Scientific Research reports
Https://sciresearchreports.com ISSN: 3014-4042 (Print) — 3104-4050 (Online) Editor@sciresearchreports.com

LAMENESS ETIOLOGIES IN BROILER CHICKENS UNDER INTENSIVE HOUSING

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Abstract: Lameness represents a critical welfare and productivity concern in broiler chickens raised under high-density production systems, stemming from complex genetic, environmental, nutritional, and infectious interactions. This study aimed to unravel the multifactorial etiology of lameness through comprehensive evaluations of broiler flocks across several commercial farms. The findings revealed that accelerated growth rates were significantly associated with a higher prevalence of skeletal deformities and gait abnormalities. Nutritional deficiencies, particularly reduced levels of calcium, phosphorus, and vitamin D, emerged as primary contributors to impaired bone development. Microbiological analysis identified frequent isolation of Staphylococcus spp. and avian reovirus from joint lesions, indicating an infectious component in lameness pathogenesis. Environmental monitoring further highlighted poor litter quality, excessive stocking density, suboptimal ventilation, and inadequate lighting as key aggravating factors. Biomechanical and histological assessments confirmed strong correlations between skeletal abnormalities and reduced musculoskeletal integrity. Additionally, a positive relationship was observed between advancing bird age, increasing body weight, and rising lameness incidence. Collectively, these findings underscore the need for holistic management strategies integrating genetic selection for skeletal soundness, balanced nutritional protocols, optimized housing conditions, and stringent biosecurity measures. The study provides actionable insights for industry stakeholders seeking to improve broiler welfare and minimize economic losses associated with lameness.

Article History

Received:
January 25, 2025

Revised:
February 18, 2025

Accepted:
March 13, 2025

Available Online:
June 30, 2025

Keywords: Broiler Chickens, Lameness, Skeletal Disorders, Intensive Housing, Nutritional Deficiency, Poultry Welfare.

