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Research Article
Effect of Free-Range Production System on the Weight of Adrenal Gland and Body Feather Coverage in Broilers

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Abstract

Background and Objective: Conventional broiler production systems result in adverse physiological and behavioural responses and therefore, stress to the birds. Enlargement of the adrenal glands and poor feather development are among the changes observed in stressed birds. This study was designed to find out if the free-range production system in broilers would minimize these changes and alleviate production stress. **Materials and Methods:** Four treatments including control were designed, the complete confinement group D and groups A to C where the birds were introduced to the free-range production system at 2, 3 and 4 weeks, respectively. The relative weight of the adrenal gland was determined at 2, 4, 6 and 8 weeks of age. In addition, weekly monitoring of feather development was done starting from week 3 and age at full feather coverage was recorded for each treatment. **Results:** Free-range production system birds recorded significantly lower adrenal gland-to-body weight ratios than those in confinement. Birds in free-range production systems had a significantly lower relative weight of the adrenal gland than those in confinement ($p<0.05$). At week 7, there were no differences between the mean of treatments A and B. Broilers in conventional broiler production took longer (treatment D had full feather cover at 7 weeks of age versus A at 5 weeks) to achieve 100% full back-side feather coverage than those in free-range production system. **Conclusion:** Broilers in free-range production system experienced less stress and hence had better welfare.

Key words: Free-range, feathers, conventional broiler production, ratio of adrenal gland weight to body weight, animal stress, corticosterone

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Conventional broiler production systems are known to increase animal stress, resulting in negative physiological and behavioural responses and decreased performance[1]. Studies have also shown that the quality of meat from birds reared under stressful conditions is decreased[2]. On the contrary, free-range systems could improve bird growth conditions and decrease stress[3]. The free-range production system (FRPS) is known to encourage increased activity in birds, which can enhance their movement and scavenging behaviour compared to other production systems[4]. Therefore, easy and efficient stress assessment and monitoring methods are needed for this purpose and researchers are trying to meet these demands[5]. The primary avian adrenal glucocorticoid is corticosterone (CORT), a hormone that increases significantly in circulation during stress in chickens[6]. Some of the stressors that cause increases in CORT are, Production stresses include shackling, stocking density, constraint, cooping, cold and heat, as well as nutritional stressors like dietary protein deficit, feed restriction and fasting[7]. The adrenal gland is critical for the secretion of this stress hormone.

One crucial function of the adrenal cells is the secretion of hormones, for example, adrenalin and nor-adrenalin, inter-renal cells, on the other hand, secrete corticosteroids such as corticosterone[8]. Adrenal gland activity is first triggered by the Hypothalamus-Pituitary Axis (HPA), which releases corticotropin-releasing hormone (CRH) from the hypothalamus when the organism encounters a stressor. The CRH then acts on the pituitary gland, which releases Adrenocorticotropin (ACTH), producing corticosterone in the adrenal glands[8]. Chronic stimulation of the adrenal gland results from chronic release of ACTH and can lead to hyperplasia and hypertrophy of the inter-renal tissue in the adrenal gland[9]. Studies show that the zona fasciculata in the adrenal glands of rats underwent hyperplasia and hypertrophy when exposed to chronic stress[9], leading to reduced performance. In another study, broilers under stressful conditions were observed to have a higher proportion of blood vessels than those in less stressful situations indicative of increased adrenal activity[10]. The consequence of the secretion of corticosterone and its effects on the morphology of the adrenal glands are parameters that indicate how much an animal suffers from chronic stress[11]. In another study, broilers with gait problems showed a higher ratio of adrenal gland to body weight than those with normal gait[10]. The conclusion was that the study of adrenal gland morphology and relative adrenal weight are indicators of chronic welfare problems in broiler chickens[10]. Therefore, the relative weight of the normal adrenal gland is often used to assess the physiological state of animals that have endured stressful situations[12]. In this study, the relative weight of the adrenal gland was used to indicate the degree of stress in broiler birds.

