JWPR
Journal of World's Poultry Research
2026, Scienceline Publication
J. World Poult. Res. 16(1): 1-8, 2026
Research Paper
DOI: https://dx.doi.org/10.36380/jwpr.2026.1
PII: S2322455X2600001-16
ISSN: 2322-455X

Effects of Feed Restriction on Physiological and Behavioural Responses in Broiler Chickens

Maake Mmatlou Christinah[1], Mokgalaka Neo Collins[1], Manyelo Tlou Grace[1], Gxasheka Masibonge[2], and Gunya Busisiwe*[1]

[1]*Department of Agricultural Economics and Animal Production, Faculty of Science and Agriculture, University of Limpopo, Sovenga, 0727, South Africa*
[2]*Department of Plant Production, Soil Science & Agricultural Engineering, School of Agricultural and Environmental Sciences, Faculty of Science and Agriculture, University of Limpopo, Sovenga, 0727, South Africa*

*Corresponding author's E-mail: Busisiwe.Gunya@ul.ac.za

Received: December 18, 2026, Revised: January 21, 2026, Accepted: February 12, 2026, Published: March 05, 2026

ABSTRACT

The rapid growth of broiler chickens can sometimes lead to metabolic disorders, skeletal issues, and excessive fat deposition, all of which affect chicken welfare and production efficiency. Feed restriction is a questionable management method used during various growth periods to improve economic efficiency, optimise gut development, and reduce the prevalence of metabolic and skeletal issues. This study aimed to ascertain the effect of feed restrictions on physiological and behavioural responses in broiler chickens. A total of 240 day-old broiler chickens, with an average body weight of 45 ± 3 g, were randomly allocated into three treatment groups. All chicks were fed *ad libitum* during the starter phase to promote uniform growth and health during this critical early stage of development. Upon reaching the grower phase (21 days), they were allocated to one of three experimental groups (n=80), including an untreated group with no feed restriction (FR0), a mild restriction (FR1) group with feed withheld for evry other days, and a moderate feed restriction (FR2) group with feed withheld for every two days. Welfare indicators, including feather condition, pecking behaviour, footpad and skin health, eye, beak, and comb conditions, gait score, body condition, vent pasting, and respiratory function, were evaluated at 42 days. Significant differences were observed across the feed restriction groups in feather condition, pecking behaviour, footpad and skin health, gait score, and body condition compared to FR0. However, respiratory function, condition of the eye, beak, and comb were not affected. Chickens in the FR0 group exhibited superior welfare outcomes, including the highest feather condition score, lowest aggression levels, healthiest footpads, and optimal body condition. In contrast, the FR2 group experienced lowest welfare outcomes including lowest feather wear score, higher aggression, and poor body condition. The present study demonstrated that broiler welfare indicators, such as feather condition, pecking behaviour, body condition score, gait score, and footpad and skin condition, are significantly impacted by feed restriction.

Keywords: Broiler chicken, Feed restriction, Feather condition, Feed efficiency, Welfare indicator

INTRODUCTION

Broiler chickens, such as Ross 308, are a specialised breed of chicken raised exclusively for meat production (Rasmussen et al., 2023). Through selective breeding and genetic advancements, broiler chickens have been optimised for rapid development and high carcass yield (Neeteson, 2023). Broiler chickens contribute significantly to the global poultry industry by meeting the growing demand for poultry products (Kleyn and Ciacciariello, 2021). However, this rapid growth is linked to several health issues, including ascites, sudden death syndrome, and leg problems (Bordbar et al., 2025).

Furthermore, one of the major challenges faced in the broiler industry is the high cost of feed, which accounts for a substantial portion of production expenses (Alhotan, 2021). To address this, feed restriction (FR) measures have been implemented to minimise feed costs, as well as to improve bird health and some disease control (Korver,

To cite this paper: Christinah MM, Collins MN, Grace MT, Masibonge G, and Busisiwe G (2026). Effects of Feed Restriction on Physiological and Behavioural Responses in Broiler Chickens. *J. World Poult. Res.*, 16(1): 1-8. DOI: https://dx.doi.org/10.36380/jwpr.2026.1

2023). Feed restriction is a potential technique to reduce feed costs, which entails limiting the quantity or timing of feed intake (Karaarslan et al., 2023).