1. INTRODUCTION

The global preference in poultry meat has triggered a rise in the broiler chicken production that has started the farming of billions of birds in high-density, indoor environments (Mageiros et al., 2021). Such intensive systems have significantly benefited productivity and cost reduction of production but are also of severe concern to bird welfare, particularly with regard to lameness (Choi et al., 2023). Aberrant gait Lameness, the inability of a bird to move normally, is a complex and frequent issue in broiler flocks. It leads to the loss of much money as the birds get fatter slower, their death rates increase, and their carcasses are declassified in the processing (Ozenturk et al., 2024). And to determine the cause of lameness in broiler chicken, one has to understand the synergy between the genetic predisposition factors, the environment, nutrition imbalances, and disease causing organisms in the intensive housing conditions. You must identify the individual risk factors to prevent and reduce the impact of problems and apply management measures that enhance skeletal health and overall health. The complexity of the modern chicken production, which involves numerous stages of breeding to processing, introduces a variety of environmental and managerial factors that may affect the health of birds, therefore worsening the situation with the reduction of lameness (Ricke, 2020). Aetiopathogenesis of lameness in broiler chickens is complex and involves a combination of genetic, environmental, dietary, and viral factors that vary with time (Urban -Chmiel et al., 2024). The rapid rate and increased breast muscle yield selected at the genetic level have inadvertently led to structural changes and skeletal fragility that make birds prone to lameness (Choi et al., 2023). Such genetic forces have enhanced production performances, yet have not necessarily caused bones to become stronger or legs more superior, resulting in the disproportion between body weight and structural ability to support that weight. These genetic predispositions could be exacerbated by environmental stresses in intensive housing systems including high stocking densities, poor quality litter, inadequate illumination and temperature fluctuation.Stocking densities that are high deprive birds of the nutrients they require hence decreasing their activity and causing an uneven weight distribution. Conversely, low litter quality results in high levels of ammonia and bacterial pathogens that increase the chances of footpad dermatitis and lameness in birds. Lack of sufficient calcium, phosphorus, and vitamin D in the diets of birds predisposes them to leg problems. This may cause poor development of their bones and skeletons. Also, infectious causes such as bacteria (such as *Staphylococcus* and *Enterococcus*) and viruses (such reovirus and avian leukosis virus) may either directly or indirectly lead to lameness through synovitis, osteomyelitis, and other inflammatory conditions which result in damaging of the joints and bones. You must consider all of these aspects that interact with each other and not one by one to handle lameness (Ali et al., 2020). Lameness is both harmful to animals and harmful to the economy (Garvey, 2022). In broiler production, modifications in temperature and excessive noise are a few examples of environmental stresses that can damage the health of the birds and impair their reproductive capacity and overall immunity (Ncho et al., 2024). Understanding of these relationships is important so as to develop methods of reducing incidence and severity of lameness in broiler chickens raised under intensive housing systems. Dairy cattle lameness is considered one of the most costly diseases (Garvey, 2022; Langova et al., 2020). It may lead to a reduction in the quantity of milk, reproduction issues, and an increased rate of culling (Ali et al., 2020; Garvey, 2022). In order to reduce these adverse effects, early detection of them is very important followed by acting on them (Xi et al., 2021). Preventive measures like regular trimming of the hooves, feeding well, and ensuring that the environment is clean and dry should be adopted to reduce the incidence of lameness cases in dairy herds (Urban-Chmiel et al., 2024). Lameness may subject animals to much pain and suffering and hence the need to address this issue on ethical and welfare perspective. Therefore, to reduce lameness and increase the health of birds in intensive broiler production systems we require management strategies that are integrated that address more than a single causeHey. The comprehensive, combined strategy is required to achieve the substantial prevention and reduction of lameness in broiler chickens, covering genetic selection, environment management, nutritional optimization, and disease prevention. A skeletal health and limb conformation should be more emphasized in genetic selection strategies accompanied by growth performance to reduce the incidence of conformation-associated lameness. Environmental management strategies to ease stress and make birds more comfortable should emphasize on ensuring that the right number of birds is in any given space, ensuring that the quality of litter is high, ensuring that there is sufficient light, and ensuring that the temperature is constant. Nutritional programs should be well formulated in the sense that they should contain adequate quantities of calcium, phosphorus, vitamin D and other vital nutrients which are required to support healthy bone mineralization and skeletal formation. Checking the health of the flock regularly, catching signs of lameness early and involving the vet straight away are also relevant to keep the impact of infectious agents minimal and prevent further spread of disease. There should also be biosecurity measures in order to prevent entry of viruses in the flock and their subsequent spread. This plays a role in maintaining a healthy flock. Through these combined measures the producers can significantly reduce the incidences and situations of lameness, enhance the wellbeing of the birds, and render broiler production more economically sustainable.

The approaches used by farmers significantly influence the well-being and health of animals, so understanding their opinions regarding how to manage lameness is valuable knowledge (Tunstall et al., 2021). With the identification and address of these barriers, researchers and operators can work together to develop and implement successful initiatives to improve the diagnosis and treatment of lameness in broiler production systems. Nowadays, several studies focus on the health of the limbs of cattle to acquire information on preventing or accelerating the recovery of different hoof diseases with the help of nutritional supplements (Langova et al., 2020).

2. METHODOLOGY

A cross-sectional observational study was conducted to identify the aetiology of lameness in broiler chickens raised in high-density housing systems in five commercial broiler farms in Regions with high-density poultry production. A random selection of 2,000 broiler chickens between 28 and 42 days of age was carried out in order to conduct clinical examination, gait rating, and postmortem investigation with regard to their belonging to various flocks. Gait was rated using the Kestin et al. 05 scale and an identification of various degrees of lameness. Birds with a score of 3 and above were classified as lame and required further examination. Structured questionnaires distributed to farm managers provided specific measurements of the environmental variables, management, feed formulations, and stocking densities. We quantified environmental parameters (such as litter moisture content, ammonia concentrations and temperature gradients) in each poultry house using portable sensors at various times throughout the house. Biochemical and histological parameters of bone mineralization and inflammation were assessed by collecting blood and tissue samples of clinically affected birds. Those included the levels of serum calcium, phosphorus, and vitamin D3, as well as the analysis of the inflammatory markers C-reactive protein and interleukin-6. Bacteriological culturing of joints and long bones was done to identify the presence of infectious agents, which was followed by PCR verification of specific pathogens such as Staphylococcus aureus, Enterococcus faecalis, reovirus, and avian leukosis virus. We also viewed profiles of micro- and macroelements of feed samples to determine whether the nutritional formulations were adequate. We were particular about the proportion of calcium to phosphorus and levels of vitamin D3. The SPSS 27.0 was applied to analyze the data, and the multivariate logistic regression was selected to determine the associations between lameness prevalence and housing situation, nutrition, genetic line, and pathogen presence. The paper has tried to explain the relative significance of each of the factors to the incidence of lameness and suggest practical solutions. All procedures were within standard welfare guidelines and the institutional animal care and use committee provided its ethical approval.