Feathers play an important role in thermoregulation, protection, sexual display, flight and insulation in broilers[13,14]. Diets containing less than 160 g kg^{-1} calcium and phosphorus can cause poor feathering in young broiler chicks[15]. Feather coverage is influenced by genetics, feather pecking behaviour, feed and metabolism[16]. Poor feather development is associated with physiological stress[17]. Feathers are a useful non-invasive way of assessing stress in broilers by determining their growth and feather corticosterone content[18-20]. The objective of this study was to determine the effect of a free-range production system on stress levels in broiler birds.

MATERIALS AND METHODS

Study area: This experimental investigation was carried out at Pwani University's poultry farm, which is located at Latitude 2° South, Longitude 40° East and an elevation of 16 m above sea level. The annual rainfall at the research site ranges from 900 to 1100 mm, while the mean annual temperature is from 25 to 30°C. It features two distinct wet seasons (April to June and October to December, interspersed by a dry spell). The study was carried out between July, 2021 and September, 2021.

Experimental design: The experimental design of this study was as described by Mbato *et al.*[21]. Briefly, duly vaccinated, 240 Cobb 500 male chicks were acquired from a nearby hatchery (Kenchic Ltd.). The chicks were raised in total confinement on a deep litter floor system for 2 weeks on normal broiler feed. Broiler chicks were randomly assigned to one of four treatments (A, B, C and D) at day 14 and three replications (20 birds each) in a completely randomized design. The treatments were:

- **Treatment A:** Six weeks of FRPS
- **Treatment B:** Five weeks of FRPS
- **Treatment C:** Four weeks of FRPS
- **Treatment D:** Zero week of FRPS

All birds were vaccinated against new castle disease on day 14 and day 28. The chicks released on the FRPS were

denied conventional broiler feed. All treatments still on commercial feed had their diet switched from broiler starter to broiler finisher on day 14. Birds in FRPS continued to enjoy unrestricted access to water in round drinkers. The stocking density in the FRPS area was 20 square feet per bird.

Effect of FRPS on adrenal to broiler body weight ratio (ABW) and feather cover: At the age of 2, 4, 6 and 8 weeks, 3 birds per replication per treatment were randomly selected, weighed and slaughtered by cervical dislocation. The weight of the birds was then recorded, the abdomen was opened and the left adrenal gland was isolated and weighed. The total body weight of the carcass and the weight of the left adrenal gland were used to calculate the adrenal-body (AB) ratio according to the following formula:

$$\text{AB ratio (g)} = \frac{\text{Adrenal weight}}{\text{Body weight}} \times 1000$$

This is a modification of the formula used by Raji *et al.*[22].

The birds were visually evaluated for feather coverage, considering the region between the edges of the right and left wings and from the head to the tail (generally the back of the bird). The number of birds with full feather coverage on the backside was estimated per treatment per replication by dividing the number of birds with full feather coverage by the total number of birds in the pen and then multiplying by 100.

Ethics review: The study was approved by the Pwani University Animal Ethics and Review Committee for the care and use of animals.

Statistical analysis: The study was a completely randomized design with one factor (FRPS). The data was analyzed using R-data management and statistical analysis[23]. The data being ordinal, the non-parametric analysis (Kruskal Wallis Test) was used at $p<0.05$. Dunn's Multiple Range Test was used to separate the means.

RESULTS

Adrenal gland to body weight ratio (ABW): The weight of birds, the weight of the adrenal gland and the ABW increased with time in all treatments (Table 1). There was a steady increase in broiler ABW over the weeks for all treatments, although exposure to FRPS at different times appeared to reduce the rise (Fig. 1). At week 4, the readings were as follows, A (0.013), B (0.016), C (0.05) and D (0.05). At week 6, A (0.015), B (0.017), C (0.049) and D (0.072). At week 8, A (0.022), B (0.022), C (0.046) and D (0.097).

