

Article

Effects of Providing Enrichment to Broilers in an Animal Welfare Environment on Productivity, Litter Moisture, Gas Concentration (CO₂ and NH₃), Animal Welfare Indicators, and Stress Level Concentration

Chan-Ho Kim ^{1,*} , Woo-Do Lee ¹, Ji-Seon Son ², Jung-Hwan Jeon ¹, Se-Jin Lim ¹  and Su-Mi Kim ¹

¹ Animal Welfare Research Team, National Institute of Animal Science, Rural Development Administration, Wanju 55365, Republic of Korea; woodo92@korea.kr (W.-D.L.); jeon75@korea.kr (J.-H.J.); limsj818@korea.kr (S.-J.L.); lookoo981@korea.kr (S.-M.K.)

² Poultry Research Institute, National Institute of Animal Science, Rural Development Administration, Pyeongchang 25342, Republic of Korea; wlts1206@korea.kr

* Correspondence: kch8059@korea.kr; Tel.: +82-63-238-7054

Abstract: As animal welfare becomes more active in livestock industry, research is being conducted on ways to improve poor housing environments, reduce stress, and meet welfare standards. Among these, environmental enrichment methods are effective in reducing stress and creating a welfare-friendly rearing environment, but there are few cases of actual application to farms. Therefore, we aimed to investigate the effect of providing pecking materials (grain blocks), known as one of the environmental enrichment methods, to commercial broiler farms. This study used two facilities that could accommodate 32,000 one-day-old broilers (Arbor acres) per building, and two groups (control and treatment groups) were designed after creating two identical areas within each building (total two treatments, two replicates, 16,000 birds per replicate). Two identical zones within the house were created by installing a partition in the center; one side was provided with grain blocks (one grain block per 1000 birds), and the other side was not. Analysis items included productivity (body weight, uniformity), environmental variables (litter and air), welfare indicators (leg, gait score, feather cleanliness score), and serum corticosterone levels. Analysis of all items was conducted twice, on the 19th and 27th, taking into account the farm's feed change date and slaughter schedule. Other environmental conditions (density, lighting, ventilation, temperature, humidity, feed, and water) were the same. As a result, no difference in productivity was observed according to enrichment, and the quality of litter and air was similar. Also, there was no significant difference in welfare indicators. Interestingly, however, provision of the environment enrichment lowered serum corticosterone levels ($p < 0.05$). The implications of our study are that grain blocks as a pecking material are an effective way to reduce stress without adversely affecting broiler performance and rearing environment. However, it is still necessary to explore optimal enrichment materials that can help not only the welfare level but also the broiler performance.

Keywords: animal welfare; broiler; pecking block; physiological indicator; welfare indicator



Academic Editor: Ralf Blank

Received: 26 November 2024

Revised: 14 January 2025

Accepted: 14 January 2025

Published: 15 January 2025

Citation: Kim, C.-H.; Lee, W.-D.; Son, J.-S.; Jeon, J.-H.; Lim, S.-J.; Kim, S.-M. Effects of Providing Enrichment to Broilers in an Animal Welfare Environment on Productivity, Litter Moisture, Gas Concentration (CO₂ and NH₃), Animal Welfare Indicators, and Stress Level Concentration. *Agriculture* **2025**, *15*, 182. <https://doi.org/10.3390/agriculture15020182>

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1. Introduction

The implementation of environmental enrichment has been shown to potentially elevate activity levels, enhance leg health, and reduce the occurrence of contact dermatitis in broiler chickens [1]. Defined by Newberry [2], environmental enrichment refers to the

enhancement of a captive animal's environment in a way that increases its behavioral opportunities and promotes better biological functioning. This enrichment works by making the environment more complex, thus providing more opportunities for natural behaviors and generally increasing activity levels. For instance, straw bales contribute to environmental complexity by serving as novel objects that can be used for foraging, elevated resting spaces, increased overall space, obstacles to navigate, and potential hiding spots from aggressive interactions [3,4]. Additionally, environmental complexity can be boosted through simple modifications, such as increasing the distance between food and water sources and creating heterogeneous spaces where various resources are distributed throughout the pen [5,6].

The provision of environmental enrichment can have a number of positive effects on poultry in a variety of ways. In broilers that were not provided with environmental enrichment, they were affected by poor locomotion, leg lameness, increased time spent lying down, and increased litter contact, which led to breast blister and contact dermatitis [7]. In addition, leg disorders and skin diseases caused by lack of activity can affect the quality of the air by generating ammonia in the litter [7]. These atmospheric problems can be a welfare problem because they cause chemical burns and pain in the poultry [7]. Spieß et al. [8] reported that environmental enrichment can make poultry more active for 80% of the time except for eating and drinking time, which induces physical activity and reduces lameness and dermatitis [7]. In addition, increased activity can reduce contact with litter, improve litter quality [9], and ultimately affect air quality, which can affect welfare improvement. In terms of productivity, it can have a positive impact by reducing mortality in poultry and increasing body weight more uniformly [10].

Environmental enrichment for poultry primarily includes features such as novel objects (e.g., strings, toy, ball, plastic bottle, aluminum can), perches, and pecking blocks [4,11,12]. Addressing pecking behavior, a natural and instinctual activity in chickens, is essential to mitigate stress and associated welfare issues [2]. In particular, providing environmental enrichment materials such as hay and mineral-based blocks has been studied for a long time because it can add complexity to the poultry environment, stimulate behavioral enrichment, and improve animal welfare [13–15]. In fact, environmental enrichment can increase exploratory behavior in poultry and induce pecking and other natural behaviors [16]. In addition, materials such as hay can be used as resting areas and provide a safe hiding place from threatened birds, thereby alleviate stress [5].

