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Abstract

The current study investigated the impact of using iron and plastic crates during summer transportation on production, physiological characteristics, and welfare of broiler chickens. A total of 160 Ross 308 male broilers were randomly selected from a battery-caged house at 35 days of age. Their average body weight was 1866.62 ± 36.048 g (mean ± SEM). Broilers were crated into fixed iron crates with 1.00 m (length) × 0.78 m (width) × 0.26 m (height) and plastic crates with 0.82 m (length) × 0.57 m (width) × 0.29 m (height) dimensions at 173 cm^2/kg densities. Afterward, they were transported in the early morning at an average speed of 30-50 km/h for 40 minutes, completing a total distance of 20 km. Body weights were recorded before and after completing the journey. Following the weighing of birds, blood samples were collected for blood metabolite (cortisol, glucose, and lactate) analysis. Cervical dislocation was performed to euthanize broilers followed by breast and drumstick collection. Dressing, drumstick, and breast meat were calculated as percentages whereas respiratory frequencies were measured as the number of breaths per minute. Collected breast meat samples were utilized to analyze physiochemical parameters such as pH, color (CIE L*, a*, b*), water holding capacity, and cooking loss. Results from skin temperature assessments showed higher temperatures ($P < 0.05$) in broilers that were loaded into iron crates, both before (iron, 41.23 ± 0.61 °C; plastic, 39.25 ± 0.06 °C) and after (iron, 43.53 ± 0.72 °C, and plastic, 41.63 ± 0.13 °C) completing the journey. However, total skin temperature change was not significantly affected. Importantly, stress-indicating blood metabolite analysis revealed that glucose and lactate levels were lower ($P < 0.05$) in broilers transported in plastic crates. Nevertheless, cortisol levels remained unaffected by crate materials. Furthermore, transit losses, carcass characteristics, and physiochemical properties were also unaffected despite the dissimilar crate types. In conclusion, the study revealed that plastic is the more advantageous crating material compared to iron. Besides, plastic

crates ensure meat quality and animal welfare, as evidenced by blood metabolite levels and skin temperature after transit.

Keywords: broiler, crate, meat quality, stress, transportation, welfare

Introduction

The global poultry meat industry, representing approximately 40% of total meat production heavily relies on transportation. Notably, chickens have constituted a staggering 87% of poultry that transit upon reaching market weight [1]. However, concerns have arisen regarding broiler transportation and its impact on production, meat quality, food safety, and animal welfare [2]. This process involves pre-transit, transit, and post-transit phases, during which broilers encounter various stressors disrupting their physiological equilibrium. These stressors include health conditions, microclimate, crating densities, trailer design, vibration, noise, and feed and water withdrawal periods [3-5]. Such stressors can compromise productivity and meat quality [6], with seasonal changes further exacerbating challenges, particularly in coping with temperature fluctuations [7, 8].

Notwithstanding, producers adopt different strategies to mitigate economic and quality losses during different phases of broiler transit [9], including temperature regulation in microclimates [10], optimizing journey length [7], crating densities [11], ventilation [12], and managing feed and water withdrawal periods [11] as crucial factors. However, these strategies must prioritize animal welfare, encompassing physical and mental states, emotional and cognitive aspects, avoidance behavior, biochemistry, and responses to stimuli [13, 14]. Stressful environments can significantly impact broiler productivity and health by activating the hypothalamo-pituitary-adrenocortical cascade and triggering hormonal secretions [15, 16]. Hence, plasma or serum corticosteroid levels serve as acute stress indicators when proper blood drawing methods are followed [17].

Stress hormones such as corticosterone and cortisol trigger rapid energy production in animals [18], increasing the demand for glucose and elevating blood glucose levels [19]. In situations where oxygen supply is inadequate for aerobic metabolism, muscles undergo anaerobic respiration, converting glucose into lactate. This accumulation of lactate in the bloodstream indicates stress in birds [20]. Stressors also elevate plasma corticosteroid levels due to heightened secretion of adrenocorticotropic hormone and corticotropin-releasing hormone. However, cortical cell function and numbers may also be altered by dietary protein restrictions as well [21].