In the poultry industry, FR is a management technique to regulate growth rates and lessen health problems (Yue et al., 2024). This strategy is particularly effective for rapidly developing breeds like the Ross 308 broiler chicken (Riber and Wurtz, 2024). While it is largely used to improve feed efficiency and reduce expenses, benefits include cost savings from increased feed conversion (Alhotan, 2021), a reduction in sudden death syndrome, mortality losses, ascites, and skeletal sickness (Eshimutu et al., 2020; Korver, 2023).

Controlled feed intake has been demonstrated to strengthen immune function and decrease stress-related disorders in broiler chickens. Moreover, it reduces the occurrence of infectious diseases, by enhancing immune competence, improving gut integrity, and lowering pathogen load through better biosecurity and physiological resilience (Yan et al., 2025). This effect is achieved through decreased fat accumulation and improved physiological resilience (Chaudhary and Mishra, 2024). Nonetheless, prolonged or severe FR may hurt welfare, emphasising the significance of implementing balanced feeding programs that promote both production and disease resistance.

Chickens on a restricted diet suffer metabolic and hormonal alterations such as energy storage mobilisation, decreased IGF-1 levels, increased corticosterone, and changes in appetite-regulating hormones (Meyer and Wittert, 2024). These physiological adaptations are associated with behavioural responses such as increased foraging, pecking, and stereotypic activity (Karpińska and Czauderna, 2022).

This study seeks to address existing gaps in research concerning the impact of FR on broiler chicken welfare, while offering recommendations for balancing optimal growth performance with ethical welfare considerations.

MATERIALS AND METHODS

Ethical approval

This study was conducted in strict accordance with established ethical guidelines for animal research and welfare. The experimental protocol was approved by the University of Limpopo animal research ethics committee (AREC), certificate number AREC/06/2024; and adhered to the guidelines established by the World organisation for animal health (OIE) to ensure the welfare of animals used for scientific purposes.

House preparation

The experimental house was carefully cleaned using water and disinfectant (Virukil, South Africa). After cleaning, the house was kept open for a week to disrupt the life cycle of any microorganisms that the disinfectant was unable to remove. The experimental house was divided into sixteen floor pens, each measuring around 2.5 m^2. Fresh sawdust was scattered to a depth of 7cm.

Study design and procedures

The study used 240 Ross 308 broiler chicks from Angela Feeds in Polokwane that were one day old and weighed between 20 and 45 grams. The chicks were randomly assigned to three treatment groups in an entirely random approach replicated five times, with each group consisting of 16 birds per pen. The treatment groups included a no feed restriction (FR0) group, FR1 restriction group (from day 21 to 42 of age) with mild restriction for every other day (one day), and FR2 moderate restriction for every two days (from day 21 to 42 of age). The chicks were provided with starter feed from day-old up to 21 days of age to support rapid growth and bone development. From day 22 to day 28, the chickens were fed grower feed to ensure consistent growth and muscular development, in accordance with their restriction schedule and the NRC (1994) recommendation.

The chickens were provided with finisher feed from day 29 to day 42, during the final stage of growth for muscle maintenance. Feed intake, growth rate, active performance, and body weight were recorded weekly to monitor the welfare indicators. The study used a 16-hour light and 8-hour dark lighting cycle for broiler chicks, keeping the light intensity between 20-25 lux and altering the schedule to enable handling and monitoring while guaranteeing optimal feed intake and welfare.

Standard management practices were adhered to throughout the experiment. The broiler house temperature was maintained between 32 ± 34 °. Relative humidity was kept at 50%, and adequate ventilation was provided to maintain air quality and prevent heat stress. Clean water and feed were supplied *ad libitum*. Litter was properly managed, bird health was checked daily, and biosecurity measures were implemented to prevent disease outbreaks. Live coccidiosis vaccine (Paracox®) Intervet South Africa (Pty) Ltd was supplemented orally through feed when they were one day old.