Meanwhile, in order to maximize the effect of providing environmental enrichment materials, it is important to explore materials that have low risk factors, are interesting to livestock, and can be used for a long time. Several studies have shown that environmental enrichment materials in the form of blocks or stones (hard and durable) or feed (nutritious feed such as hay, carrots, mealworms, etc.) can have different effects on livestock welfare and environmental improvement depending on the material provided. Although hay has been reported to be effective in reducing pecking behavior (e.g., cannibalism), stimulating foraging behavior, and lowering stress hormones [11], it may be a factor in aggravating plantar dermatitis and increasing the risk of bacterial infections [17]. Insects such as mealworms have the advantage of being nutritious and popular with chicks, but the effects vary depending on the insect species and can be problematic for broiler health, especially if they are consumed contaminated [18,19]. Enrichment materials such as carrots, silage, and corn straw have been reported to reduce negative poultry behaviors but have potential nutritional imbalances and safety concerns associated with spoilage on farms [20]. Therefore, the environmental enrichment materials provided to poultry must be raw materials that are guaranteed to be safe when consumed, and one such material can be grains used in feed [15].

The provision of commercially available and durable pecking blocks can provide enrichment to the poultry environment [21]. And heavy structured environmental enrichment can be used by livestock for a long time, improve welfare indicators such as stress, and eliminate risk factors such as beak trimming [11,21]. The porous concrete blocks used in the study by Holcman et al. [22] were also of great interest to poultry due to their complex and destructible properties. Considering this, it was hypothesized that a somewhat rigid but breakable and edible material would enrich the behavior of poultry, reducing stress and improving welfare. However, there are few cases in which grain-based blocks are provided as environmental enrichment that are safe for broilers, provide nutrients, and are breakable by pecking behavior.

Against this backdrop, we have specially manufactured grain blocks based on broiler feed raw materials. In addition, most studies on environmental enrichment through pecking material provision have been conducted at the laboratory scale, so they need to be verified at the farm level. Therefore, this study aimed to investigate the effect of providing grain-based pecking blocks using two facilities in an animal welfare-certified broiler farm. We investigated welfare indicators, stress levels, productivity, and the housing environment (air conditions, litter quality), and these results can confirm the practical effect of providing pecking material (grain-based blocks) on farms.

2. Materials and Methods

We received review and approval (approval No. NIAS-2021-534) from the Animal Experiment Ethics Committee at the National Institute of Animal Science, Rural Development Administration, Republic of Korea.

2.1. Farm Selection and Experimental Design

The experiment was conducted on a farm certified for animal welfare. The farm was situated in Boseong-gun, Jeollanam-do, and consisted of two houses, each measuring 120 m in length and 16 m in width, covering an area of 1920 m². Each house housed approximately 32,000 birds, resulting in a stocking density of 16.7 birds/m². The bedding material provided in each house was fresh rice hulls. The houses were windowless and equipped with tunnel-type forced ventilation. Each house had 2 m-long wooden perches, with one perch for every 1000 birds.

Other management specifications followed the guidelines recommended by the integrated company. Briefly, the lighting schedule started at 23 h of lightness (L) and 1 h of darkness (D) on day 1, with the day length gradually decreasing until reaching 18L:6D by day 5. After that, lighting schedule was then maintained continuously until the end of the experiment. The house temperature was maintained at 30 °C during the first week of the experiment and gradually decreased to 24 °C at the end of the experiment. The humidity of the broiler house was maintained from 50 to 70% during the experiment (Table 1).

Table 1. Characteristics of commercial experimental farms.

Farm	
Farm	Animal welfare certified farms
Region	Boseong-gun, Jeollanam-do, South Korea
Strain	Arbor acres
Housing type	Windowless
Ventilation type	Forced exhaust
Flock size, number of size	32,000
House size, m, m ²	120 × 16, 1920

Table 1. *Cont.*

	Farm
Stock density, birds/m ²	16.7
Litter type	Rice hulls
Perches installed	Wood type, 2 m length, 1000 birds/m
Lighting schedule ¹	Gradually from 23L:1D to 18L:6D in the first 5 days, and continued at 18:6D

¹ The lighting schedule is represented at the number of hours of lightness (L): darkness (D).

The broiler strain used 1-day-old Arbor Acres (body weight 42.54 ± 1.34 g) supplied by the integrated company and was allocated to a total of 2 treatments, 2 replicates, and 16,000 birds per replicate. A wall was built in the center of the house to prevent the chickens from mixing, and one side was provided with enrichment (enrichment group) and the other was not provided (control). The enrichment was a grain-based block, with one grain block per 1000 birds (16 pecking blocks per replicate). The locations of the pecking blocks were alternated across different sections of the house. The housing facilities and experimental design used in this study are summarized in Figure 1.

