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<td>Article Title</td>
<td>Animal welfare indicators and stress response of broiler chickens raised at low and high stocking density</td>
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<tr>
<td>Running Title</td>
<td>Animal welfare of stock density in broilers</td>
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<tr>
<td>Author</td>
<td>Chan Ho Kim¹, Ki Hyun Kim¹, Ju Lan Chun¹, Se Jin Lim¹, Jung Hwan Jeon¹</td>
</tr>
<tr>
<td>Affiliation</td>
<td>Animal Welfare Research Team, National Institute of Animal Science, Rural Development Administration, Wanju 55365, Korea</td>
</tr>
</tbody>
</table>
| ORCID               | Chan Ho Kim (https://orcid.org/0000-0003-2121-5249)  
Ki Hyun Kim (https://orcid.org/0000-0002-9834-2126)  
Ju Lan Chun (https://orcid.org/0000-0002-4618-586X)  
Se Jin Lim (https://orcid.org/0000-0002-0465-1666)  
Jung Hwan Jeon (https://orcid.org/0000-0001-9725-547X) |
| Competing interests | No potential conflict of interest relevant to this article was reported. |
| Funding sources     | This work was carried out with the support of "Cooperative Research Program for Agriculture Science and Technology Development (Project No. RS-2021-RD009994)", Rural Development Administration, Republic of Korea |
| Availability of data and material | Upon reasonable request, the datasets of this study can be available from the corresponding author. |
| Authors’ contributions | Conceptualization: Kim CH  
Data curation: Lim SJ, Jeon JH, Chun JL  
Formal analysis: Kim CH  
Methodology: Kim CH, Kim KH  
Software: Kim CH  
Validation: Kim CH  
Investigation: Kim CH  
Writing - original draft: Kim CH  
Writing - review & editing: Kim KH, Chun JL, Lim SJ, Jeon JH |
| Ethics approval and consent to participate | The experimental protocol was subject to review and approval by the Institutional Animal Care and Welfare Committee of the National Institute of Animal Science, Rural Development Administration, Republic of Korea (approval No. NIAS-2021-534) |

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<tr>
<td>First name, middle initial, last name</td>
<td>Chan Ho Kim</td>
</tr>
<tr>
<td>Email address – this is where your proofs will be sent</td>
<td><a href="mailto:kch8059@korea.kr">kch8059@korea.kr</a></td>
</tr>
<tr>
<td>Secondary Email address</td>
<td><a href="mailto:kch110380@naver.com">kch110380@naver.com</a></td>
</tr>
<tr>
<td>Address</td>
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</tr>
<tr>
<td>Cell phone number</td>
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</tr>
<tr>
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</tr>
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Abstract

Stocking density is a crucial parameter that impacts animal welfare, performance, and economic returns for producers. In our current investigation, we explored the influence of stocking density on the growth performance, litter quality, footpad dermatitis, and corticosterone concentrations in broiler chickens. Low and high stocking densities were defined as 16.7 birds/m² (certified for animal welfare, n = 32,000; initial BW = 42.1±0.32g; Arbor Acres) and 20.3 birds/m² (commercial farm, n = 32,000; initial BW = 42.9±0.31; Arbor Acres), respectively. A basal diet typical of commercial standards was developed to meet or surpass the nutritional requirements outlined by the National Research Council (NRC) for broiler chickens. The control group was housed for 29 days to compare productivity and animal welfare indicators in high stocking density (20.3 birds/m²) as per livestock industry regulations and low stocking density (16.7 birds/m²) according to animal welfare standards. During the grower periods (21-29 days) and the overall period (0-29 days) of the experiment, feed intake and body weight were lower in the lower stocking density group (p < .05). Additionally, the feed conversion ratio significantly improved at the lower stocking density. By day 29, the average footpad dermatitis score, litter moisture, NH₃ concentration, and feather cleanliness were significantly higher at the higher stocking density. Corticosterone concentrations decreased by 2.35% at the lower stocking density by day 29. These results indicate that decreasing stocking density enhances the welfare and growth performance of broiler chickens, as indicated by decreases in litter moisture, footpad dermatitis, and corticosterone concentrations.