Table 1. Nutritional and environmental essentials for optimal broiler chicken performance

Nutrient Component	Starter (1-21 days)	Grower (22-35 days)	Finisher (36-42 days)
Metabolizable energy (MJ/kg)	12.5	13.0	13.2
Crude protein (%)	22.0	20.0	18.0
Crude fat (%)	4.5	5.0	5.5
Crude fibre (%)	3.0	3.5	4.0
Calcium (%)	1.0	0.9	0.8
Available phosphorus (%)	0.45	0.40	0.35
Lysine (%)	1.3	1.1	1.0
DL-Methionine (%)	0.55	0.45	0.40

Source: NRC (1994)

Data collection

At 42 days of age, all chickens remaining in the study were evaluated using the Welfare Quality Assessment Protocol for Poultry (Quality, 2009). They were evaluated for plumage condition, skin wounds/scratches, footpad dermatitis, hock burns, footpad hyperkeratosis, plumage dirtiness, bumblefoot, and accumulation of faeces around the vent. Welfare indicators were evaluated using standardised scoring systems to ensure consistent and reliable assessments. Plumage condition was assessed using the system developed by Decina et al. (2019), which categorises feather damage into three levels, including 0 (no damage), 1 (mild damage), and 2 (severe damage), allowing for evaluation across different body regions.

Footpad dermatitis was scored using a histologically validated 5-point scale proposed by Michel et al. (2012), ranging from 1 (no lesion) to 5 (severe lesion affecting more than 50% of the footpad). Hock burns were evaluated according to the Welfare Quality® Assessment Protocol on a 5-point scale, from 0 (no lesions) to 4 (very severe lesions), a method widely used to assess skin lesions on broiler hocks. Bumblefoot severity was graded on a 5-point scale from 1 (superficial lesion) to 5 (necrosis), enabling categorisation of foot infections (Poultry DVM). Finally, vent pasting was assessed using a simple binary scale, with 0 indicating no pasting and 1 indicating the presence of pasting, which is effective for detecting digestive issues in poultry (Borgonovo et al, 2024).

Four skilled observers assessed the chickens during the study. The observers were jointly educated on the technique used for the current study, including how to discriminate between scores. Furthermore, the chickens in each pen were dispersed uniformly among the observers, reducing any potential observer bias. The study used a 16-hour light and 8-hour dark lighting cycle for broiler chicks, keeping the light intensity between 20-25 lux and altering the schedule to enable handling and monitoring while guaranteeing optimal feed intake and welfare. Four trained observers visually evaluated the chicks while discussing various behavioural and physical welfare scenarios to ensure scoring consistency. Each observer began assessing chickens in all the pens, each containing sixteen chickens. After evaluating approximately 25% of the chickens in one pen, the observer moved on to another pen. This rotation continued until all chickens in experimental units had their welfare assessments completed, ensuring randomisation and minimising observer bias.

Following the welfare quality assessment protocol for poultry (2009) slaughter guidelines, the chickens were humanely killed by cervical dislocation at 42 days of age, after all welfare evaluations were completed for ethical compliance. Accuracy, inter-observer consistency, and adherence to ethical standards were the goals of this systematic evaluation approach, which was modelled after the methodology used in broiler chicken welfare assessment studies by Riber and Wurtz (2024).

Data analysis

The collected data were analysed using the SPSS General Linear Model procedure of statistical analysis of variance (ANOVA) version 27.0 software program. The Least Significant Difference (LSD) test was used to separate means. Means were considered significant at 5% level of significance.

RESULTS

Welfare indicators

The impact of FR on various clinical welfare indices in Ross 308 broiler chickens is summarized in Table 3. Significant differences were observed across the treatment groups in terms of feather condition, pecking behaviour, footpad and skin condition, gait score, and body condition

score. No significant difference was observed in respiratory issues and eye, beak and comb condition ($p > 0.05$).

Feather condition

Chickens in FR0 (no feed restriction) exhibited the best feather condition with an average score of 4.5, indicating minimal feather wear or loss. Chicks in FR1 (mild restriction) and FR_2 (moderate restriction) scored lower, with average scores of 3.6 and 3.5, respectively, indicating noticeable loss in feather wear score ($p > 0.05$).

Pecking behaviour

Feed restriction affected pecking. Aggression, as measured by pecking behaviour, varied significantly between groups. The FR0 group had the highest score of 4.9, indicating low aggression. In contrast, FR1 and FR2 showed increased aggression, with scores of 2.5 and 1.3, respectively, reflecting more frequent pecking and injuries ($p > 0.05$).

Footpad and skin condition

Footpad health was superior in the FR0 group with an average score of 5.0. Both FR1 and FR2 showed slightly reduced scores of 4.7, indicating minor footpad irritation or wear. The differences were statistically significant ($p > 0.05$).