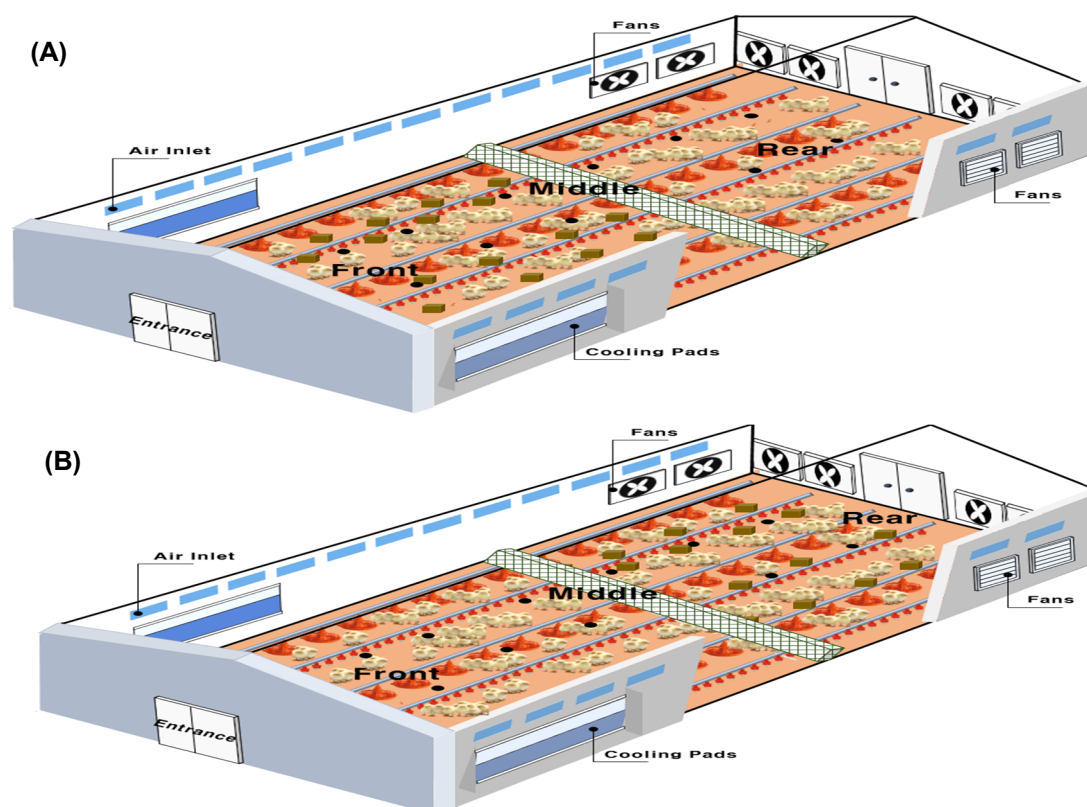


Figure 1. Schematic diagram of the sampling locations and placement of pecking blocks in house. (A) Enrichment placement and sampling locations: The symbol '□' represents the placement of enrichment (grain-based pecking block), while the symbol '●' represent specific sampling locations. The enrichment blocks are placed in the front, middle and rear sections of the house. Sampling locations '●' symbols indicate where productivity, blood sampling, litter sampling, litter ammonia, carbon dioxide, footpad dermatitis, hock burn, and feather dirtiness were determined. (B) Modified sampling setup with additional partitions: This layout introduces partitions dividing the front, middle, and rear sections to analyze the impact of spatial separations on enrichment and sampling results. The placement of enrichment ('□') and sampling locations '●' remains consistent with the setup in (A).

Water and feed were available *ad libitum*, and commercial diets were provided. In addition, considering the feed supply program (starter: 1d–21d; finisher: 22d—before slaughter) and slaughter date (30d) operated by the farm, the analysis dates for each index in this study were conducted at 19 and 27 days of age. Therefore, this experiment lasted 27 days.

2.2. Pecking Blocks

In this study, to provide environmental enrichment for broilers, grain-based pecking blocks have been developed by Sinaebio Co., Ltd. (Sungnam-si, Republic of Korea). These blocks were designed as cubic structures with dimensions of $25 \times 25 \times 25$ cm (Figure 2) and consisted mainly of 50~60% by-products such as wheat bran, 10~20% grains and 10~15% limestone, supplemented with additional components such as moisture and glycerin. The grain blocks were changed regularly every 14 days for a total of 27 days of experiment.



Figure 2. Grain block used in the experiment for enrichment. Block sized $25 \times 25 \times 25$ cm, mixed with a grain base in the form of a cube. The block consisted of 50~60% of by-products as brans, 10~20% of grains, 10~15% of limestone, and other ingredients (moisture, molasses, and glycerin), and it was manufactured by mixing raw materials and applying pressure in a mold. One pecking block per 1000 birds was supplied, and all blocks supplied were completely consumed during the experimental period.

2.3. Productivity

In terms of productivity, we investigated body weight and uniformity. The body weight measurement was conducted twice in total, at 19 and 27 days of age, and an electronic automatic measuring scale (GI-1000, G tech Co., Ltd., Uijeongbu-si, Republic of Korea) was used to measure the body weight of each individual. For each measurement, 90 broilers were measured per treatment group, and for uniformity, they were randomly selected and surveyed at the points indicated in Figure 1 (from 7 to 8 birds were measured at each point). Afterwards, to investigate the uniformity of body weight (expressed as coefficient of variation (CV)) for each measurement day, the average value of the measurement location was used, and the value was calculated and determined.

2.4. Litter Moisture and Gas Emissions

Litter samples were randomly collected from six designated locations (Figure 2) within each barn at 19 and 27 days of age, with moisture content analyzed according to AOAC method 934.01 [23]. Briefly, the moisture content in the litter was analyzed by collecting 100 g of litter from each location on the day of measurement. The moisture content was measured by drying in dry oven at 105°C for 24 h, and the moisture content was expressed as a percentage (%) of the difference in weight after drying from the weight before drying.

To measure gas concentrations, a gas sampling pump (Gastec Corp., Ayase-city, Japan) was used along with specific detector tubes—No. 3M and 3La for ammonia, and No. 4LL and 4LK for carbon dioxide.

2.5. Gait Score

To assess animal welfare, gait scoring was conducted using a 3-point scale according to AssureWel Meat Chicken Assessment Protocol [24], chosen for its effectiveness and practicality in a farm setting. This analysis examined 180 broilers randomly selected per treatment (15 birds per location $\times$ 6 locations $\times$ 2 houses) on each measurement day. Broilers exhibiting abnormal gait while walking across 20% of the house area were identified, and the flock's movement was recorded using a GoPro Hero 12 camera (CPST1, GoPro, Inc., San Mateo, CA, USA) along their walking path. In terms of scoring, a score of 3 indicated an abnormal gait and impaired mobility, a score of 4 reflected a severe gait issue with only a few steps possible, and a score of 5 signified the inability to walk at all [15].

