Research Article

Animal Welfare Indicators, Carcass and Meat Characteristics Broiler Chickens Raised in Closed House with Plastic Slatted Flooring

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Abstract | This study aimed to evaluate the use of rice husk litter mats with plastic slats in the maintenance of broiler chickens in industrial-scale closed houses. The research was conducted from June 2024 to March 2025 at the Teaching Farm Closed House of PT Hasanuddin Agrivisi Internusa in Makassar, South Sulawesi. This study used two cage mat treatments: a closed house with a rice husk base and a plastic slat. The variables measured included animal welfare indicators, carcass characteristics, and broiler meat quality. Plastic slats reduced footpad and hock burn but significantly increased arthritis. Body weight increased on slats, but meat shear force increased and water-holding capacity decreased. The body weight of broiler chickens kept on the plastic slat was significantly higher 3,8% than that of those kept on the litter mat. The shear force of chicken meat raised on a litter mat was significantly lower, whereas the water-holding capacity indicator of chicken meat was significantly higher than that of chickens raised on a plastic slat. The conclusion states that the use of plastic slats does not negatively impact animal welfare indicators, carcass characteristics, or the quality of broiler chicken meat raised in closed houses.

Keywords | Broiler chickens, Closed house, Plastic slatted flooring, Animal welfare

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INTRODUCTION

Broiler chicken production continues to increase in line with the growing demand for chicken meat, driven by the increasing global need for animal proteins. A factor supporting the growth of broiler chicken production is the short production cycle, which allows higher production rates than those of other livestock species (Sumanu *et al*., 2022). In addition, the increase in poultry product consumption motivates farmers to optimize their production systems, including adopting modern technologies and improved house management, to enhance the growth performance and meat quality of chickens.

Litter management is a crucial factor in intensive broiler production systems, as it directly affects poultry health, welfare, and productivity (Mocz *et al*., 2022). In closed-house systems, litter not only serves as a surface for standing but also acts as a microenvironment that can be either a source of stress or a performance-supporting factor. Poor litter quality, especially due to high moisture content from excreta and spilled drinking water, has been shown to negatively correlate with chicken health (Alabi *et al*., 2023). This condition is a major cause of contact dermatitis, including footpad dermatitis lesions and breast blisters, which not only indicate poor welfare but can also reduce carcass quality (Duman *et al*., 2024). The occurrence of breast blistering can cause rejection of the chest, which is the main and high-value piece, thus impacting the profitability of chicken farmers and processors. The associated decline in meat quality can also affect consumer confidence in broiler chicken products (Zanetti *et al*., 2018; Vnucec *et al*., 2024).

Commercial broiler production systems commonly use litter bedding because it absorbs moisture and provides a medium for chickens to express their natural behaviors. However, the main challenge with litter bedding is keeping it dry and minimizing ammonia levels, as failure to manage it can reduce performance and increase the risk of pathogen exposure (Cavusoglu *et al*., 2018). Bone health and leg-related problems, such as bone deformities and tibial cartilage dysfunction (*Tibial dyschondroplasia*), which frequently occur in fast-growing broilers, negatively impact carcass and meat quality, as these conditions elevate mortality rates, increase carcass rejection, and reduce growth performance (Xu *et al*., 2021).

In response to these challenges, the industry has developed alternative flooring systems, such as plastic slats. These systems are designed to separate chickens from their waste, potentially improving cleanliness, maintaining feather hygiene, and reducing skin lesions caused by contact with wet litter (Cavusoglu and Petek, 2019). However, the use of plastic slatted in broiler production has some disadvantages. The harder, less comfortable surface of plastic slats can limit chickens' natural behaviors, such as scratching and dust bathing, and may also cause physical stress as their body weight increases (Cavusoglu *et al*., 2018). A combination of plastic slats with clean, easy-to-replace litter, such as wood powder or other fine, dry organic materials, can be a solution so that chickens still have an area to forage and express natural behavior (Jacobs *et al*., 2021).