The World Organization for Animal Health acknowledges the crucial role of maintaining appropriate animal welfare measures during transportation and recognizing its significant impact on meat quality [2]. European Council regulation (EC No 1/2005) complements this stance by aiming to prevent animal suffering and promote welfare regulations for European operators. This regulation covers various aspects, including transport preparation, responsibilities, competence, equipment standards, and documentation requirements [22]. Additionally, countries such as the USA, Australia, and the Republic of Korea have implemented regulations prioritizing crate design and construction within the respective regions [23, 24]. However, [25] identified four major risk factors associated with animal transportation across different jurisdictions: climatic conditions, animal fitness, stocking densities, and transit durations.

The selection of crate materials for broiler transportation is diverse globally due to factors such as operational scale, cost, technology, durability, and environmental impact. Recently, plastic crates have been among commonly used, while balancing convenience with ecological considerations. However, researchers have traditionally overlooked crate materials as a major concern. Emerging factors like environmental impact, hygiene, and local regulations should now shape these decisions. Thus, the current study aims to explore the effects of different crate materials on broiler production, stress levels, meat quality, and welfare, providing insights to improve transportation practices, especially during the summer season.

Materials and Methods

The Animal Ethics Committee of Chungnam National University, Daejeon, Republic of Korea, approved the protocols used in this experiment (approval number: 202206-CNU-081)

Birds, experimental design, and treatments

Before transportation, all birds were housed in Chungnam National University's experiment farm which had 48 battery cages (76 × 61 × 46 cm^3) that housed six birds until transportation and were managed according to the Ross 308 broiler management guideline [26]. A total of 160 Ross 308 male broilers were used at 35 days of age with an average body weight of 1,866.62 ± 36.048 g (mean ± SEM). They were randomly selected after 4 h of feed withdrawal before catching. Afterward, birds were taken out from the cages and transported securely by holding their wings against the handler's body using both hands (Japanese method) [27]. The birds were transported in different types of crates as follows: an iron crate having dimensions of 1.00 m (length) × 0.78 m (width) × 0.26 m (height); a plastic crate having dimensions of 0.82 m (length) × 0.57 m (width) × 0.29 m (height) with 4 replicates per crate type. The birds were placed in crates based on optimal crating density suggested by the Korean transportation standards [28] of an average of 173 cm^2/kg. The transportation's distance was 20 km for 40 min at an average speed of 30-50 km/h during the early morning from 8:00 a.m.

Transportation losses

Body weight loss (g) in transit was measured as the difference between all broilers' weight before transportation and the final body weight (g) from all crates upon arrival at the destination after transportation [29].

Carcass traits and sample collection

Once birds arrived at the destination, carcass trait measurements and sample collection were taken place. Two birds were selected based on closeness to the mean body weight of the birds in the respective crate, and the resulting weight was recorded as the live body weight. Blood samples were collected from the brachial vein into a vacutainer coated with lithium heparin (BD Vacutainer, BD, Franklin Lakes, NJ, USA) before euthanizing the birds. The birds were then euthanized by cervical dislocation for the evaluation of some carcass characteristics. The dressing percentage with giblets (heart, gizzard, and liver) was determined as a function of the live weight of the birds. The breast meat was then separated and weighed to measure its relative to the total carcass weight. The breast meat of broilers was then collected for meat quality analyses [29].

Physiological responses

Collected blood samples were centrifuged (LABOGENE 1248R, Gyrozen, Daejeon, Korea) at 3,000 × g for 10 min at 4 ℃ and the plasma was separated and stored at -80 ℃ (UniFreez U 400, DAIHAN Scientific, Wonju, Korea) until analysis. Cortisol concentrations were determined from the plasma with a cortisol ELISA kit (CUSABIO, Wuhan Huamei lotech Co., Ltd., Wuhan, China) used in accordance with the manufacturer’s instructions. Lactate concentration was determined by lactate assay kit (Sigma Aldrich, Co., Burlington, USA) using the manufacturer’s instructions. Briefly, glucose was determined from the collected plasma using a glucose assay kit (Asan Pharmaceutical Co. Ltd., Seoul, Republic of Korea), following the manufacturer’s instructions.

After finishing transportation, the respiratory frequency was measured as the number of breaths per minute using three randomly selected broilers per crate observed by the camera (GoPro Hero 8, San Mateo, CA) for 1 minute [30].