2.6. Footpad Dermatitis, Hock Burn, and Feather Cleanliness

Footpad dermatitis, hock burn, and feather cleanliness were assessed following the Welfare Quality Assessment protocol for poultry [25]. On days 19 and 27, a total of 180 birds were randomly selected from each house (15 birds per location $\times$ 6 locations $\times$ 2 houses) and inspected. Both footpad dermatitis and hock burn were scored on a 3-point scale (from 1 to 3), where a score of 1 indicated no signs of the condition, 2 indicated mild symptoms, and 3 indicated visible symptoms. Feather cleanliness was also rated using a 3-point scale (from 1 to 3), with 1 representing clean feathers, 2 representing slightly dirty feathers, and 3 representing significantly dirty feathers. Figure 3 shows examples of the score criteria used in our study to measure foot pad dermatitis and feather cleanliness.

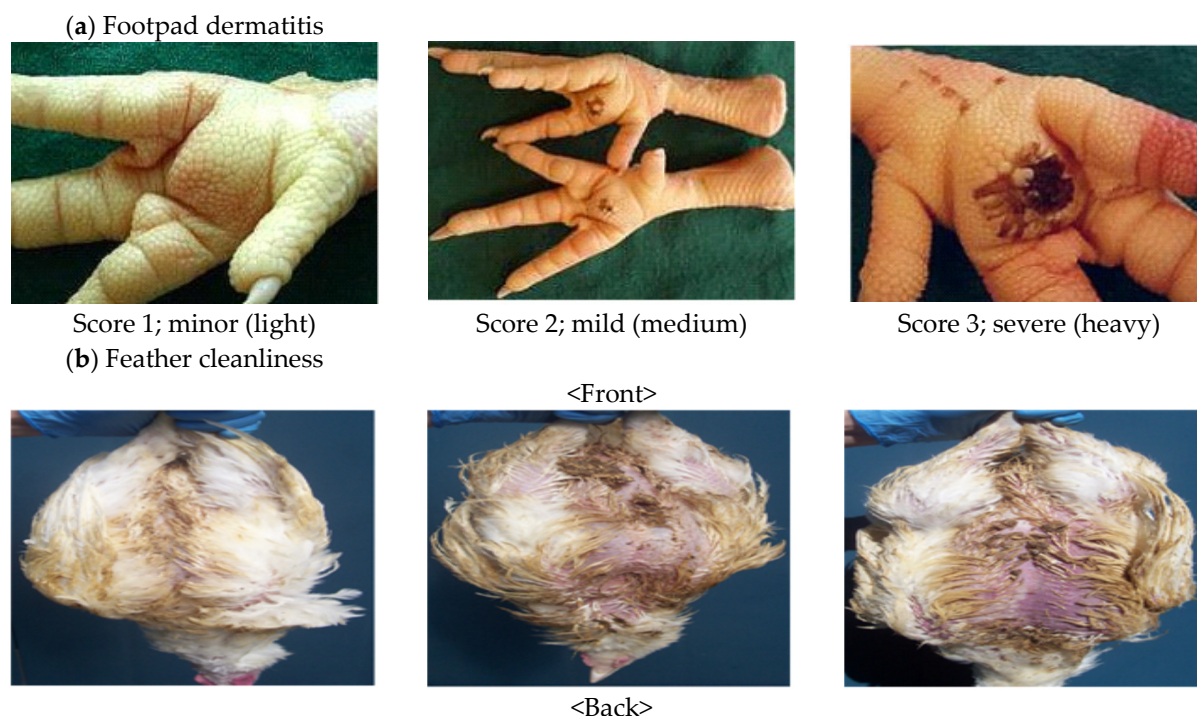


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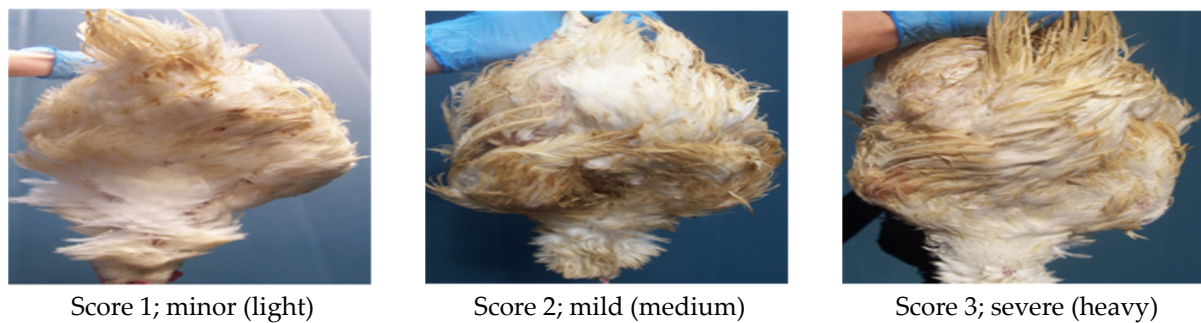


Figure 3. Footpad dermatitis of broilers showing how the degree of damage was scored (a) and feather condition and cleanliness for the scores from 1 to 3 on the body of each broiler (b).

2.7. Stress Hormones (Corticosterone) in the Blood

To assess the stress levels associated with pecking block provision, the stress hormone corticosterone was analyzed from blood samples. Blood samples were collected from the wing vein of 16 birds randomly selected from 12 locations per treatment group (6 locations per replicate) on days 19 and 27, using EDTA-coated BD Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ, USA). After collection, the serum was separated and stored at -70°C until further analysis. The analysis was performed using a chicken stress hormone enzyme-linked immunosorbent assay (ELISA) kit (Wuhan Fine Biotech Co., Ltd., Wuhan, China) according to the protocol provide in the manual. Absorbance was measured with a spectrophotometer (Epoch 2; BioTek Instrument, Inc., Winooski, VT, USA) following the analysis.