Broiler welfare is directly and importantly linked to the quality of the resulting meat. Several animal welfare indicators, such as footpad dermatitis, arthritis, hock burns, gait scores, and cleanliness, are vital in welfare assessment protocols for commercial broiler production systems (Eijk *et al*., 2023). Chronic stress, whether from poor litter conditions or discomfort from plastic slatted, can trigger physiological responses that ultimately affect post-slaughter meat quality. Broiler welfare, including physical health (especially bones and muscles), environmental conditions (such as housing and lighting), and stress management, directly impacts the quality of meat produced, including its physical and chemical properties and nutritional value. Husbandry practices that prioritize animal welfare will drive the production of high-quality and sustainable broiler meat (Mocz *et al*., 2022; Honig *et al*., 2024; Wu *et al*., 2024).

Several studies have reported the impact of floor design on performance and welfare (Li *et al*., 2017; Cavusoglu and Petek, 2019). Research on the use of plastic slats in closed houses on an industrial scale remains limited. Comprehensive studies integrating the impact of using plastic slats as cage flooring on key animal welfare parameters, carcass characteristics, and meat quality have been conducted on a laboratory scale, but remain limited at an industrial scale in commercial closed-house environments. This study aimed to compare the use of rice husk litter and plastic slats in industrial-scale commercial closed-house broiler production systems. This study aimed to analyze the impact of using plastic slats on animal welfare indicators, carcass characteristics, and meat quality compared with the use of litter flooring.

MATERIALS AND METHODS

Research time and place

The research was conducted from June 2024 to March 2025 at the Teaching Farm Closed House of PT. Hasanuddin Agrivisi Internusa Makassar. Carcass and meat characteristics were tested at the Laboratory of Animal Product Technology, Hasanuddin University.

Research tools and materials

The equipment used was a closed house with a tunnel ventilation system, litter mat, and plastic slats for the cages. Each cage was 120 m long and 12 m wide with a capacity of 25,000 heads. The research cage was equipped with an eating and drinking system, heating system, and an automatic ventilation system. The test equipment used for each parameter is described in the research procedure. The cages used in both treatments were not swapped, which is a limitation of this study.

The materials used in this study were day-old chick (DOC) Cobb strain 50,000 with an average weight of 50.1±5.3 g/head, rice husks, drinking water, vitamins, vaccines, disinfectants, and commercial feed in the pre-starter, starter, and finisher phases. The nutritional content of the broiler feed met the required, The Indonesian National Standard (SNI) series 8173, with a crude protein content of 19-21%, metabolizable energy of 3000-3200 kcal/kg, and a maximum crude fiber content of 5%.

Research procedure

Broiler chicken maintenance

Broiler chickens were raised according to standard industrial operating procedures, with a rearing period of 4 weeks (28 days). The chickens were divided into two closed-house units, each with a capacity of 25,000 birds. The litter mat-type house used a 10 cm thick layer of rice husk bedding, whereas the slat-type house used plastic slats with 1×1 cm holes and a height of 20 cm from the floor. In this study, the brooding period lasted for two weeks. Each house consisted of four compartments separated by partitions, with each compartment measuring 12×30 m and housing 6,250 chickens. Before the day-old chicks (DOC) were reared, each house was sprayed with a disinfectant and fumigated. The DOCs used in this study were already vaccinated at the hatchery. The feed and drinking water were provided ad libitum. The rearing temperature was regulated automatically with an automatic controller, and in the 4th week the temperature ranged from 24.2 °C - 28.2 °C, with humidity levels between 70% - 92%.

Animal welfare indicators

The measurement of animal welfare scores in broiler chickens includes the assessment of hock burn, footpad dermatitis, breast blister, and cleanliness scores based on the EWQC (2009). The samples observed for animal welfare assessment of each treatment group consisted of 100 broiler hens randomly selected from four areas in the pens (25 each from each area) during each period. Observations were carried out over three rearing periods as repetitions at 28 d of age. The total number of chicken samples observed was 600, consisting of 300 chickens per treatment cage.