Keywords: Broiler; corticosterone; footpad dermatitis; litter moisture; stocking density
Introduction

Over the past few decades, efforts have been made in the poultry industry to increase production output while minimizing production costs. In traditional broiler farming, optimal conditions include providing birds with ample access to high-energy feed and water, ensuring effective disease control, and maintaining modern housing facilities. Stocking density, which refers to the number of birds housed per unit area, significantly influences bird welfare, performance, and economic outcomes for producers. In Korea, both the Livestock Industry Act (39 kg/m²; no more than 21 birds/m²) and the Animal Welfare Standard (30 kg/m²; 16.6 birds/m²) have set specific limits on stocking density. High stocking densities can lead to decreased productivity due to rapid temperature increases in the broiler house [1]. Consumers now perceive stocking density as a crucial factor influencing animal welfare, believing that adhering to higher welfare standards (i.e., lower stocking density) will yield higher-quality products [2].

Studies have indicated that feed intake [3] and growth performance [4] are influenced by stocking density. Additionally, broiler welfare is a significant concern in modern production systems [5]. Stress in broilers can arise from various environmental factors, with stocking density being a key consideration [6]. Elevated stocking densities have adverse effects on broiler performance, health, and immunity [7], primarily attributed to limited access to feed and water [8]. Moreover, decreased airflow at the birds’ level hampers the dissipation of body heat [9]. High stocking density leads to an increase in ammonia concentration levels in the litter due to elevated litter moisture [10]. The quality of the litter reflects the amount of excrement produced. Excessively moist litter occurs when the moisture added to the litter surpasses the rate of absorption [11]. As broilers are in constant direct contact with the litter, wet litter can pose problems. Footpad dermatitis (FPD) [12], breast blisters [13], or hock burns are common consequences. Footpad dermatitis can progress swiftly, initially manifesting as changes in skin coloration, which then progress to erosions that may develop into ulcers. Concurrently, inflammatory responses and hyperkeratosis of the pad surface may occur, resulting in the characteristic appearance of brown-black lesions. Compared with lower stocking densities, higher stocking densities result in an increased occurrence of FPD [14,15]. Footpad dermatitis can cause discomfort in birds, potentially leading to
decreased mobility [16]. External factors such as high stocking densities can also act as sources of
immune stress, disrupting immune homeostasis [17-19]. Factors like high stocking density have been
documented to cause reductions in the weights of primary and secondary lymphoid organs in broilers [20].
Consequently, this reduction is associated with decreased lymphocyte counts and increased heterophil
counts, resulting in an elevated heterophil-to-lymphocyte (H:L) ratio. A high H:L ratio reliably indicates
elevated glucocorticoid concentrations [21]. Both in commercial and experimental environments, higher
stocking densities have been observed to induce alterations in behavior [22, 23]. Generally, as the number
of birds per housing area increases, there is a rise in abnormal behavior incidence and a reduction in
resting or lying down time. Although on-farm welfare status in broiler flocks has been reported, the
continuous monitoring welfare status including stress indicators (i.e., corticosterone) in broiler flocks has
not been studied. Thus, in this study, we aimed to investigate the effects of different stocking densities
regulated by the Korean national animal husbandry laws and animal welfare certifications on growth
performance, litter quality, gas emissions, animal welfare scores, and corticosterone levels in broiler
chickens.

Materials and Methods

The experimental protocol underwent thorough review and received approval from the Institutional
Animal Care and Welfare Committee of the National Institute of Animal Science, Rural Development
Administration, Republic of Korea (approval No. NIAS-2021,534). This ensured adherence to ethical
guidelines and standards throughout the study.