2.8. Statistical Analysis

In this study, we attempted to remove outliers and missing values by checking the homogeneity of variance and normality of data. If the residuals were more than three times the standard error of the parameter, they were considered outliers to be excluded from the data set before statistical analysis. Subsequently, all data were analyzed using analysis of variance (ANOVA) in a completely randomized design in statistical analysis system (SAS) software (version 9.4; Statistical Analysis System Institute Inc., Cary, NC, USA) through the Proc Mixed procedure. Outliers were checked with the UNIVARIATE procedure in SAS; however, none were identified. Differences among least-squares means were assessed using the PDIFF option with a *t*-test. Animal welfare indicators were analyzed using a chi-square test, with Fisher's exact test applied when the expected frequency was less than 5. A macro program was utilized to categorize output values into letter groups. Statistical significance was defined at $p < 0.05$, with trends considered for $0.05 \leq p \leq 0.10$.

3. Results

3.1. Growth Performance and Uniformity

This study evaluated the effect of environmental enrichment on body weight and uniformity in broilers at 19 and 27 days of age (Table 2). The results indicated that environmental enrichment did not have a significant effect on the body weight of broilers at either 19 or 27 days. At 19 days of age, the average body weight of the control group was 733.6 ± 77.0 g, while the enriched group averaged 735.3 ± 53.51 g, with no significant difference between the two groups ($p = 0.926$). The CV in body weight also showed no significant difference between the control group ($10.56 \pm 1.25\%$) and the enriched groups ($7.29 \pm 0.85\%$). At 27 days of age, the control group had an average body weight of 1290.7 g, and the enriched group averaged 1285.4 g, with no significant difference between the two

groups ($p = 0.589$). The CV for body weight in the control group ($12.43 \pm 1.58\%$) compared to the enriched group ($9.10 \pm 1.25\%$), was not statistically significant.

Table 2. Body weight and uniformity of 19- and 27-day-old broilers with or without enrichment ¹.

Items	Treatment ²		<i>p</i> Value
	Control	Enrichment	
19 day			
Body weight (g/bird)	733.6 ± 77.0	735.3 ± 53.51	0.926
CV ³ (%)	10.56 ± 1.25	7.29 ± 0.85	0.233
27 day			
Body weight (g/bird)	1290.7 ± 159.7	1285.4 ± 117.3	0.799
CV ³ (%)	12.43 ± 1.58	9.10 ± 1.25	0.427

¹ Values are means of 90 replicate per treatment. ² Control, environmental enrichment (grain-based pecking blocks) not provided; enrichment, environmental enrichment (grain-based pecking blocks) provided (one grain block per 1000 birds). ³ CV, coefficient of variation (standard deviation/average weight of 180 broilers at 19 and 27 days of age per 1 location).

3.2. Litter Moisture and Gas Emission

The effects of environmental enrichment on litter moisture in broilers at 19 and 27 days of age (Table 3). The results showed that environmental enrichment did not significantly influence litter moisture or gas emissions at either age. At 19 days of age, litter moisture in the control group averaged $29.1 \pm 2.83\%$, while the enrichment group averaged $28.2 \pm 4.71\%$. At 27 days of age, litter moisture averaged $35.2 \pm 1.98\%$ in the control group and $36.1 \pm 3.98\%$ in the enrichment group, but this difference was not statistically significant. Regarding the effect of gas concentrations (CO_2 and NH_3) of 19- and 27-day-old broilers with or without enrichment (Table 3), there was no significant difference between the two groups. CO_2 concentration levels were $1244.8 \pm 36.4 \text{ mg/m}^3$ for the control group and $1226.6 \pm 37.7 \text{ mg/m}^3$ for the enrichment group, showing no significant difference. Similarly, NH_3 concentration levels were $4.60 \pm 0.41 \text{ mg/m}^3$ and $4.59 \pm 0.44 \text{ mg/m}^3$ for the control and enrichment groups, respectively, with no statistical significance. At 27 days of age, CO_2 concentrations were $1333.7 \pm 37.3 \text{ mg/m}^3$ in the control group and $1326 \pm 39.1 \text{ mg/m}^3$ in the enriched group, with no significant differences between treatments, and NH_3 concentrations were also not significantly different between treatments.

Table 3. Litter moisture and gas concentration (CO_2 and NH_3) of 19- and 27-day-old broilers with or without enrichment ¹.

Items	Treatment ²		<i>p</i> Value
	Control	Enrichment	
19 day			
Litter moisture (%)	29.1 ± 2.83	28.2 ± 4.71	0.277
Gas concentration			
CO ₂ (mg/m ³)	1226.6 ± 37.7	1244.8 ± 36.4	0.325
NH ₃ (mg/m ³)	4.60 ± 0.41	4.59 ± 0.44	0.698
27 day			
Litter moisture (%)	35.2 ± 1.98	36.1 ± 3.98	0.398
Gas concentration			
CO ₂ (mg/m ³)	1278.3 ± 35.8	1271.8 ± 37.48	0.258
NH ₃ (mg/m ³)	7.41 ± 1.58	7.20 ± 1.60	0.359

¹ Values are means of 12 replicate per treatment. ² Control, environmental enrichment (grain-based pecking blocks) not provided; enrichment, environmental enrichment (grain-based pecking blocks) provided (one grain block per 1000 birds).