- Cleanliness score by comparing the hygiene conditions of the chicken feathers. The score percentage assessment was based on Figure 1 (EWQC, 2009).
- The breast blister score is obtained by comparing the condition of the chicken breast. The score percentage assessment was based on Figure 2 (EWQC, 2009).
- Footpad dermatitis scores were measured by assessing the condition of the chickens' feet. The score percentage assessment was based on Figure 3 (EWQC, 2009).
- The hock burn score was measured by comparing the condition of the back of the joint (hock joint). The score percentage assessment was based on Figure 4 (EWQC, 2009).
- Arthritis was assessed based on the following scoring: 0 (no swelling in the hock joint) and 1 (swelling in the hock joint) (Xu *et al*., 2021).
- The Gait Score was assessed using a scoring system developed by Kestin *et al*. (1992) as follows: 0 (normal, no abnormality); 1 (fast-moving chickens with slight walking defects); 2 (chickens can move freely, but have definite and identifiable defects); 3 (obvious gait defects that affect movement); 4 (severely deformed chickens that move with difficulty); and 5 (severely deformed chickens that often use their wings to crawl) (Topal and Petek, 2021).

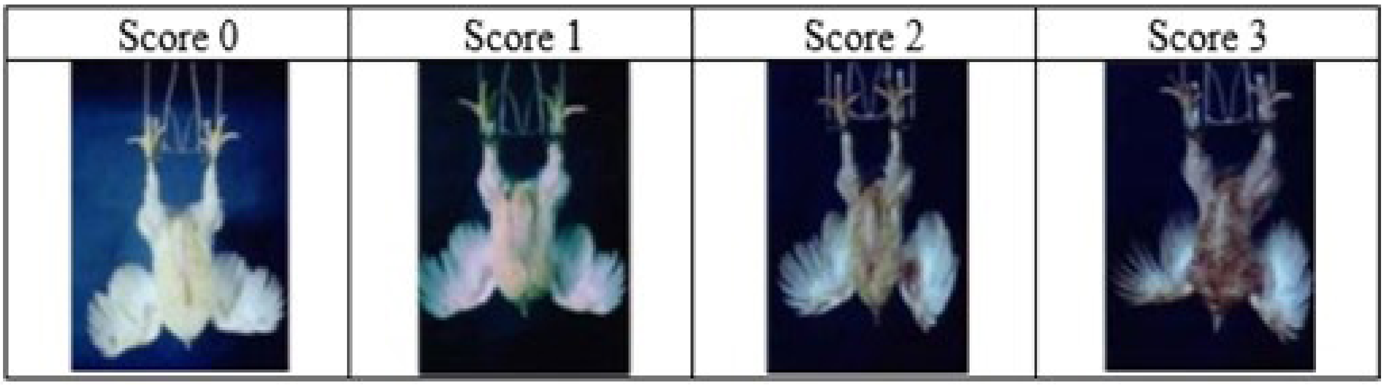

Figure 1: The cleanliness score score assessment (EWQC, 2009)

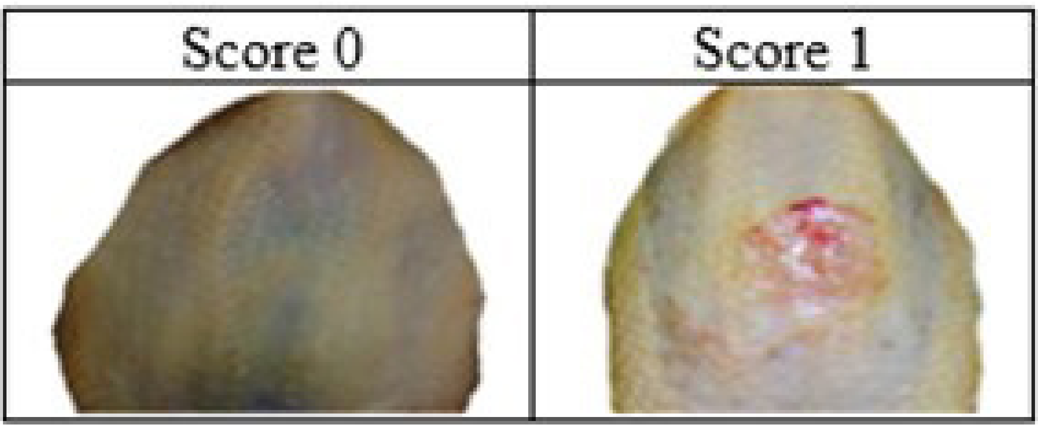

Figure 2: The breast blister score assessment (EWQC, 2009)

Figure 3: The footpad dermatitis score assessment (EWQC, 2009).

Figure 4: Hock burn score assessment (EWQC, 2009).