Gait Score

Gait scores remained relatively good across all groups, with the FR0 group scoring 0.0, indicating no walking difficulties.FR1 and FR2 showed slightly higher scores of 0.1 and 0.2, respectively, indicating minor movement issues ($p > 0.05$).

Body condition score

The FR0 group had the highest body condition score of 4.0, reflecting good body mass and keel bone coverage. FR1 scored 3.5, while FR2 had the lowest score at 2.4, indicating a deterioration in body condition with more prominent keel bones ($p > 0.05$).

Weight gain

Figure 1 below shows initial and final weight gain across different treatments. At day 21, FR also had an impact on the broilers' weight gain. Initially, FR1 and FR2 chicks had higher mean weights (753.77 g and 734.82 g, respectively) compared to the FR0 group (638 g). However, the FR0 group reached the highest final weight (2128.63 g) at the end of the research, followed by FR1 (1958.1 g) and FR2 (1300 g), suggesting that FR considerably decreased weight gain. The FR0 group experienced the greatest weight gain, whereas the FR2 group had the least final weight.

Table 2. Effects of feed restriction on feather condition, pecking behaviour, gait score, body condition, footpad and skin condition of broiler chickens

Variables	FR0	FR1	FR2	P-value
Feather condition	$4.5^{a} \pm 0.51$	$3.6^{b} \pm 0.50$	$3.5^{b} \pm 0.51$	<001
Pecking	$4.9^{a} \pm 0.51$	$2.5^{b} \pm 0.57$	$1.3^{c} \pm 0.48$	<001
Footpad and skin condition	$5.0^{a} \pm 0.18$	$4.7^{b} \pm 0.47$	$4.7^{b} \pm 0.48$	0.01
Eyes, beak, and comb condition	5.0 ± 0.00	5.0 ± 0.00	5.0 ± 0.00	0.01
Gait score	$0.0^{b} \pm 0.0$	$0.1^{b} \pm 0.35$	$0.2^{a} \pm 0.44$	0.015
Body condition score	$4.0^{a} \pm 0.00$	$3.5^{b} \pm 0.51$	$2.4^{c} \pm 0.49$	<001

[abc:] Means in the same row with different subscript letters are significantly different ($p < 0.05$). FR0: No feed restriction (Control). FR1: Mild feed restriction. FR2: Moderate feed restriction

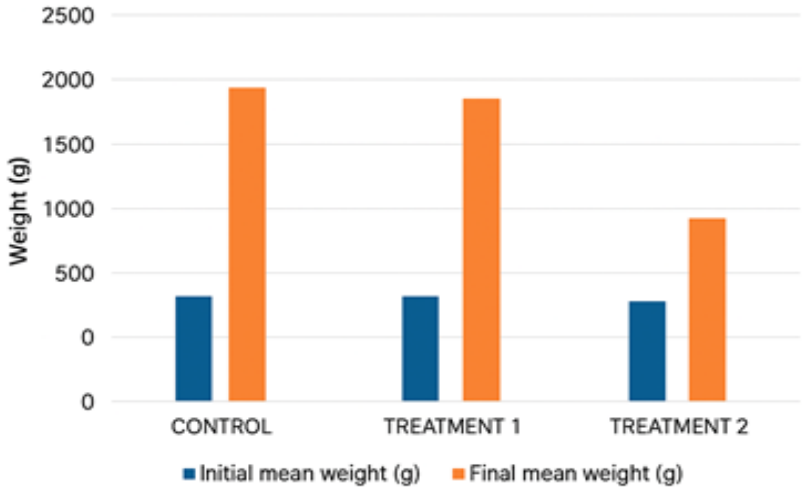

Figure 1. Effect of different levels of feed restriction on weight gain in broiler chickens from 21 days to 42 days. Control (FR0): No feed restriction. Treatment 1 (FR1): Mild feed restriction. Treatment 2 (FR2): Moderate feed restriction

DISCUSSION

The findings highlighted the complex trade-offs between feed management strategies and brioler chicken welfare, particularly in terms of physical health, behaviour, and performance. The data provide important insights into how FR can affect feather condition, behavioural indicators such as pecking and gait**.**

Welfare indicators

In the present investigation, FR altered feather condition. This resulted in reduced feather quality and a decline in overall welfare indicators in Ross 308 broiler chickens. Broiler chickens subjected to FR0 treatment showed mild feather damage and minimal feather loss. This might be because the nutrients needed for feather growth and maintenance are readily available. Significant feather loss was seen in broiler chicks exposed to FR1 and FR2. Nutritional deficiencies, especially in vitamins, protein, and minerals necessary for feather development, could be one of the causes (Taylor et al., 2025).