3.3. Gait Score, Footpad Dermatitis, Hock Burn, and Feather Cleanliness

The gait score was evaluated in 20% of the flock per house using the AssureWel Meat Chicken Assessment Protocol. At 19 and 27 days of age, chi-square tests showed no significant differences between the control and treatment groups, although poorer well-being and health were associated with higher walking scores. Fisher's exact test was used when the expected frequency was less than five, but again no significant difference was detected (Figure 4). Figure 5 presents the scores associated with pecking block provision for plantar dermatitis, sole burns, and feather contamination at 19 and 27 days of age. No statistically significant differences were observed across pecking block treatments for plantar dermatitis, sole burns, or feather contamination. Figure 4 displays gait scores for pecking block provision, with no significant differences detected between treatments. The figure presents the distribution of broiler assessment results based on gait scores at 19 and 27 days of age, comparing control and enrichment (grain block) groups.

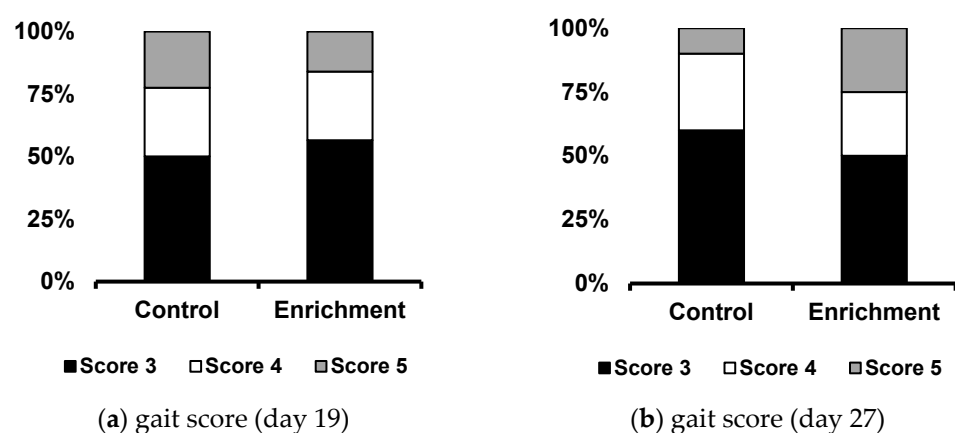


Figure 4. Distribution of broiler assessment results according to the level of gait score between the control and enrichment (grain block) groups at 19 and 27 days of age. Gait score (19 days, $\chi^2 = 0.498$, 27 days; $\chi^2 = 0.891$) were assessed in 20% of the flock per house using the AssureWel Meat Chicken Assessment Protocol [26]. Higher scores indicate poorer welfare and health outcomes. Fisher's exact test was used rather than the χ^2 test if at least one expected frequency between the treatments was less than 5. No significant differences were found in the assessment. Control, environmental enrichment (grain-based pecking blocks) not provided; Enrichment, environmental enrichment (grain-based pecking blocks) provided (one grain block per 1000 birds).

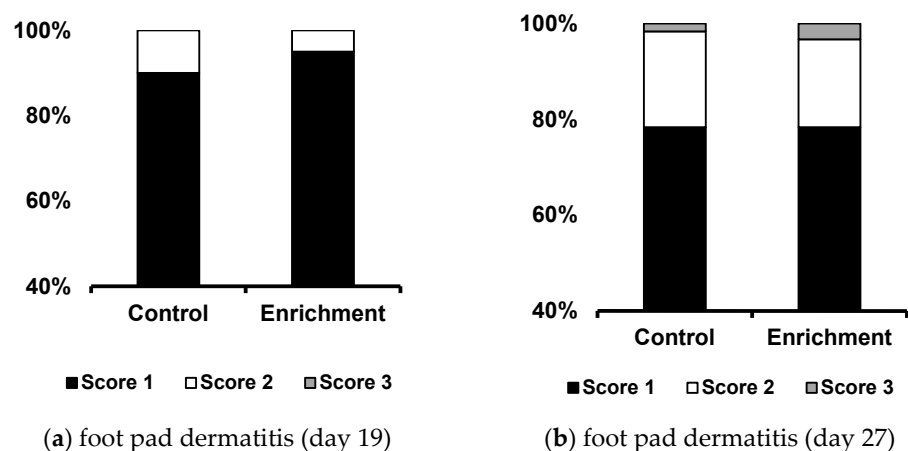


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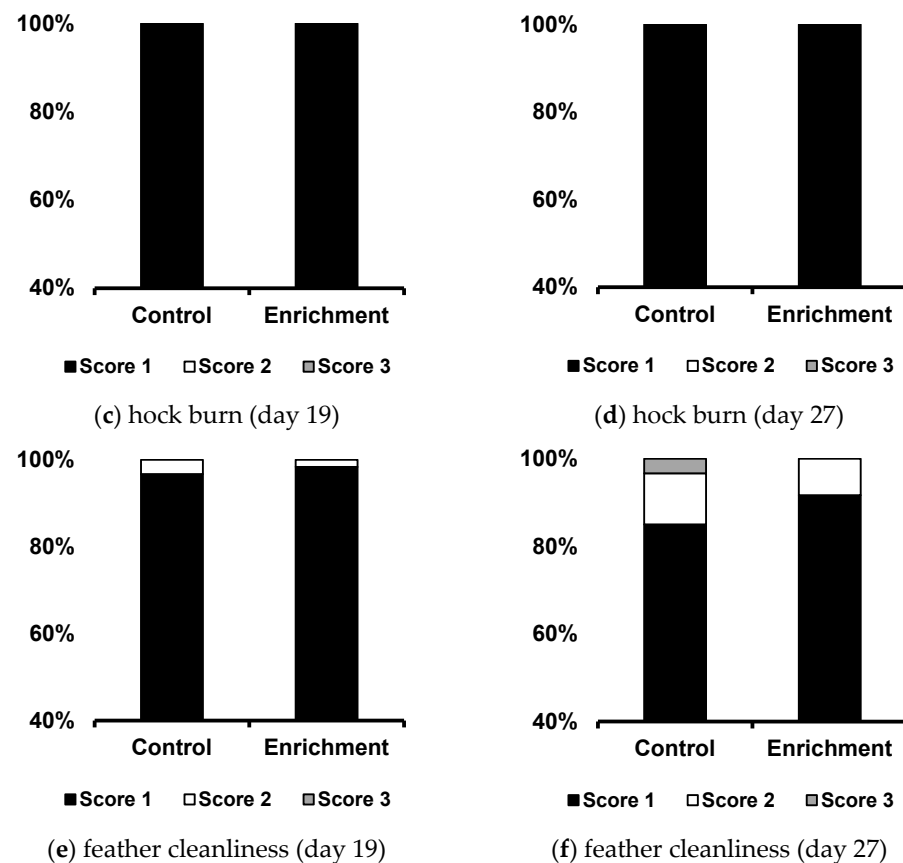