Birds and Experimental Design

Low and high stocking densities were defined as 16.7 birds/m² (Animal welfare certified farm, n =
32,000; initial BW = 42.1±0.32 g) and 20.3 birds/m² (commercial farm; n = 32,155; initial BW = 42.9 ±
0.31 g), respectively (Table 1). Broiler strain used in this study were straight-run Arbor Acres. All chicks
were fed commercially available corn and soybean meal-based starter and grower diets that met NRC
requirements [24]. (Table 2). To compare the productivity of animals based on the stocking density of
livestock industry act and the stocking density of animal welfare certification standards. The control
group was reared for 29 days to compare productivity and animal welfare indicators in high-density
housing according to livestock industry act and low-density housing according to animal welfare
certification standards as the treatment. In the first week of the experiment, the brooder house and barn
were kept at a steady temperature of 32°C, which then gradually decreased to 26°C by the end of the
study. The lighting schedule started with 23 hours of light and 1 hour of darkness on day 0, with daylight
gradually reducing until it settled at 18 hours of light and 6 hours of darkness by day 5. This lighting
regimen remained constant until day 29. The farm visits were made on July and August. During each visit,
the indoor observations were performed in 2 broiler houses per farm.

Growth performance

On 21 and 29 days, 90 birds were randomly chosen from each farm and weighed. The feed
conversion ratio (FCR) was computed for each experimental unit by dividing the total feed intake (in
kilograms) by the total live bird weight gain (in kilograms). Average feed intake per bird and FCR were
determined per housing unit. Mortality was monitored daily during the experiment by the farm’s owner
and mortality rates were calculated.

Litter moisture and gas emissions

Litter samples were collected from 6 preassigned locations (Figure 1) on each farm at both 21 and 29
days, and the moisture content was assessed following the AOAC method 934.01 [25]. Gas emissions
from the litter were determined by sampling litter gas using a Gastec Gas sampling Pump (Model GV-100,
Gastec Corp., Ayas-city, Japan) equipped with Gastec detector Tubes No. 3 M and 3 La for ammonia, and
No. 4LL and 4LK for hydrogen sulfide.

Animal welfare indicators (FPD, hock burn, and feather cleanliness)

On the 21st and 29th, fences were erected around six sampling points on each farm and 15 birds were
sampled at each of the six randomly selected points, for a total of 90 birds per farm. Footpad dermatitis
was assessed for both feet using the Swedish classification system, where scores ranged from 1 (no lesions) to 3 (deep lesions with ulcers or scabs, indicative of bumblefoot) [26]. Hock burns were evaluated on both hocks according to The Welfare Quality Consortium's scoring system, with scores ranging from 1 (no hock burn) to 3 (presence of large black spots) [26]. Feather cleanliness was determined by examining the breasts and assigning a cleanliness score between 1 and 3, with 1 indicating clean and 3 indicating very dirty conditions [Figure 2,26].

Stress hormones (corticosterone) in the blood

To assess the variation in stress levels associated with different stocking densities, corticosterone levels were measured as part of the circulating hormone profile. At six time points at 21 and 29 days of age at each stocking density, blood samples were collected from the wing vein of 10 randomly selected birds per treatment. These samples were collected in EDTA-coated BD Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ, USA) and stored at -70°C until analysis. Corticosterone levels were quantified using a chicken corticosterone ELISA kit (Wuhan Fine Biotech Co. Ltd., Wuhan, China). The antigen-coated 96-well plate underwent dual washes before the addition of 50 μL of sample and 50 μL of biotin-labeled antibody, followed by incubation at 37°C for 45 minutes. After three wash cycles, the plate was treated with HRP Conjugate working solution and incubated for 30 minutes at 37°C. Following five additional washes, the plate was developed with TMB substrate, and absorbance readings were measured at 450 nm using a spectrophotometer (Epoch 2; BioTek Instrument, Inc., VT, USA), with stop solution applied subsequently.

Statistical analysis

The data underwent analysis using the analysis of variance (ANOVA) technique within SAS (SAS Institute, Inc., Cary, NC, USA), employing a fully randomized design and the Proc Mixed procedure. Any potential outliers were scrutinized using SAS's UNIVARIATE procedure, which revealed no outliers. To assess differences between the least-squares means, the PDIF option was utilized alongside a t-test.
When examining animal welfare indicators, a chi-square test was employed, resorting to Fisher's Exact Test when the expected frequency fell below 5 in the chi-square test. Output values were summarized using a macro program designed to assign letter groups [27]. Significance levels and trends for statistical tests were set at $p < .05$ and $.05 \leq p \leq .10$, respectively.