Physicochemical traits

The pH values of the breast meat were monitored immediately after sample collection. An aliquot (9 mL) of distilled water was added to 1 g of muscle, followed by homogenization (T25 basis, IKA-Werke GmbH & Co. KG, Germany) for 30 seconds. The homogenate was centrifuged at 2,090 × g (ScanSpeed 1580R, Labogene ApS, Lillerød, Denmark) for 10 min and the supernatant was filtered through filter paper (No. 4, Whatman, Maidstone, UK). The pH of the filtrate was measured using a pH meter (SevenEasy, Mettler-Toledo Intl. Inc., Schwerzenbach, Switzerland).

The CIE (Commission Internationale de l'Eclairage) lightness (L*), redness (a*), and yellowness (b*) of broiler breast meat were determined using a spectrophotometer (CM-3500d, Minolta Inc., Tokyo, Japan). Measurements were taken perpendicularly to the surface of the broiler breast meat with a 30 mm diameter illumination area at two different locations per sample. The results were analyzed in the SpectraMagic software (SpectramagicTM NX, Konica Minolta Inc., Tokyo, Japan).

For the water holding capacity (WHC) measurements, a 2 g sample of raw broiler breast meat was precisely weighed, placed on cotton wool, and then added to a centrifuge tube. The weight of the meat after centrifugation at 2,090 × g (ScanSpeed 1580R, Labogene ApS, Lillerød, Denmark) for 10 min was measured and compared to the initial meat weight. The moisture content of meat was determined by drying 2 g of samples placed in aluminum dishes for 3 h at

110 °C. The remaining moisture (%) present in the meat after centrifugation was expressed as the WHC [31].

To measure the cooking loss, the breast meat of the broiler was weighed vacuum packaged and cooked for 20 min in a water bath at 80 °C until the internal temperature reached 70 °C. The cooked breast meat of broilers was cooled at room temperature (20 °C) for 30 min. After removal of the vacuum bag, the surface moisture of the breast meat of the broiler was removed with paper towels, and the cooked breast meat of the broiler was weighed. The cooking loss was calculated as the difference between the weight of raw breast meat and cooked breast meat.

Skin temperature measurements

The body surface temperature of broilers within individual broiler cages was assessed utilizing a portable thermal imaging camera (IRay T3PRO, manufactured by Shandong, China) both before and after transportation. The measurements were then averaged to derive a representative value for each cage. Furthermore, temperature differentials pre- and post-arrival were quantified by converting them into absolute values, facilitating rigorous analysis of the thermal dynamics experienced by the broilers during transport [32].

Statistical analysis

The statistical analysis of the data was performed using SPSS (Version; IBM SPSS 2019). The data obtained from the experiment except for the skin temperature were analyzed by independent sample t-test. The data of skin temperature were analyzed by a two-way ANOVA model to evaluate the main effects (types of crate and transportation) followed by Tukey's multiple range analysis with each crate as the experimental unit. In terms of transportation loss and respiratory frequency measurements, the experimental unit was defined as the crate. For carcass traits, meat quality, and blood metabolites, selected individual birds were considered as the experimental unit. Statistical significance was determined at a significance level of $P < 0.05$.

Results

The broilers used in the experiment were transported according to the appropriate transport density specified in Korean Law [28], so the mortality did not occur regardless of the two crate material types.

Transportation losses and carcass traits

The results of the transportation losses and carcass traits of the broiler using different types of crates during transportation are shown in Table 1. There was no significant difference ($P > 0.05$) in body weight loss and carcass traits such as dressing ratios, relative breast meat, and drumstick weights between the treatments.

Physiological responses

The results of broiler blood metabolites, after transporting with different crate types are shown in Figure 1. Broilers transported in plastic crates had reduced glucose and lactate contents ($P < 0.05$) compared with those in iron crates. However, plasma cortisol levels remained unaffected ($P > 0.05$) despite the different types of crates used during transportation. The impact of different crate materials on broiler chicken respiration after transportation is shown in Figure 2. There was no significant difference ($P > 0.05$) in respiratory rate between the two treatments.

Physicochemical traits

The results of the physicochemical characteristics of broilers related to different crate types during transportation are shown in Table 2. The meat quality parameters such as pH, water holding capacity, cooking loss, and meat color (L*, a*, b*) were not significantly different (P > 0.05) related to the two treatments.

Skin temperature evaluation

The skin temperature of transported broilers in crates made of different materials during transportation in summer is presented in Table 3. The interaction between transportation and crate type did not show any significant effect in the current study (P > 0.05). However, transportation did affect the increase in total shipment temperature after transportation (p < 0.001), while crate type demonstrated higher (P < 0.01) temperatures in fixed iron crates compared to plastic crates.