Carcass characteristics observations

The carcass characteristics were measured as percentages of the carcass and its commercial parts. A total of 120 chickens, 20 males per cage/period, were used in the three maintenance periods. Before dissection, the chickens were fasted for 12 h. Chicken slaughter was performed in accordance with the SNI 99002:2016. The carcass characteristics were measured as follows:

- Slaughter weight (g/head) was measured at the end of maintenance, before cutting. Before the weight of the broiler chickens was measured, the quail was fasted for 12 h.
- The percentage of carcasses was calculated by dividing the carcass weight by the slaughter weight and multiplying by 100% (Topal and Petek, 2021).
- The percentage of commercial carcass parts was obtained by dividing the weight of commercial carcass parts by the carcass weight and multiplying by 100%. The parts of the commercial carcasses observed were the chest, thighs, back, and wings (Topal and Petek, 2021).

Observations of the characteristics of meat

The meat characteristics were measured using samples from the lower thigh (drumstick). The sample consisted of 120 lower thighs from 120 roosters, with 20 chickens (five per area) per pen per period, and experiments were conducted over three maintenance periods. The measurement of the physicochemical properties of meat based on the method of Abustam and Ali (2020) which is an internal laboratory manual includes:

- pH measurement using a pH meter (Abustam and Ali, 2020)
- The water-holding capacity (WHC) (%) was measured using the Hamm method. First, a 0.3 g sample was placed on a Whatman 42 filter paper, then sandwiched between two glass plates under a 35 kg weight for 5 min. The area covered by the meat sample that became flat and wet around the filter paper was marked or drawn on the graph paper with the help of a candling tool, and the wet area was obtained after subtracting the area covered by the sample (from the total area) (Abustam and Ali, 2020)
- Cooking loss (%) was measured by weighing the samples before boiling as the initial weight. The breast meat sample was pierced with a bimetal thermometer and boiled in water until the internal temperature reached 71-81°C. After boiling, the sample was lifted and weighed again (Abustam and Ali, 2020)
- The shear force (N) was measured using a shear force tool (Abustam and Ali, 2020)

Data analysis

This study used two cage mat treatments: A closed house with a rice husk litter floor and a closed house with a plastic slat. Each treatment consists of 3 replicates. The data obtained on animal welfare indicators and carcass characteristics were analyzed using the t-test (independent t-test) (Mattjik and Sumertajaya, 2013).

RESULTS AND DISCUSSION

Animal welfare

The condition of broiler chickens is crucial for their maintenance. The animal welfare indicators of broiler chickens raised in different cages are presented in Table 1.

The cleanliness score in broiler chickens reflects the level of cleanliness associated with the cage environment, encompassing litter quality, excreta contamination, and overall cage sanitation. In this study, the cleanliness score showed no statistically significant difference (P>0.05) between the two treatments. The lack of difference in cleanliness suggests that litter management was adequate to prevent excessive soiling. Factors such as litter quality and resting comfort greatly influence the hygiene score of chickens, where better management of the cage base results in a better hygiene score (Federici *et al*., 2016). Poor hygiene increases the number of pathogenic microorganisms in the environment and ammonia levels, which can interfere with respiratory health and immune status. This can cause physiological stress and interfere with growth rates. Therefore, hygiene can indirectly affect performance by reducing stress-induced immune suppression and improving the health status of chickens (Kim *et al*., 2022). Additionally, a cleaner environment helps maintain gut health by minimizing the presence of pathogenic microorganisms. This supports better nutrient absorption, thereby improving feed conversion and growth efficiency. In contrast, dirty cage conditions can increase intestinal epithelium turnover and energy expenditure to maintain intestinal function, leading to lower growth efficiency (Castro *et al*., 2024).

Table 1: Animal welfare indicator of broiler chickens raised in closed houses with different floors.

Variables	Litter	Slat
Cleanless	1.04±0.06	0.9±0.04
Breast blister	0	0
Footpad dermatitis	1.55 ±0.23[a]	0.43±0.14[b]
Hockburn dermatitis	0.92±0.31[a]	0.59±0.26[b]
Arthritis	0[b]	0.16 ±0.03[a]
Gait score	0.52±0.06	0.59±0.04

Mean ± standard error. Different superscripts (a, b) within the same row differ significantly (P<0.05).