**Results**

Stock density had no effect on BW gain, feed intake, feed conversion ratio, and mortality during the starter period (0 to 21 days) of the experiment. During the experiment's grower (21 to 29 days) and overall (0–29 d) periods, BW gain and feed intake increased ($p < .05$) at the low stocking density. In addition, the feed conversion ratio was improved ($p < .05$) at the lower stocking density (Table 3). On day 21 of the experiment, stock density had no effect on the moisture content of the litter or the gas emissions (CO$_2$ and NH$_3$). However, litter moisture and ammonia (NH$_3$) contents decreased ($p < .05$) at the low stocking density on day 29, whereas carbon dioxide (CO$_2$) concentration was not affected (Table 4). Hock burns and feather cleanliness were unaffected by stock density on day 21 of the trial. However, the average FPD score increased significantly ($p < .05$) at the higher stocking density. The frequency of a score of 1 (no lesions) also decreased by 10% as the stock density increased. At the end of the experiment (day 29), the average scores for FPD and feather cleanliness increased significantly ($p < .05$) at the higher stocking density at the end of the experiment (day 29), but there was no influence on hock burn. The ratio of score 2 (mild lesions) to score 3 (severe lesions) increased by 7.78% at the higher stocking density at the end of the experiment (Table 5 and Figure 3). Corticosterone concentrations were unaffected by stock density on day 21 of the experiment. However, the corticosterone concentration decreased significantly ($p < .05$) by 2.35% at before the end of the trial (Table 6).