The study has shown that nutritional stress significantly impacts the development of ornamental plumage in chickens, with poor feather quality serving as an indicator of compromised health (Tahamtani et al., 2024). However, Taylor et al. (2025) postulated that FR is linked to increased stress and hostility in hens. As a result, chickens may engage in more pecking behaviour, which can result in feather loss or damage (Girard et al., 2017). A known issue with feed-restricted birds is increased feather pecking, which can lead to harmful behaviours as a result of frustration brought on by hunger or boredom.

Additionally, Kemper and Tetens (2024) demonstrated comparable feather-pecking outcomes in laying hens under extended FR. Feed restriction also affected pecking behaviour in this investigation. The FR0 group displayed minimal aggression with a high score of 4.9, whereas pecking aggression was significantly higher in the restricted groups. The chickens' increased feed competition and related stress during mealtime may be the cause of this pecking behaviour. Broiler chickens subjected to FR1 scored 2.5, and FR2 showed the most aggressive pecking (1.3). This aggressive behaviour in restricted groups may reflect increased competition for resources, which can lead to injuries and poor welfare outcomes. The differences between the groups highlight the importance of providing adequate feed to mitigate harmful behaviours. According to Trocino et al. (2020), feed-restricted broilers were more aggressive than birds given ad libitum, especially on mornings when feed was withheld. This suggests that the motivational state brought on by restriction directly affects competitive interactions among birds.

Wurtz et al. (2025) suggest that dietary deficits, which result in a restricted amount of nutrients such as amino acids, protein, or minerals, may promote cannibalism and feather pecking. In contrast, another study suggests that specialised feeding strategies, such as qualitative FR, can reduce aggressive behaviours by improving feed satisfaction and reducing competition among chicks (Yan et al., 2021). In contrast, Pizolotto et al. (2024) discovered that the ability of chickens to acquire the eating pattern is diminished when the number of restriction days is increased.

Footpad and skin conditions were slightly affected by FR, with the FR0 group scoring slightly higher (5.0) compared to the restricted groups (4.7 for both FR1 and FR2). Although these observed variations were fairly minor, the differences were statistically significant. This implies that FR might not have an impact on footpad health as it does on other welfare indicators. Despite not being very large, these differences were statistically significant. Even slight deterioration can limit mobility and comfort, raising the risk of secondary infections and reducing feed intake, so footpad dermatitis is still a significant welfare concern for broiler chickens (Tahamtani et al., 2024).

On the other hand, when properly implemented, FR can result in notable improvements in footpad health, according to research by Zukiwsky et al. (2021). This study indicated that moderate FR, when combined with suitable environmental conditions, can help reduce the incidence of footpad dermatitis. This improvement is achieved by promoting better overall body condition and minimising obesity-related issues that often worsen footpad problems. Variations in the feed's nutritional makeup and the length of the restriction period could be the cause of this discrepancy, which could have an impact on general health and well-being (Tahamtani et al., 2024).

Growth and body condition

Feed restriction has significant effects on body composition and growth performance. Initial and final body weights, weight increase, body condition ratings, feed intake, and feed conversion ratio were used to assess the broiler chickens' growth performance. The FR0 group had the highest body condition score (4.0), indicating well-covered keel bones, while the restricted groups

showed significantly lower scores (3.5 for FR1 and 2.4 for FR2). This finding indicated that feed-restricted chicks had a much more prominent keel bone, reflecting poorer body condition, which may compromise their long-term health.

Furthermore, it has been demonstrated that quantitative FR lowers overall body mass and carcass fat deposition in broilers during restriction periods. This could make skeletal structures like the keel more noticeable because of decreased muscle and fat accumulation (Naeem, 2025). The significance underscores the importance of adequate nutrition for maintaining optimal body condition in broiler chickens. According to the study conducted by Zukiwsky et al. (2021), it was found that FR0 (fed *ad libitum*) led to FR, when implemented appropriately, can lead to improved growth efficiency and better overall body condition in broiler chickens. The variation in the results was due to the duration and timing of FR.