The breast blister score in broiler chickens reflects the severity of the lesion or injury to the skin of the chest, which is mainly caused by prolonged contact with a hard or wet surface of the base. In this study, the breast blister score showed no statistically significant difference (P>0.05) between the two treatments. Breast blisters affect animal welfare, growth performance, and meat quality in broiler chickens. Lower scores indicate better skin condition, improved welfare, higher meat quality, and reduced economic losses at slaughter, making these highly valuable parameters for monitoring and managing broiler production (Jong *et al*., 2022; Emous *et al*., 2024). Breast blister in broiler chickens can be caused by several factors that are mainly related to intensive farming practices. High population densities in broiler farms can exacerbate these conditions by restricting movement and increasing contact with the coop base, often leading to the formation of chest blisters (Bordignon *et al*., 2022).

The animal welfare score for incidence of footpad dermatitis was significantly higher (P<0.05) in chickens raised with a litter mat than in those raised with a plastic slat, but this score was still low. A high score indicates a disorder in the chicken's legs. This is due to the presence of litter mixed with excreta, resulting in higher humidity and base temperatures, which cause chicken feet to experience footpad dermatitis. In contrast to those who use plastic slatted, the temperature and humidity of the cage mats are lower. In addition, bacteria that are caged in excreta and litter have the potential to cause infections in chicken legs. Broiler chickens raised on wet pads will develop footpad dermatitis earlier and with greater severity compared to broilers raised on dry pads. Litter conditions with a moisture content above 25-30% begin to show an increased risk of wet conditions that damage the skin of chicken legs (Swiatkiewicz *et al*., 2017; Van der Hoeven-Hangoor, 2014). This suggests that lowering the moisture content of the base through routine litter replacement or optimal management practices can reduce the progression and progressivity of dermatitis footpad (Alabi *et al*., 2023).

Hock burn dermatitis is one of the main indicators for assessing animal welfare. The hock burn dermatitis data in this study showed a statistically significant difference (P<0.05) in the hock dermatitis score of chickens in the litter mat group, which was higher than that of chickens maintained on the plastic slat, although the scores were still low. Chickens are prone to hock burns due to prolonged contact with a bad or wet mat in the cage. This causes skin inflammation and lesions in the hock joint, causing pain and discomfort in chickens. These lesions can interfere with the chicken's ability to walk and move, thereby reducing its well-being and changing its behavior (Mocz *et al*., 2022). When the chickens rest, their knees will be in contact with the base of the cage, so litter that has a higher temperature and humidity will have the potential to cause hock burn dermatitis. Several studies have shown that slatted systems provide better results than litter-bottomed floors in terms of the incidence rate of dermatitis in chicken legs (Cavusoglu and Petek, 2019). This is mainly because the material and the arrangement of the floor reduce direct contact of the chicken legs with wet dirt, which is usually the main cause of hock burn dermatitis.

The arthritis score in this study showed that chickens raised on plastic slatted had significantly higher scores (P<0.05) than those raised on litter mats. Although numerically low, the incidence of arthritis on plastic slats was significantly higher than on litter where no arthritis was observed. The chicken supports its body weight at rest using the knee part that hits the plastic slat. This causes the knee to develop arthritis due to the pressure of the body on a harder plastic slat. In this study, the incidence of arthritis was observed in chickens with heavier weights. Broiler chickens raised on plastic floors showed increased sitting time, poorer locomotor scores, and a higher incidence of leg or joint injuries, suggesting that hard, less padded plastic surfaces can cause discomfort that limits the normal movement behavior of chickens (Przybulinski *et al.*, 2025). Poor leg health, including arthritis, is common in intensive production systems owing to factors such as high population density, poor litter quality, and the inability of chickens to perform their natural behaviors. This condition can exacerbate stress and cause leg disorders, such as arthritis, joint cysts, femoral head necrosis, and other related symptoms that result in lameness or paralysis, thus greatly affecting movement and eating behaviors (Tainika *et al.*, 2023). Poor soil conditions, including hardness, can increase the incidence of foot deformities in line with the high incidence of arthritis and other skeletal disorders in broilers raised on unsuitable soils (Honig *et al.*, 2024; Xu *et al.*, 2021).