**Discussion**

Broilers reared at higher stocking densities displayed reduced final body weights in contrast to birds reared at lower densities. This correlation is in line with earlier research findings, which suggested that
broilers raised at a stocking density of 10 birds/m² achieved superior weight gain compared to those raised at densities of 13 or 16 birds/m² [2]. Thomas et al. [28] suggested that broilers housed at a density of 5 birds/m² exhibited accelerated growth and higher feed intake compared to those accommodated at densities of 10, 15 or 20 birds/m². In the present investigation, elevating stocking density led to reductions in both body weight and feed intake among the broiler under study. This finding is consistent with prior studies demonstrating that broiler growth performance is compromised at higher stocking densities compared to that at lower densities [1,29,30]. High-density rearing often leads to decreased productivity attributed to diminished feed intake resulting from constrained feeding space, as commonly reported in literature [4]. The difference in the change in weight with stocking density between 21 to 29 days of age is likely to be due to differences in feed intake as the broiler grow. These observations have been attributed to various environmental and behavioral factors. Birds housed at high stocking densities, which restricts their movement, often experience limited access to feeders and drinkers [29]. Additionally, as noted by Feddes et al. [1], birds raised at high stocking densities may experience moderate heat stress due to reduced heat dissipation caused by overcrowding. Litter moisture plays a role in the development of FPD and hock burns [31,32]. Studies suggest that litter moisture levels are influenced by house ventilation and drinker design [33]. Raising birds at elevated densities correlates with heightened excreta output, and prolonged exposure to damp litter can contribute to the development of contact dermatitis [14]. As stocking density increases, the amount of wet litter in the barn tends to increase, and activity levels decrease as chickens develop leg problems [34]. Footpad dermatitis, one of the major diseases in the poultry industry, is also directly related to economic losses [12]. Meluzzi et al. [33] demonstrated a higher incidence of FPD with increased litter moisture, while de Jong et al. [32] induced FPD in broilers by elevating litter moisture content. Previous studies have also linked higher stocking densities to poorer footpad scores in broilers [14,22]. Enhancing litter quality is a crucial step in FPD control. However, litter management poses challenges in Korea due to its humid climate. Ammonia accumulation in poultry houses originates from nitrogen present in broiler feces and undigested protein [35,36]. Exposure of poultry to elevated levels of ammonia can lead to irritation of the mucous membranes in the ocular and respiratory systems, thereby increasing susceptibility to respiratory diseases and negatively impacting...
feed conversion efficiency [37]. According to Cheon et al. [38] prolonged exposure to ammonia concentrations of 20 ppm resulted in reduced appetite and growth inhibition, while productivity and carcass quality deteriorated at 40 ppm. Kristensen and Wathes [37] recommended maintaining ammonia concentrations at 25 ppm or below for poultry welfare. Nevertheless, it was observed that ammonia concentrations remained low on the high-density farm, indicating no concerns regarding ammonia levels arising from this study. Litter quality is influenced by factors such as material type, depth, friability, moisture, as well as housing, technical equipment, and management practices. From a welfare standpoint, excessively high stocking densities may result in issues such as increased airborne ammonia and heat production from the birds, leading to stressful conditions and potential mortality among hens. FPD is a crucial aspect of welfare. In severe cases, lesions from FPD may cause pain, which, combined with deteriorating health, poses a welfare concern. FPD and hock burns, both forms of contact dermatitis, serve as indicators of leg health and are influenced by litter moisture content and overall condition [5,31,39]. Moreover, body weight itself plays a significant role, with a greater impact on the prevalence of hock burns compared to FPD [40,41]. Feather cleanliness, or dirtiness, is also influenced by litter condition and affects thermoregulation [28]. A strong and positive correlation has been reported between heavily soiled feathers and severe FPD [40]. The observed differences in welfare indicators in this study could be attributed to the increased likelihood of birds encountering wet or contaminated litter, depending on the stocking density [4,42,43]. Moreover, the stocking density is associated with litter quality and can also affect feather cleanliness [44]. Therefore, adhering to welfare certification standards for broilers, which include effective litter management, has the potential to improve conditions such as FPD and hock burns and improve feather cleanliness. de Jong et al. [32] demonstrated that increasing litter moisture content induced FPD in broilers, highlighting the importance of enhancing litter quality in FPD control. However, managing litter in Korea poses challenges due to its humid climate. Overall, our study revealed that welfare-certified farms, compared to conventional farms, exhibited improvements in FPD and feather cleanliness, indicating enhanced welfare status. Corticosterone has been established as a biological stress indicator in various species, including poultry [45]. Analyzing broiler feces and feather corticosterone provides a non-invasive method for quantifying stress hormone levels [46]. Blood corticosterone
concentration is commonly used to evaluate environmental stress in poultry [47]. Kang et al. [48] noted that increased stocking density resulted in higher total plasma corticosterone concentration. Hocking et al. [49] observed that at 36 days of age, the mean corticosterone concentration in broiler breeders was 0.5 ng/mL under normal stocking density (9 birds/m²). Son et al. [50] discovered that laying hens exhibited significantly lower plasma corticosterone concentrations at 500 cm² than at 750 cm²/bird, suggesting that social stressors may contribute to elevated corticosterone levels in hens. Subsequent research indicated that as the population density increased, blood corticosterone concentration rose due to competition among birds for feeding and watering spaces [51]. However, according to Buijs et al. [52], stocking density showed no significant effect on fecal corticosterone levels. Moreover, another study indicated that blood corticosterone concentration does not exhibit a correlation with stocking density [53]. According to Thaxton et al. [54], stocking densities ranging from 30 to 45 kg/m² were found to not induce stress, as evidenced by various physiological markers derived from blood samples, such as the heterophil-to-lymphocyte ratio, corticosterone levels, glucose, and cholesterol. The authors underscored that while stress parameters remained unaffected within this stocking density range, it does not necessarily indicate improved welfare, echoing the conclusion drawn by Dawkins et al. [55]. The assertion that environmental factors have a greater impact on broiler welfare than stocking density was made by unspecified sources. These conflicting outcomes may stem from variations in broiler species and management practices, underscoring the need for further research to validate these claims. It was concluded that rearing broilers at low density (welfare certified) led to higher welfare indicators, including reduced incidence of FPD, improved feather cleanliness, better litter quality, lower gas emissions (NH₃), and decreased corticosterone concentrations in blood compared to high-density (conventional farm) rearing. Overall, our study confirms that lower stocking density (animal welfare certified farms) results in improved welfare indicators compared to higher stocking density (conventional farms). These findings are expected to contribute to the expansion of broiler animal welfare certified farms in Korea.