Figure 5. Distribution of broiler assessment results according to the level of footpad dermatitis, hock burn, and feather cleanliness between the control and enrichment (grain-based pecking block) groups at 19 days and 29 days of age on animal welfare-certified farm. Footpad dermatitis (19 days; $\chi^2 = 0.299$, 27 days; $\chi^2 = 0.559$) and feather cleanliness (19 days; $\chi^2 = 0.828$, 27 days; $\chi^2 = 0.281$) were measured in an average of 90 birds/house in the control and enrichment, according to the RSPCA. Higher scores indicate negative outcomes for welfare and health. Fisher's exact test was used instead of the χ^2 -test if at least one expected frequency was less than 5 between the treatments. No significant differences were found in the assessments. Control, environmental enrichment (grain-based pecking blocks) not provided; enrichment, environmental enrichment (grain-based pecking blocks) provided (one grain block per 1000 birds).

3.4. Corticosterone

The effect of environmental enrichment on blood corticosterone levels in 19 and 27 d-old broiler were assessed (Table 4). At 19 days of age, broilers in the enriched group exhibited significantly lower corticosterone levels (1.65 ± 0.164 ng/mL) compared to the control group (1.77 ± 0.147 mg/mL, $p = 0.022$). No significant treatment differences at 27 days of age.

Table 4. Stress hormone (blood corticosterone) of 19- and 27-day-old broilers with or without enrichment ¹.

Items	Treatment ²		<i>p</i> Value
	Control	Enrichment	
Corticosterone, ng/mL			
19 day	1.77 ± 0.147 ^a	1.65 ± 0.164 ^b	0.022
27 day	1.82 ± 0.277	1.78± 0.341	0.622

^{a,b} Means in same rows with different superscripts are significantly different ($p < 0.05$). ¹ Values are means of 12 replicate per treatment. ² Control, environmental enrichment (grain-based pecking blocks) not provided; enrichment, environmental enrichment (grain-based pecking blocks) provided (one grain block per 1000 birds).

4. Discussion

Research on environmental enrichment through providing pecking materials to broiler chickens is actively being conducted, but it has been shown that productivity varies depending on the provided materials [15,19,26]. In our study, the grain block provided did not significantly affect the performance and uniformity of broilers. This means that the consumption of the provided grain block did not have a negative effect on the performance of broilers, which is similar to the results of the study by Kwon et al. [15]. Corn forage provided by Jones et al. [26] contributed to lower broiler productivity, which was a result of replacing regular feed intake with nutritionally inadequate forage intake. In another study, when *Tenebrio molitor* larvae were provided as an environmental enrichment, better feed efficiency was shown than in the non-provided treatment or *Hermetia illucens* larvae [19]. This is because chicks are naturally oriented towards insect consumption, and *Tenebrio molitor* larvae have higher nutritional value [19]. In view of this, it is important to explore substances that can improve behavioral enrichment and welfare level without negatively affecting the performance of broilers.

Wet litter and high concentrations of NH_3 and CO_2 pose a potential hazard to chickens and farm workers [8]. The NH_3 from poultry feces (urea) causes chemical burns when mixed with moisture, resulting in breast blisters and footpad dermatitis [7]. Wet litter is one of the areas that should be improved in terms of welfare, as it worsens the rearing environment, restricting the movement of broilers and negatively affecting their productivity [27]. Litter and air quality within poultry houses depend on environmental enrichment methods [7]. Baxter et al. [28] expected that oat hulls with dry properties would improve litter quality but had no effect on litter condition or air quality. Jacobs et al. [29] found that the provision of live insects stimulated movement and foraging behavior in poultry and had positive effects on litter quality, contact dermatitis, and walking ability, but the improvement effects may vary depending on the number of larvae. Hamad et al. [30] also showed that when various environmental enrichment materials (wood chips, corn cobs, and processed paper) were provided, air quality (NH_3 and CO_2) was improved in the corn cob group. In contrast, our study showed similar litter quality and air quality regardless of grain block provision, but gas concentrations in all groups were within normal ranges (NH_3 : <25 ppm; CO_2 : <3000 ppm) [8].