Gait scores in broiler chickens are important indicators of walking ability and foot health. The gait score data in this study showed no statistical difference (P>0.05) between the two treatments, but this figure was still low. This occurs because one of the gait scores is influenced by the condition of the chickens' legs. Chickens raised on chicken litter mats experienced footpad dermatitis and hockburn dermatitis, while chickens raised on plastic slats experienced arthritis which both caused disturbances in gait scores. Kennel pad management can affect the occurrence of problems in chicken legs, such as footpad dermatitis, hock burn dermatitis, and arthritis, thus affecting gait (Tainika *et al.*, 2023). Poor gait has a direct impact on physical health, leading to well-being problems such as foot disorders, increased mortality rates, and other health disorders (Riber and Wurtz, 2024).

Carcass characteristics

Carcass characteristics are key determinants of consumer preferences for chicken meat. The characteristics of broiler chicken carcasses raised in closed houses with different floor types based on slaughter weight, carcass weight, and commercial parting carcass are presented in Table 2.

The body weight data in this study showed a statistically significant difference (P<0.05), where chickens raised on plastic slats had a higher body weight than those raised on a litter base. Optimal body weight gain is supported by nutritional factors and good management, which maximizes muscle tissue growth and increases carcass size and cut weight (Oddon *et al.*, 2021). In addition, the condition of the digestive system and a good level of immunity promote the efficiency of nutrient absorption and reduce stress levels, resulting in optimal feed consumption and increased weight gain, which then has a positive impact on cut weight (Khukhodziinai *et al.*, 2024). Body weight is also influenced by several factors, such as the distribution of body tissues, such as muscle and fat proportions, genetics, age of the animal at slaughter, and maintenance conditions, such as physical activity, which can affect the outcome of the carcass (Güz *et al.*, 2021).

Table 2: Characteristics of broiler chicken carcasses reared in closed houses with different floor.

Variables	Litter	Slat
Body weight (g/head)	1572 ±49.86^{b}	1632 ±35.58^{a}
Carcass Weight (g/head)	1088 ±10.35^{b}	1139 ±5.63^{a}
Carcass Weight (%)	69.24 ±1.45	69.78 ±1.29
Commercial parting of carcasses		
Thigh (%)	29.18 ±1.67	29.29 ±1.58
Lower thighs (%)	13.33 ±0.80	13.81 ±2.61
Chest (%)	42.25 ±2.08	42.52 ±2.12
Upper back (%)	17.09 ±1.56	17.50 ±1.20
Wing (%)	10.63 ±0.68	10.69 ±0.54

Mean ± standard error. Different superscripts (a,b) within the same row differ significantly (P<0.05).

The carcass weight data in this study showed a statistically significant difference (P<0.05), where chickens raised on plastic slats had a higher carcass weight than those raised on a litter mats. This is related to the difference in body weight between the two treatments. Broiler chickens with a higher live weight have a heavier carcass weight. In addition, live weight is strongly correlated with the weight of giblets or internal organs (Horhoruw and Ismael Kewilaa, 2024).

The percentage of carcass weight and commercial part pieces showed no noticeable difference in the two treatments. This shows that the difference in the cage base does not affect the percentage of carcass weight and the keen cut-off of the chicken meat. The percentage of carcass weight and commercial part pieces is influenced by the interaction between nutritional factors, feed management, and chicken physiology. The quality and nutrient composition of feed, such as high levels of metabolic energy and adequate consumption of amino acids, can increase carcass weight and feed use efficiency, thus affecting the ratio of carcasses to the live weight of chickens (Toghyani *et al.*, 2024). The process of converting feed nutrients into carcass tissue and the distribution of growth between the muscle, fat, and internal organ tissues are important. This process involves the availability of amino acids and glucose at protein deposit sites, such as skeletal muscles, which determines the amount of protein that can be stored in muscle tissue and directly affects the relative proportions of carcass pieces, such as the chest and thighs (Macelline *et al.*, 2021).

Meat characteristics

The characteristics of broiler chicken meat raised in a closed house with different flooring based on pH, shear force, water holding capacity, and cooking loss are presented in Table 3.

Table 3: The meat characteristics of broiler chicken raised in a closed house with different flooring.