Gait score also worsened with FR, with the FR0 group showing perfect mobility (0.0), while restricted groups showed slight increases in gait score (0.1 for FR1 and 0.2 for FR2). Statistically significant differences suggest that even slight feed limitation can impair movement in birds due to low energy supply and decreased muscular development, rather than an increase in disease incidence. Due to underdeveloped muscles and decreased energy availability, statistically significant differences indicate that even a small FR can affect a bird's mobility (Duvall et al., 2025).

Weight gain

Feed restriction also led to reduced weight gain. The highest final mean weight (2128.63 g) was attained by broilers in the FR0 group, which received unrestricted feed. This indicates optimal nutrient intake and growth potential. The FR1 and FR2 groups, on the other hand, displayed steadily decreasing final weights (1958.1 g and 1300 g, respectively), suggesting that FR decreased growth efficiency. These findings are in line with other research showing that quantitative feed limitation dramatically lowers broiler body weight gain because of decreased energy intake and restricted nutrient availability (Karaarslan et al., 2023; Duvall, 2025).

The study reveals that feed availability significantly impacts broiler chicken growth performance. Rather than killing the chickens prematurely, which can lower their final body weight and market value, producers can restrict their feed intake during certain growth stages to keep them from eating excessively while permitting them to reach market weight by the end of the production cycle.

The FR0 group achieves the highest body weight, while the feed-restricted groups show less weight gain. This highlights the trade-off between limiting feed costs and preserving optimal growth and welfare. The significant differences in weight gain highlighted the potential trade-offs between feed efficiency and growth, where FR may reduce costs but at the expense of bird welfare and performance (Ramankevich et al., 2025). Conversely, a study by Zukiwsky et al. (2021) found that FR can lead to compensatory growth when chicks are allowed *ad libitum* feeding after a period of restriction. The study found that feed-restricted birds often exhibit increased feed intake during refeeding periods, which can mitigate some negative impacts on overall weight gain and body condition. The difference in the results may be due to the different compositions of feed used by the treatments.

CONCLUSION

The study's findings show that restricting feed lowers body condition, growth performance, and some welfare metrics like pecking behaviour and feather condition. Although FR may result in lower feed costs, these advantages are outweighed by the harm done to overall welfare and physical development, especially at moderate to severe restriction levels. Research indicates that restricting dietary intake causes stress-related behaviours, especially pecking, as well as decreased body health and lower final weights. These findings highlighted the need for careful implementation of FR practices to ensure a balance between economic efficiency and animal welfare. Further studies are needed to identify alternative feeding strategies that support both optimal welfare and performance in broiler chickens.This study was subject to several limitations. The experimental period was relatively short (21-42 days) and focused solely on the grower–finisher phase, which may not adequately reflect long-term responses to FR. Generalizability to other strains or sexes is restricted by the exclusive use of Ross 308 broiler chickens. Even when environmental variables like humidity and temperature are controlled, there may still be slight impacts on behaviour and welfare reactions. There is a chance of observer bias when using visual observations for behavioural assessments. Other significant signs, such as immunological response or oxidative stress markers, were not included in the evaluation of the chosen welfare criteria. Finally, the study's relevance to commercial

broiler operations may be diminished by its controlled setting

DECLARATIONS

Acknowledgements

The authors are grateful to the University of Limpopo Experimental Farm staff for allowing us to conduct this study on the farm and to the Department of Agricultural

Funding

There was no external funding for this study.

Authors' contributions

Conceptualisation, Data collection was handled by Tlou Grace Manyelo, Masibonge Gxasheka, and Busisiwe Gunya. The data analysis was done by Mmatlou Maake and Collins Mokgalaka. Busisiwe Gunya and Neo Collins Mokgalaka wrote the manuscript's initial draft. The manuscript has to be reviewed and edited by Neo Collins Mokgalaka. Tlou Grace Manyelo, Masibonge Gxasheka, and Busisiwe Gunya also helped with the editing and review. All authors have reviewed and approved the manuscript's final draft and have given their permission for this article to be published.

Ethical considerations

The writers attest that this work is unique and has not been submitted for publication anywhere else. They also declare that the information in this publication is correct and has not been altered. No AI tool was used to conduct this study.

Availability of data and materials

All materials needed to complete this research are accessible at the University of Limpopo's Department of Agricultural Economics and Animal Production.

Competing interests

The authors disclosed no possible conflicts of interest related to this study.