**Competing interests**
No potential conflict of interest relevant to this article was reported.

Acknowledgments

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Author Contributions

Conceptualization: Kim CH; Data curation: Lim SJ, Jeon JH, Chun JL; Formal analysis: Kim CH; Methodology: Kim CH, Kim KH; Software: Kim CH; Validation: Kim CH; Investigation: Kim CH; Writing - original draft: Kim CH; Writing - review & editing: Kim KH, Chun JL, Lim SJ, Jeon JH.

Ethics approval

The experimental protocol was subject to review and approval by the Institutional Animal Care and Welfare Committee of the National Institute of Animal Science, Rural Development Administration, Republic of Korea (approval No. NIAS-2021-534)
References


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Zulkifli I, Liew PK, Israf DA, Omar AR, Hair-Bejo M. Effect of early age feed restriction and heat conditioning on heterophil/lymphocyte ratios, heat shock protein 70 expression and body...


55. Dawkins MS, Donnelly CA, Jones TA. Chicken welfare is influenced more by housing conditions than by stocking density. Nature. 2004;427:342-4. https://doi.org/10.1038/nature02226
Figure 1. Schematic representation of the sampling locations (●) where productivity, blood sampling, litter ammonia, carbon dioxide, footpad dermatitis, hock burn, and feather cleanliness were determined.
Figure 2. Footpad dermatitis of broilers showing how the degree of damage was scored (A) and feather condition and cleanliness for the scores of 1~3 on the body of each broiler (B). (RSPCA, 2013)
Figure 3. Distribution of broiler assessment results according to the level of footpad dermatitis (A, D), hock burn (B, E), and feather cleanliness (C, F) between high and low stocking density at 21 and 29 days of age. Footpad dermatitis (21 days; $\chi^2=0.926$, 29 days; $\chi^2=0.926$, $p<0.05$), hock burn (21 days; $\chi^2=0.926$, 29 days; $\chi^2=0.926$, $p<0.05$), and feather cleanliness (21 days; $\chi^2=0.926$, 29 days; $\chi^2=0.926$, $p<0.05$) were measured in an average 90 birds/house on high stocking density and 90 birds/house on low stocking density according to the RSPCA (2013). The asterisk (*) indicates significance at $p < 0.05$. 
Table 1. Main characteristics of the conventional (high density) and animal welfare (low density) farms

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¹The lighting schedule is represented at the number of hours of light(L): darkness(D).
Table 2. Composition and nutrient content of the experimental diets.

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Analysis composition

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</tr>
<tr>
<td>Methionine + Cystein, g/kg</td>
<td>8.8</td>
<td>7.4</td>
</tr>
</tbody>
</table>

\(^1\) Provided per kilogram of the complete diet: vitamin A (vitamin A acetate), 12,500 IU; vitamin D\(_3\), 2,500 IU; vitamin E (DL-\(\alpha\)-tocopheryl acetate), 20 IU; vitamin K\(_3\), 2 mg; vitamin B\(_1\), 2 mg; vitamin B\(_1\)\(_2\), 2 mg; vitamin B\(_2\), 5 mg; vitamin B\(_6\), 3 mg; vitamin B\(_12\), 18 \(\mu\)g; calcium pantothenate, 8 mg; folic acid, 1 mg; biotin 50 \(\mu\)g; niacin, 24 mg.

\(^2\) Provided per kilogram of the complete diet: Fe (FeSO\(_4\cdot\)7H\(_2\)O), 40 mg; Cu (CuSO\(_4\cdot\)H\(_2\)O), 8 mg; Zn (ZnSO\(_4\cdot\)H\(_2\)O), 60 mg; Mn(MnSO\(_4\cdot\)H\(_2\)O), 90 mg; Mg (MgO) as 1,500 mg. \(^3\) Nutrient contents in all diets were calculated.
### Table 3. Effect of stocking density on body weight in broilers