Variables	Litter	Slat
pH	5.77 ±0.10	5.69 ±0.19
Shear force (N/cm^2)	0.68 ±0.05^b	0.78 ±0.09^a
Water holding capacity (%)	42.31 ±3.75^a	39.11 ±3.39^b
Cooking loss (%)	37.43 ±5.68	37.84 ±3.59

Mean ± standard error. Different superscripts (a,b) within the same row differ significantly (P<0.05).

The pH data in the two studies showed no noticeable difference. Factors that affect the pH of broiler chicken meat include genetic factors, maintenance management, feed, and post-slaughter processes. In this study, there was no difference in the type of chicken, feed, or process before and after slaughter. The difference in the cage base in the maintenance process did not cause the microclimate conditions of the cage to have differences, and they were in the comfort zone of the chickens, so that the chickens did not experience heat stress. If chickens are exposed to heat during the rearing process, it can lead to oxidative stress. Oxidative stress can lead to increased production of free radicals that can damage fats, proteins, and muscle cells, thereby causing oxidative damage (Xing *et al*., 2021). This oxidative damage interferes with mitochondrial function and glycolysis in muscles, where glycogen is broken down into lactic acid. This breakdown can accelerate lactic acid accumulation, leading to a decrease in meat pH (Zhang *et al*., 2022). pH characteristics are an important parameter for consumer preference because normal pH is related to the texture, color, and durability of broiler chicken meat (Park *et al*., 2021).

Data on the shear force of meat showed that chicken meat raised on plastic slats had a higher shear force than those raised on litter mats. This is because chickens raised on plastic slats use a lot of thigh muscles to support and maintain body balance when standing on slats that have gaps. In contrast to chickens raised on a litter bed, chickens find it easier to balance their bodies because the cage bed is flatter and there are no gaps. The use of plastic mats in broiler chicken coops has implications for the behavior and welfare of chickens, which can ultimately affect the quality of meat, including its breaking power (Jacobs *et al*., 2021).

The water-holding capacity data showed a noticeable difference in chicken meat raised on a litter mat, which was higher than that on a plastic slatts. This is in line with the data on shear force, where chickens with higher water holding capacity have lower tenderness or shear force of meat. Shear force, which refers to the shear force required to break meat fibers, significantly affects the water-holding capacity of broiler chicken meat (Yibar and Uzabaci, 2024). The high shear force of chicken meat can reduce the water-holding capacity due to damage and denaturation of myofibrillar proteins, as well as changes in collagen structure that cause muscle tissue to be denser, stiffer, and unable to hold water properly (Geronimo *et al*., 2021).

The cooking loss data revealed no significant differences between the two treatments. The quality of meat, especially cooking loss, is also affected by the cooking method and processing after carcass retrieval. Cooking methods using the sous vide technique show lower moisture loss than other baking and frying methods, which can have implications for lower cooking losses (Silva *et al*., 2017).

CONCLUSION

Plastic slatted flooring significantly reduced footpad dermatitis and hock burn compared to rice husk litter. However, plastic slats significantly increased arthritis prevalence. Body weight was higher on slats, but meat from slats had higher shear force (lower tenderness) and lower water-holding capacity. Carcass yields did not differ. Therefore, plastic slats offer trade-offs: benefits for contact dermatitis but risks for joint health and meat quality. Flooring choice should depend on which outcomes are prioritized.

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NOVELTY STATEMENT

This study tested the application of plastic slats as a cage base in closed houses on an industrial scale for broiler chickens.

AUTHOR'S CONTRIBUTION

D: Conceptualization, experimental design, data collection, laboratory analysis, data interpretation, manuscript drafting, and revision. NU: Supervision, study design refinement, critical review, and manuscript editing. RA: Supervision, study design refinement, critical review, and manuscript editing. AY: Supervision, study design refinement, critical review, and manuscript editing. HMA: Supervision, study design refinement, critical review, and manuscript editing. LORM: Data collection, laboratory analysis.

Ethical approval

All materials, equipment, and procedures used in this study were approved by the Animal Ethics Committee of the School of Veterinary Medicine and Biomedical Sciences, Bogor Agricultural University (approval number 332/KEH/SKE/V/2025).

Generative AI and AI-assisted technology statement

The author declares that no generative AI was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest regarding the publication of this manuscript.

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