Discussion

The current study intended to evaluate the impact of different crating materials used during transportation on the production, physiological characteristics, and welfare of broilers in the summer season. The broilers used in the current study were transported in compliance with the transport density regulations stipulated by Korean Law [28], which could result in non-mortality during transportation.

Iron possesses high heat conducting and heat transferring properties as a structural material. These characteristics enhance the heat absorption from the outer environment and convey it from highly heated areas to low-heated areas through conductivity. Ultimately, this process increases the total surface temperatures in particular areas [33, 34]. In comparison, plastic has excellent insulating capabilities with inherited heat resistance properties which can be used as a structural material in many industries of the world [35]. In our study, crates made of iron have been observed to elevate the microenvironment temperature, as evidenced by the rise in the skin temperatures of broilers. Conversely, broilers housed in plastic crates, under similar conditions, exhibited lower skin temperatures. Since body surface temperature serves as a common indicator of thermal comfort or stress in broiler chickens [36, 37], it is possible that iron crates contribute to increased temperatures within the crate space due to radiation reflection and high thermal absorptivity. In contrast, plastic crates exhibit lower temperatures, due to their better thermal insulation properties against heat.

Typically, the plasma glucose levels in an avian species are 150% to 200% greater than those found in mammals with comparable body mass [38]. Hence, its concentration directly affects the metabolism of poultry. According to [39], there is a significant impact on glucose metabolism in chickens related to their stress regulations. Particularly, glucose and triglycerides are recognized as major metabolites that play crucial roles in biochemical and physiological functions, providing the energy needed to fuel these processes [40]. This glucose concentration can vary based on several factors in poultry including, physiological status, age, gender, energy intake, and ambient temperature [39]. In relevance, the glucose level increment in broilers transported in iron crates could be due to the stress, caused by the type of crating material and macroenvironment (in summer) temperatures.

While transportation, broilers experience acute stress conditions (such as bruising or broken wings) from hard surfaces like iron crates and they could lead to increased gluconeogenesis and glucose mobilization within the animal body. Additionally, this sudden introduction of broilers into an excessive heat and humidity environment (in summer) from a relatively constant environment can exhibit a detrimental effect on them [27]. Consequently, elevated microclimate temperatures can further exacerbate these physiological processes in broilers, potentially resulting in augmented glucose levels in broiler plasma [41]. Similarly, lactate level increment in metal-crated broilers could also be due to the aforementioned stress factors similarly glucose level fluctuations.

The current results on broiler transport and welfare, emphasize the importance of further research into the effects of crate materials on broiler health and the economic and practical benefits for the industry. In conclusion, the study underscores the importance of crate material choice in broiler transportation while revealing the plastic crate as the advantageous crate material type compared to the iron that can ensure meat quality and animal welfare in terms of blood metabolite changes and skin temperature changes after loading.

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Tables

Table 1. Live weight loss and carcass traits as affected by different materials of crates during transportation in summer.

Items	Iron	plastic	SEM	*P*-value
Body weight loss (g)	32.15	26.46	1.737	0.102
Dressing ratio[1] (%)	89.58	89.72	0.238	0.788
Relative breast meat weight[2] (%)	28.03	28.23	0.604	0.878
Relative drumstick weight[3] (%)	10.53	10.41	0.155	0.713

[1](carcass weight/Live body weight) × 100
[2](breast meat weight/carcass weight) × 100
[3](drumstick weight/carcass weight) × 100

Table 2. Physicochemical traits of chicken breast meat under different materials of crates during transportation in summer.

Items	Iron	Plastic	SEM	*P*-value
pH	5.92	5.96	0.035	0.588
WHC (%)	63.13	67.22	2.019	0.335
Cooking loss (%)	23.13	21.42	0.966	0.402
L*	53.45	52.85	0.411	0.476
a*	6.74	7.20	0.287	0.440
b*	16.34	17.19	0.250	0.095

WHC: Water Holding Capacity

Table 3. Skin temperature of broilers under different materials of crates and transportation in summer

Transportation	Type of crate	Skin temperature (℃)
X	Iron	41.23
	Plastic	39.25
O	Iron	43.53
	Plastic	41.63
SEM		0.239
Main effect		
Transportation		
X		40.24
O		42.58
SEM		0.341
Type of crate		
Iron		42.38
Plastic		40.44
SEM		0.383
P-value		
Transportation		<0.001
Type of crate		0.002
Transportation × Type of crate		0.939

SEM: standard error of the mean.