REFERENCES

Alhotan RA (2021). Commercial poultry feed formulation: Current status, challenges, and future expectations. World's Poultry Science Journal, 77(2): 279-299. DOI: https://www.doi.org/10.1080/00439339.2021.1891400

Borgonovo F, Ferrante V, Grilli G, and Guarino M (2024). An innovative approach for analysing and evaluating enteric diseases in poultry farms. Acta IMEKO, 13(1): 1-5. DOI: https://www.doi.org/10.21014/actaimeko.v13i1.1627

Bordbar F, Guo W, Wadood A, and Nie Q (2025). Skeletal muscle myopathies and cardiovascular diseases in poultry: Challenges for meat production. World's Poultry Science Journal, 81(3): 705-729. DOI: https://www.doi.org/10.1080/00439339.2025.2506400

Chaudhary A and Mishra B (2024). Systemic effects of heat stress on poultry performances, transcriptomics, epigenetics and metabolomics, along with potential mitigation strategies. World's Poultry Science Journal, 80(4): 1017-1053. DOI: https://www.doi.org/10.1080/00439339.2024.2364884

Decina C, Berke O, van Staaveren N, Baes CF, and Harlander-Matauscheck A (2019). Development of a scoring system to assess feather damage in Canadian laying hen flocks. Animals, 9(7):436. DOI: https://www.doi.org/10.3390/ani9070436

Duvall ES, Derry LA, McIntyre PB, and Flecker AS (2056). Ecological and evolutionary influences on the elemental composition of birds. Proceedings B, 92: 20251276. DOI: https://www.doi.org/10.1098/rspb.2025.1276

Eshimutu UA, Mallam I, Abdulhameed U, Olaloye MA, Akintoye SB, and Orisadare MO (2024). Long-time feed withdrawal effect on the performance and cost benefits of broiler production. Nigerian Journal of Animal Science and Technology, 7(4): 158-166. Available at: https://njast.com.ng/index.php/home/article/view/386

Girard MT, Zuidhof MJ, and Bench CJ (2017). Feeding, foraging, and feather pecking behaviours in precision-fed and skip-a-day-fed broiler breeder pullets. Applied Animal Behaviour Science, 188: 42-49. DOI: https://www.doi.org/10.1016/j.applanim.2016.12.011

Karaarslan S, Tatlı O, Kaya M, Toplu HDO, Fidan ED, Türkyılmaz MK, and Nazlıgül A (2023). Influence of early qualitative feed restriction and barrier perch access on some meat quality traits, growth performance, and diet cost analysis in broiler chickens. Annals of Animal Science, 23(3): 247-256. DOI: https://www.doi.org/10.2478/aoas-2023-0080

Karpińska M and Czauderna M (2022). Pancreas —its functions, disorders, and physiological impact on the mammalian organism. Frontiers in Physiology, 13: 807632. DOI: https://www.doi.org/10.3389/fphys.2022.807632

Kemper N and Tetens J (2024). Feather pecking behaviour in laying hens: Challenges in management and breeding. In: J. J. Gross (Editors), Production diseases in farm animals: Pathophysiology, prophylaxis and health management. Springer., Cham, pp. 493-515. DOI: https://www.doi.org/10.1007/978-3-031-51788-4_21

Kleyn FJ and Ciacciariello M (2021). Future demands of the poultry industry: Will we meet our commitments sustainably in developed and developing economies?. World's Poultry Science Journal, 77(2): 267-278. DOI: https://www.doi.org/10.1080/00439339.2021.1904314

Korver DR (2023). Current challenges in poultry nutrition, health, and welfare. Animal, 17(2): 100755. DOI: https://www.doi.org/10.1016/j.animal.2023.100755

Meyer EJ and Wittert GA (2024). Approach the patient with obstructive sleep apnea and obesity. The Journal of Clinical Endocrinology & Metabolism, 109(3): e1267-e1279. DOI: https://www.doi.org/10.1210/clinem/dgad572

Michel V, Prampart E, Mirabito L, Allain V, Arnould C, Huonnic D, Le Bouquin S, and Albaric O (2012). Histologically-validated footpad dermatitis scoring system for use in chicken processing plants. British Poultry Science, 53(3): 275-281. DOI: https://www.doi.org/10.1080/00071668.2012.695336