At week 4 there were no significant differences between A-B and C-D ($p>0.05$). However, there were significant differences between treatments A-C, A-D, B-C and B-D ($p<0.05$). At weeks 6 and 8 no significant differences were recorded between the comparisons of treatments A-B, B-C and C-D ($p>0.05$). However, there were significant differences

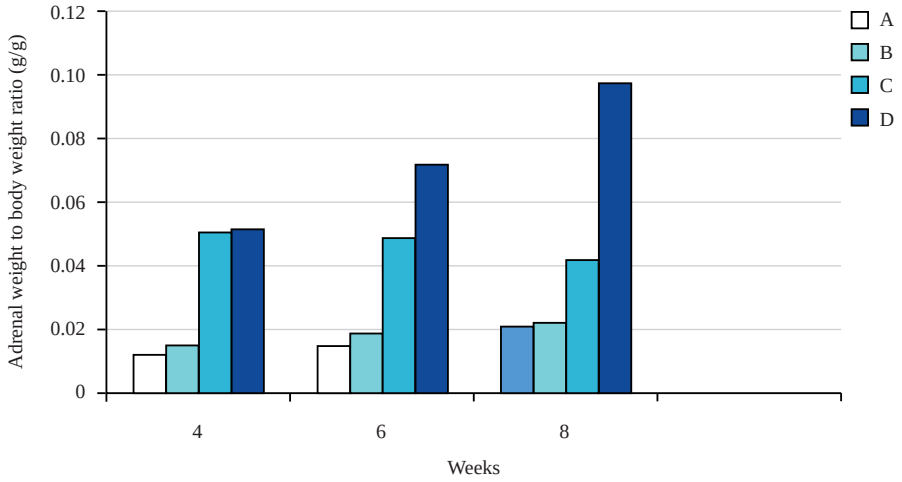

Fig. 1: Effects of FRPS on the ratio of weight of the adrenal gland to body weight (g g^{-1}) (ABW) of broiler birds at 4, 6 and 8 weeks of age

Treatments A, B and C are where, the birds were exposed to FRPS for 6, 5 and 4 weeks, respectively, while D remained in confinement for the whole experimental period of 8 weeks

Table 1: Effect of FRPS on mean weight of the bird and adrenal gland and ABW at weeks 4, 6 and 8 weeks of age

Week	Treatment/mean	A	B	C	D
4	Bird weight (g)	1074.6700	1390.560	1775.330	1770.220
	Adrenal gland weight (g)	0.0139	0.022	0.091	0.092
	ABW	0.0130	0.016	0.051	0.052
6	Bird weight (g)	1224.9000	1689.220	1999.220	2847.000
	Adrenal gland weight (g)	0.0180	0.032	0.098	0.205
	ABW	0.0150	0.019	0.049	0.072
8	Bird weight (g)	1367.8900	1781.440	2504.220	3600.560
	Adrenal gland weight (g)	0.0300	0.039	0.105	0.353
	ABW	0.0220	0.022	0.042	0.098

Treatments A, B and C are where the birds were exposed to FRPS for 6, 5 and 4 weeks, respectively, while D remained in confinement for the whole experimental period of 8 weeks and ABW refers to the relative weight of the adrenal gland

Table 2: Comparison of the effects of FRPS on ABW of the different treatments at 4, 6 and 8 weeks of age of broilers

Week	Comparison	Mean rank difference	p-value
4	A-B	-3.667	>1.00
	A-C	-19.330	0.00*
	A-D	-20.330	0.00*
	B-C	-15.670	0.01*
	B-D	-16.670	0.00*
	C-D	-1.000	>0.00
6	A-B	-5.444	>1.00
	A-C	-16.220	0.01*
	A-D	-25.220	<0.00*
	B-C	-10.780	0.18
	B-D	-19.780	0.00*
	C-D	-9.000	0.42
8	A-B	-1.000	>1.00
	A-C	-14.000	0.03*
	A-D	-23.000	<0.00*
	B-C	-13.000	0.05
	B-D	-22.000	<0.00*
	C-D	-9.000	0.42

*Comparisons significant at the p<0.05 level, Note: A-B implies the comparison of the ABW of the birds of treatment A with the ABW of the birds of treatment B. The same applies to rows 2, 3, 4, 5 and 6 per week, Treatments A, B and C are where the birds were exposed to FRPS for 6, 5 and 4 weeks, respectively, while D remained in confinement for the whole experimental period of 8 weeks and refer to free-range production system (FRPS) and relative weight (ABW) of the adrenal gland and, respectively

Table 3: Effect of FRPS on the percentage of broilers with full feather coverage (%) at different weeks in different treatments

	Broilers with full feather coverage (%)				
Treatment	Week 3	Week 4	Week 5	Week 6	Week 7
A	81.98	95.05	100.00	100.00	100.00
B	34.30	78.57	97.61	100.00	100.00
C	33.33	50.00	94.40	100.00	100.00
D	33.33	50.00	77.47	93.63	100.00

Treatments A, B and C are where the birds were exposed to FRPS for 6, 5 and 4 weeks, respectively, while D remained in confinement for the whole experimental period of 8 weeks and free-range production system (FRPS)

between the comparisons of the treatments A-C, A-D and B-D (p<0.05) (Table 2).