<table>
<thead>
<tr>
<th>Items</th>
<th>Stock density</th>
<th>SEM</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Starter periods (0 to 21 d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW gain, g</td>
<td>794.4</td>
<td>802.1</td>
<td>33.39</td>
</tr>
<tr>
<td>Feed intake, g</td>
<td>1,150</td>
<td>1,147</td>
<td>18.38</td>
</tr>
<tr>
<td>FCR (feed/gain)</td>
<td>1.37</td>
<td>1.36</td>
<td>0.081</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>2.58</td>
<td>2.68</td>
<td>0.031</td>
</tr>
<tr>
<td>Grower periods (21 to 29 d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW gain, g</td>
<td>468.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>766.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28.58</td>
</tr>
<tr>
<td>Feed intake, g</td>
<td>765.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>999.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.52</td>
</tr>
<tr>
<td>FCR (feed/gain)</td>
<td>1.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.30&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.125</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>2.35</td>
<td>2.02</td>
<td>0.025</td>
</tr>
<tr>
<td>Overall periods (0 to 29 d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW gain, g</td>
<td>1,281&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1,568&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40.258</td>
</tr>
<tr>
<td>Feed intake, g</td>
<td>1,916&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2,147&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.025</td>
</tr>
<tr>
<td>FCR (feed/gain)</td>
<td>1.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.045</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>4.92</td>
<td>4.70</td>
<td>0.035</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Means in the same row with different superscripts differ significantly (p < .05).

<sup>1</sup>Data are least squares means of 90 per treatment.

<sup>2</sup>Stock density: High = 20.3 birds/m², Low = 16.7 birds/m².

<sup>3</sup>Standard error of the mean.
Table 4. Effect of stocking density on litter moisture and gas emission in broilers

<table>
<thead>
<tr>
<th>Items</th>
<th>Stock density</th>
<th>SEM</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Litter moisture, %</td>
<td>30.9</td>
<td>32.9</td>
<td>1.29</td>
</tr>
<tr>
<td>Gas emission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂, ppm</td>
<td>625.3</td>
<td>635.5</td>
<td>19.25</td>
</tr>
<tr>
<td>NH₃, ppm</td>
<td>6.54</td>
<td>6.67</td>
<td>3.891</td>
</tr>
<tr>
<td>Litter moisture, %</td>
<td>37.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.29</td>
</tr>
<tr>
<td>Gas emission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂, ppm</td>
<td>650.5</td>
<td>648.5</td>
<td>18.25</td>
</tr>
<tr>
<td>NH₃, ppm</td>
<td>10.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.95&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.406</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Means in the same row with different superscripts differ significantly (p < 0.05).

<sup>1</sup>Data are least squares means of six per treatment.

<sup>2</sup>Stock density: High = 20.3 birds/m², Low = 16.7 birds/m².

<sup>3</sup>Standard error of the mean.
Table 5. Average scores for footpad dermatitis, hock burn, and feather condition in broilers.

<table>
<thead>
<tr>
<th>Items</th>
<th>Stock density</th>
<th>21 d</th>
<th>29 d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Footpad dermatitis</td>
<td>1.13±0.28a</td>
<td>1.03±0.11b</td>
<td>1.26±0.35a</td>
</tr>
<tr>
<td>Hock burn</td>
<td>1.00±0.00</td>
<td>1.02±0.12</td>
<td>1.00±0.00</td>
</tr>
<tr>
<td>Feather cleanliness</td>
<td>1.13±0.35</td>
<td>1.06±0.10</td>
<td>1.18±0.25a</td>
</tr>
</tbody>
</table>

a, b Means in the same row with different superscripts differ significantly (p < 0.05).

Data are least squares means of 90 per treatment.

Stock density: High = 20.3 birds/m², Low = 16.7 birds/m².
Table 6. Effects of stocking density on corticosterone in broilers\(^1\)

<table>
<thead>
<tr>
<th>Items</th>
<th>Stock density(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Corticosterone, ng/mL</td>
<td></td>
</tr>
<tr>
<td>21 d</td>
<td>2.52±0.06</td>
</tr>
<tr>
<td>29 d</td>
<td>2.55(^a)±0.06</td>
</tr>
</tbody>
</table>

\(^{a,b}\) Means in the same row with different superscripts differ significantly (\(p < 0.05\)).

\(^1\)Data are least squares means of 20 per treatment.

\(^2\)Stock density: High = 20.3 birds/m\(^2\), Low = 16.7 birds/m\(^2\).