Naeem M (2025). Improving bone health in broiler chickens: Integrating population density, housing, and nutritional strategies for enhanced welfare and productivity. Poultry Science and Management, 2(1): 14. DOI: https://www.doi.org/10.1186/s44364-025-00017-y

National research council and subcommittee on poultry nutrition (NRC) (1994). Nutrient requirements of poultry: 1994. National

Academies Press, pp. 1-11. DOI: https://www.doi.org/10.17226/2114

Neeteson AM, Avendaño S, Koerhuis A, Duggan B, Souza E, Mason J, Ralph J, Rohlf P, Burnside T, Kranis A et al. (2023). Evolutions in commercial meat poultry breeding. Animals, 13(19): 3150. DOI: https://www.doi.org/10.3390/ani13193150

Pizolotto W, Costa MM, Gasperin NZ, Rodrigues LB, dos Santos LR, and Pilotto F (2024). Economic and productive performance of broilers subjected to quantitative feed restriction. Acta Veterinaria Brasilica, 18(2): 173-178. DOI: https://www.doi.org/10.21708/avb.2024.18.2.12410

Quality W (2009). Assessment protocol for poultry. Welfare Quality®., Lelystad, Netherlands, pp. 117-127. Available at: https://www.welfarequalitynetwork.net/media/1293/poulty-protocol-watermark-622020

Ramankevich A, Danko S, Banaszkiewicz R, Kasperek K, and Zięba G (2025). Residual feed intake as a behavioural, nutritional and economic criterion in poultry production. Animals, 15(8): 1115. DOI: https://www.doi.org/10.3390/ani15081115

Rasmussen SN, Wurtz KE, Erasmus M, and Riber AB (2023). Animal-based methods for the assessment of broiler chicken welfare in organic and conventional production systems. Applied Animal Behaviour Science, 276: 106300. DOI: https://www.doi.org/10.1016/j.applanim.2024.106300

Reda GK, Ndunguru SF, Csernus B, Knop R, Lugata JK, Szabó C, Czeglédi L, and Lendvai ÁZ (2024). Dietary restriction reveals sex-specific expression of the mTOR pathway genes in Japanese quails. Scientific Reports, 14(1): 8314. DOI: https://www.doi.org/10.1038/s41598-024-58487-9

Riber AB und Wurtz KE (2024). Impact of growth rate on the welfare of broilers. Animals, 14(22): 3330. DOI: https://www.doi.org/10.3390/ani14223330

Tahamtani FM, Kittelsen KE, and Vasdal G (2024). Qualitative feed restriction affects frustration, fear, motivation to explore, and feather fault bars in Ross 308 broiler breeder cockerels. Applied Animal Behaviour Science, 276: 106327. DOI: https://www.doi.org/10.1016/j.applanim.2024.106327

Taylor PS, Forder R, and Morgan N (2025). Meat chicken breeder stress: causes, effects, and mitigation strategies. World's Poultry Science Journal, 81(1): 35-64. DOI: https://www.doi.org/10.1080/00439339.2024.2437674

Trocino A., White P, Bordignon F, Ferrante V, and Xiccato G (2020). Effect of feed restriction on the behaviour and welfare of broiler chickens. Animals, 10(5): 830. DOI: https://www.doi.org/10.3390/ani10050830

Wurtz KE, Thodberg K, and Riber AB (2025). Impact of feeding a high fibre diet and roughage on stress and clinical welfare indicators in fast-growing broiler breeder pullets. Poultry Science, 104(12): 105960. DOI: https://www.doi.org/10.1016/j.psj.2025.105960

Yan C, Xiao J, Chen D, Turner SP, Li Z, Liu H, Liu W, Liu J, Chen S, and Zhao X (2021). Feed restriction induced changes in behaviour, corticosterone, and microbial programming in slow-and fast-growing chicken breeds. Animals, 11(1): 141. DOI: https://www.doi.org/10.3390/ani11010141

Yue K, Cao QQ, Shaukat A, Zhang C, and Huang SC (2024). Insights into the evaluation, influential factors and improvement strategies for poultry meat quality: A review. Science of Food, 8(1): 62. DOI: https://www.doi.org/10.1038/s41538-024-00306-6

Zukiwsky NM, Afrouziyeh M, Robinson FE, and Zuidhof MJ (2021). Broiler growth and efficiency in response to relaxed maternal feed restriction. Poultry Science, 100(4): 100993. DOI: https://www.doi.org/10.1016/j.psj.2021.01.016