Figures

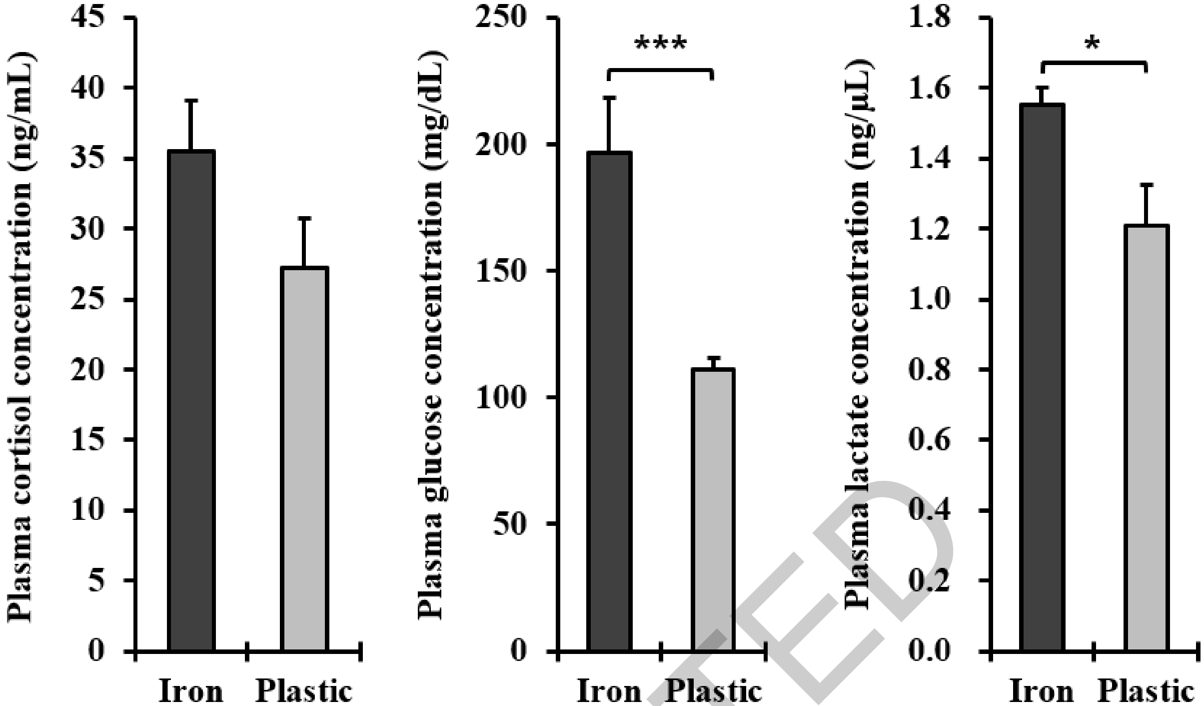

Figure 1. Blood metabolites of transported broilers under different materials of crates during transportation in summer. The values in the histogram are the means ± SEM (n = 8). *Indicates a significant difference of p<0.05 and ***indicates a significant difference of p<0.01.

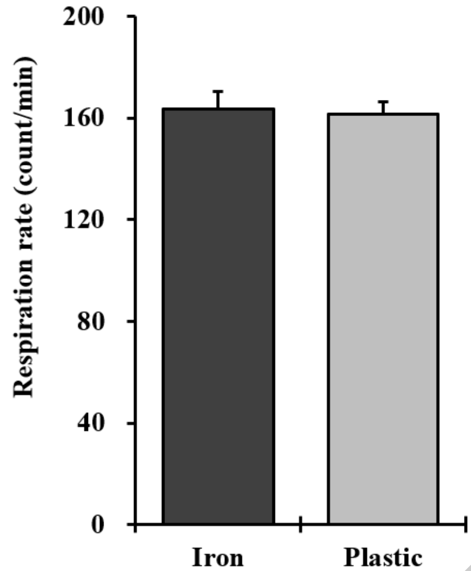

Figure 2. Respiration rate of transported broilers under different materials of crates during transportation in summer. The values in the histogram are the means ± SEM (n = 4).