FPD, HB, and feather cleanliness are important indicators that can be used to evaluate the welfare level of poultry, and they are closely related to the moisture content of the litter [15,27,31]. Usually, towards the end of the production period, broilers become heavier, less active, and have increased contact time between the litter and the skin [27,32]. At this time, moist litter soils the feather condition and has a detrimental effect on the footpad skin [31]. Therefore, high FPD, HB, and feather cleanliness scores indicate poor broiler welfare. In our study, there was no significant effect of grain block provision on FPD, HB, and feather cleanliness. Providing environmental enrichment to increase activities such as litter scratching in broilers may be a way to improve litter conditions and prevent leg disorders and maintain health [32–34]. However, previous studies have not observed any positive effects on the activity level and prevention of leg disorders in broilers despite the provision of various pecking materials (wood chips, whole wheat, etc.) [35]. In particular, when maize roughage was provided, the moisture content of the litter was found to increase, which was identified as a risk factor for the development of footpad dermatitis [34]. On the other hand, when mealworms, a favorite food of poultry, were provided in the litter, litter pecking and scratching increased, which helped maintain activity and leg health [36]. Meanwhile, Tahamtani et al. [34] reported that providing a platform that prevents contact with litter rather than providing a pecking material is more effective in preventing the occurrence of plantar dermatitis. From this perspective, it is necessary to

seek the optimal method to stimulate the activity of broilers, help their leg health, and maintain a clean environment.

In our study, gait scores also did not show significant differences between groups. The gait score of broilers is an indicator of leg impairment and leg lameness and is used to assess leg health and welfare levels [37]. The effects of environmental enrichment on broiler gait scores vary, and the provision and combination of appropriate enrichment is important to stimulate natural behaviors and enhance walking ability of broilers [32,37]. In a study by Dejong and Gunnink [32], the combination of straw bales and natural light promoted activity and improved walking scores compared to unenriched controls or straw bales alone. Additionally, natural light was more effective when provided with straw than when combined with wood chips [32]. Providing oat hulls was suitable for stimulating active behaviors such as foraging and dust bathing and improving leg health, with higher gait scores observed at the end of the experiment [5]. However, the lack of significant difference in the gait scores of broilers despite providing environmental enrichment may have been due to the small sample size [32], so further studies should include a larger sample size.

Interestingly, providing grain blocks as an environmental enrichment agent was effective in lowering stress hormones (corticosterone) in broilers. The corticosterone concentration in animals is an important analysis item for evaluating the level of animal welfare in relation to hunger, fear, stress, and the housing environment [11]. Absolute corticosterone measures in chickens differ heavily among studies [38]. To summarize, basal corticosterone concentrations have been described to range between 0.27 and 2.7 ng/mL [35,39]. Many researchers have already reported that providing environmental enrichment to poultry is effective in lowering the levels of stress hormones (corticosterone, serotonin, etc.) [11,40]. Son et al. [11] reported that providing pumice and hay to laying hens significantly reduced stress levels compared to the non-concentrated treatment group. Additionally, a study in broilers found that laser-enhanced environments reduced serum corticosterone levels by up to 21% [41]. One study found that when laying hens were provided with toys, their corticosterone levels gradually decreased over time [42]. This means that continuous provision of environmental materials is effective in reducing poultry stress and increasing satisfaction with the rearing environment. However, most of the studies investigating the effect of environmental enrichment on reducing poultry stress were conducted on laying hens. Therefore, future research is also needed on environmental improvement methods that can effectively reduce the stress of broiler rearing. In addition, the venipuncture itself may induce an increase in corticosterone concentrations levels, and therefore the interpretation of the results should be discussed with caution, and future experiments should be repeated.

Meanwhile, environmental enrichment methods through providing pecking materials can influence the behavioral patterns of poultry, stimulate instinctive activities, and provide a satisfactory rearing environment [43]. In particular, pecking between poultry birds is a bad behavior that causes great injury and stress to the flock and causes great damage to the farm economy [11,44,45]. When poultry raised in harsh environments are provided with pecking materials such as strings and highly valued feed items (e.g., hay, insects, mealworms), their pecking behavior decreases, and other behavioral patterns emerge (foraging, dustbathing, and locomotion) [29,43]. In the case of straw bales, they also serve as protection and shelter, but after two weeks, they have been observed to function as resting areas, where they rest or lie down [46]. Environmental enrichment using hay and perches stimulated standing, resting, and moving behaviors [47], while studies providing insects resulted in more wing flapping, stretching, scratching, preening, and ground pecking. Dixon et al. [43] reported that providing environmental enrichment reduced the frequency of pecking behavior as poultry spent more time with the enriched objects. Additionally,

several studies have shown that the lack of foraging material on the ground affects feather pecking behavior [20]. Although it is known to be difficult to completely reduce pecking behavior using environmental enrichment materials, continued exploration of environmental enrichment materials that are effective in improving poultry behavior is warranted [20,41].

5. Conclusions

In conclusion, the application of enrichment to broilers did not have a negative effect on productivity, litter moisture, sole lesions, hock burn, feather soiling, and gait score, but the blood stress hormone content, which can be used to assess stress, was significantly reduced in the enriched treatment (pecking grain block).

Author Contributions: Conceptualization, C.-H.K.; methodology, C.-H.K. and J.-S.S.; software, C.-H.K. and J.-S.S.; validation, C.-H.K., J.-S.S. and J.-H.J.; formal analysis, C.-H.K., J.-S.S. and J.-H.J.; investigation, C.-H.K., W.-D.L., J.-S.S., J.-H.J., S.-J.L. and S.-M.K.; resources, C.-H.K., W.-D.L., J.-S.S., J.-H.J., S.-J.L. and S.-M.K.; data curation, C.-H.K. and J.-S.S.; writing—original draft preparation, C.-H.K. and W.-D.L.; writing—review and editing, C.-H.K., W.-D.L., J.-S.S., J.-H.J., S.-J.L. and S.-M.K.; visualization, C.-H.K., W.-D.L., J.-S.S., J.-H.J., S.-J.L. and S.-M.K.; supervision, C.-H.K.; project administration, C.-H.K.; funding acquisition, C.-H.K. All authors have read and agreed to the published version of the manuscript.

Funding: 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.

Institutional Review Board Statement: 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).

Data Availability Statement: The data are available upon request from the corresponding authors.

Conflicts of Interest: The authors declare no conflicts of interest.

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