There was a general increase in feather coverage for all treatments (Table 3).

Percentage of birds with full backside feather coverage: At week 3 the percentage of birds with full backside feather coverage (FBFC) was at an average of 33% except for treatment A, which had 82%. At week 4 the FBFC percentages increased to an average of 50% for treatments C and D while treatments A and B recorded 95 and 79%, respectively. At week 5 treatments A, B, C and D recorded 100, 98, 94 and 78%, respectively. At week 6 treatment A, B and C recorded 100% while treatment D recorded 94%. At week 7 all treatments recorded a 100% FBFC of 100% (Fig. 2).

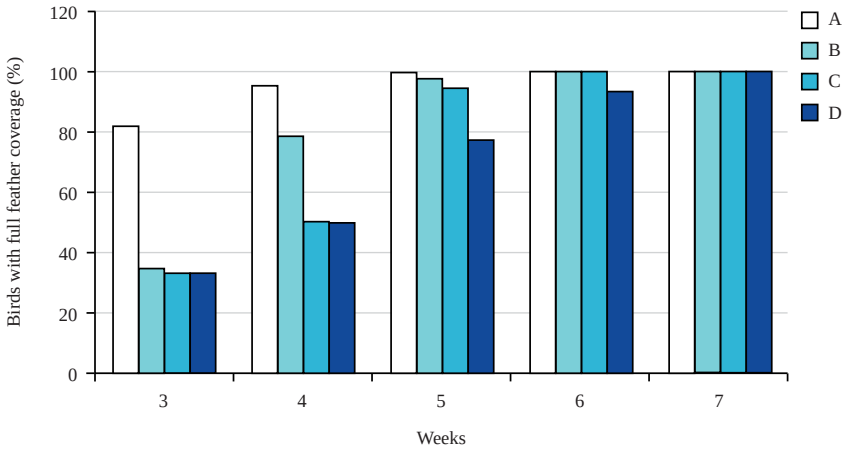

Fig. 2: Percentage of broilers with full feather coverage (%) at different weeks and in different treatments

Treatments A, B and C are where the birds were exposed to FRPS for 6, 5 and 4 weeks, respectively, while D remained in confinement for the whole experimental period of 8 weeks

DISCUSSION

In the current study, the relative weight of the adrenal gland (ABW) was used to evaluate the stress levels to which broiler birds were subjected to different treatments. The finding was that the more birds were exposed to FRPS, the less ABW leading differences in treatments. It is postulated that the mean ABW of treatment A was significantly different from treatments C and D because A had been exposed to FRPS long enough for the ease of stress in the bird to be reflected in the adrenal gland at week 4. The same applies to the significant differences between treatments B and D ABW.

On the other hand, there were no significant differences between ABW means of treatment (A and B) and (B and C) for the same reason that the ease of stress in the broilers had not been long enough for the weight change to be reflected in the adrenal glands of the broilers. This postulation is also confirmed by the release of treatment C to FRPS at week 4. At week 6 the mean ABW for treatment C was lower than that of D, although without significant differences. This contrasts with approximately the same reading of the mean ABW of treatments C and D at 4 weeks before the release of C to FRPS. Additionally, FRPS appears to bring significant differences in broiler ABW. This finding implies that FRPS to broilers reduces stress in birds, as indicated by a reduction in ABW. However, the confinement of birds increases stress in birds, as indicated by higher values of ABW for those broilers still in confinement. This finding agreed with Harvey and Sutcliffe[24], who found higher relative adrenal weights in response to increased adrenal activity due to stress in broilers. Similar results were also recorded in studies where stress was induced by thirst[25] and noise[26] in broilers. However, it should be noted that the increase in this ratio may not be entirely due to hyperplasia of the adrenals. It could also be due to broilers' weight loss, as stress levels take their toll on the growth rate. This is mainly because circulating stress hormones (corticosteroids) lead to decreased growth[27].

