantial effect on lactic acid; glucose; or on the hormones, adrenalin, noradrenaline, and corticosterone; drip loss; or broiler meat pH. The authors expected that changes in meat quality, such as WHC, pH, lactic acid content, and water content, would indicate greater resilience of kampong chickens to greater transportation stress than that of broilers. The weight loss of kampong chickens had no effect on carcass production as it was caused by a decrease in visceral weight ($P < 0.05$). This result agrees with Bonou *et al.* (2018), who stated that carcass weight of village chickens raised traditionally was not affected by transportation distances up to 75 km/2 h, nor were carcass cuts and drip loss affected, although a substantial change was perceived in the flavour and pH. Stress from transportation to 90 km was more tolerable for kampong chickens compared to broilers, which might be because broiler muscles contain more Na, K, Mg, and Ca and creatinine kinase per mg than muscles of layer hens and traditional chickens do (Sandercock *et al.*, 2009). By comparison, the broiler chicken genotype has three times the bodyweight of a kampong chicken and has a paler breast muscle colour (Sandercock *et al.*, 2009).

Broilers bred for rapid growth present thicker muscle fibres and lower muscle capillary density, which limits the oxygen supply and causes body posture problems and macroscopic lesions and myopathy in the *pectoralis major* and surrounding muscles (Radaelli *et al.*, 2017). Muscle fibre generation occurs after two weeks of growth, increasing dramatically within 28 d (Radaelli *et al.*, 2017). In addition, when reaching slaughter weight, broilers have greater muscle mass than standard chickens, but because collagen tissues, cartilage, tendons, and bones are structurally young, their heavier muscle mass is less tension-resistant (stretchability) in connecting tissues, cartilage, tendons, and bones, making the body prone to bruising and thus affecting the carcass quality). The current study used male kampong chickens with a characteristically lower bodyweight, bones, and lower muscle mass than broilers, which are then less prone to bruising.

The significant difference in the score of the bruised carcass area was believed to be from shocks during traveling and fatigue, particularly on the thighs of chickens transported for longer distances. The area of bruising is proportional to the force applied and amount of trauma or injury (Cockram & Dulal, 2018) from pressure and collision that cannot penetrate the skin, and damages underlying cells and capillaries (Northcutt and Buhr, 2010). In the present research, greater fatigue potential was expected to cause greater bruises on thighs. A bruise on chicken tissue typically starts with a red colour within two minutes of the trauma, darkening up to 6 h (Cockram & Dulal, 2018). Longer transportation distances can increase the pressure and the frequency of collisions among kampong chickens inside their crates.

Conclusion

Transportation distances up to 90 km seemed physiologically tolerable by kampong chickens and resulted in only minor negative impacts to overall carcass traits.

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Author's contributions

Conceptualization, T. A. Sarjana.; data curation, E. Suprijatna, L. D. Mahfudz, D. Sunarti, S. Kismiati, R. Muryani, and S. Susanti; formal analysis, T. A. Sarjana and R. Muryani; methodology, T. A. Sarjana and B. Ma'rifah ; supervision, E. Suprijatna.

Conflicts of Interest

The authors declare there is no conflict of interest.

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