In the current study, the percentage of birds with full back-side feather cover was also used to compare the effects of stressors on the confinement and free-range production systems. At week 3, differences in the percentage of birds with full coverage with treatment A were observed with the highest (82%). Treatments are still in confinement B, C and D, recording an average percentage of birds with full feather coverage of about 33%. At week 4 treatment A and B recorded 95 and 79%, respectively.

And with both C and D recording 50%. It can be seen that when treatment B remained in confinement, the percentage of birds with 100% feather coverage was as low as that for treatments C and D (33%). However in the exposure to FRPS at week 3, treatment B responded by having more birds receive full feather coverage by week 4 (79%) compared to those still in confinement C and D (50%) in the same week. This implies that FRPS increased the growth of feathers compared to the groups still in confinement. This was agreed with many other studies demonstrating that FRPS improves feather coverage[28,29]. In the current study, stress is postulated to reduce the amount of protein available protein for forming feathers. This postulation agrees with the finding of other researchers that consistent increases in the circulating concentrations of urate/uric acid with the administration of dexamethasone[27] reflect increased protein catabolism.

In addition[30], demonstrated that even among those birds who had free-range, the ones who free-ranged farther had better feather coverage than the ones that free-ranged nearer. Blatchford *et al.*[31], also found better feather cover in FRPS birds than in birds in confinement in cages. However, this could probably be due to more abrasion by the cages for those birds in confinement than to the limited growth compared to those in FRPS. Other studies do not show an association between FRPS and feather cover[32]. This can be explained by the fact that not all broilers in FRPS exploit the opportunities available in the system. If the percentage of broilers that choose not to use the FRPS is significantly high, this may not significantly affect the study outcome. Other studies have reported that using FRPS by broilers can be enhanced by trees, brushes and artificial shelters[33,34]. This enrichment in structures that provide shade and some protection from aerial predators. Gilani *et al.*[34] reported that threats of aerial predators usually lead birds to run back toward the confinement, reducing the use of FRPS. The birds were fully feathered at the end of week 6 except group D, which recorded 95% of the birds with complete coverage. There was a similar finding of Edens *et al.*[35], who determined that broilers typically reach full plumage at 40 days of age, although some strains can be slower. From Fig. 2 it can be deduced that the number of birds having complete feathering increased faster for both those in confinement and those in FRPS in the latter stages of feathering (week 4 to 6). A similar finding was reported by Özkan *et al.*[36], who found no significant difference between different genotypes at 6, 8 and 20 weeks of age. It is postulated that this is due to the increased feather growth rate in late feathering birds between 5 and 6 weeks of age, which reach full feather cover around the age of 6-7 weeks.

The current study aimed to investigate the impact of FRPS on the adrenal to broiler body weight ratio and the feather coverage of Cobb 500 male chicks. Understanding these parameters can help improve bird welfare and optimize production practices. Early exposure to FRPS significantly influenced the ABW ratio and positively correlated with increased feather coverage. These results emphasize the potential benefits of introducing FRPS early in the rearing process to improve bird welfare and overall production outcomes.

CONCLUSION

The current study highlights the importance of incorporating FRPS in the broiler-rearing system to positively impact its adrenal-to-body weight ratio and feather coverage. Early exposure to free-range significantly influences these parameters and could potentially contribute to improved bird welfare and sustainable poultry production. Further research and industry adoption of such alternative systems is recommended to improve animal welfare and sustainable poultry farming practices.

SIGNIFICANCE STATEMENT

Complete confinement broiler production systems are associated with stress to the birds. In animals, adrenal gland weight is frequently employed as a stress indicator. The study's examination of adrenal gland weight in broilers under different production systems provides insights into how the birds adapt to their environment. This information can help veterinarians, researchers and farmers enhance the health and well-being of broilers. Feather coverage is critical to broiler welfare and health. It is a simple visual indicator of how successfully birds adapt to their surroundings. This research contributes to animal welfare issues by its investigation of the impact of various production systems on physiological and physical qualities, as well as its ability to educate industry practices and consumer choices.

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