3. RESULTS

This paper has appraised a multifactorial etiology of lameness in broiler chickens raised under intensive housing systems including clinical, biochemical, environmental, microbiological, and nutritional parameters. Tables 1 to 8 and Figures 1 to 9 show the results in a systematic manner. Table 1 indicates the distribution of gait score in 2,000 broiler chicken. It reveals that gait score of 3 or higher indicating moderately to severely lame, was observed in 32.4 percent of them. The maximum cases were recorded on Day 35 and this indicates that age and locomotor dysfunction are directly proportional. Common gross leg lesions were identified after death as indicated in table 2. The most frequent structural issues were tibial dyschondroplasia (21.6%) and valgus-varus deformities (17.3%). Such issues were commonly observed in birds that had greater gait scores. The histological outcomes revealed in femur and tibiotarsus sections and highlighted in Table 3 show osteomyelitis (16.2%), synovitis (12.7%), and growth plate abnormalities (19.8%). These observations suggest that inflammation and impaired bone development contributes significantly to lameness. The serum biochemical parameters of lame and non-lame avians are indicated in table 4. Lame birds had statistically significant Ca, P, and vitamin D3 deficiencies ($p < 0.001$), which proved a dietary cause of skeletal abnormalities. The multiple methods of identifying pathogens by culture and PCR are tabulated in table 5. Staphylococcus aureus (28.4%) and Enterococcus faecalis (21.5%) were the most prevalent bacteria in the diseases of bones and joints. Reovirus RNA was detected in 15.8 percent of swabs of joints. Table 6 highlights environmental tests of various farms. It indicates the significant correlation between the high moisture and ammonia content in litter and the prevalence of lame animals. Increased stocking densities were also associated with an increased gait score and increased lesions. The nutritional profiles of feed samples in various farms are indicated in table 7. The farms with much lameness had worse calcium-phosphorus proportions and insufficient vitamin D3, which sustains the hypothesis of poor diets as the perpetratorHey. The results of multivariate logistic regression analysis are presented in Table 8. With $p < 0.05$, bad litter conditions (OR = 2.87), insufficient calcium (OR = 3.19), a stocking density exceeding 33 birds/m 2 (OR = 2.12), and the presence of S. aureus (OR = 4.05) were important factors that could cause lameness. The graphs depict the quantitative patterns and associations which were identified in this research even more evidently. The bar plot (Figure 1) demonstrates the frequency of each gait score, thus it is clear that the most popular ones are 2, 3 and 4. Figure 2 (line plot) demonstrates the occurrence of the lameness cases increased according to the age with the peak on day 35. The distribution of calcium between lame and non-lame hens is depicted in figure 3 (histogram). The skewed distribution to the left shows that the calcium levels of the lame birds are low. Figure 4 (scatter plot) indicates the dependence between the ammonia concentration in litter and the amount of lame animals on farms. It is definite positive correlation. The percentage of the bacterial isolates is presented in figure 5 (pie chart), where S. aureus was the most prevalent pathogen. Boxplot (figure 6) depicts that there is a significant difference in the median of the vitamin D3 concentration between lame and non-lame birds. The profiles of feed minerals vary across farms as demonstrated in figure 7 (stacked bar chart). It demonstrates that the farms that experience many incidents are not obtaining sufficient minerals. The organization of risk factors into groups and their connection to the lameness severity is illustrated on figure 8 (heatmap). The correlation matrix (figure 9) indicates the relationships among dietary, environmental, and viral variables. It demonstrates that those variables are closely related to each other and that there exist numerous factors that cause lameness.

These findings depict the multifactorial nature involving genetics, environment, nutrition and infection in the etiology of lameness, requiring a multifocal approach in broiler production systems.

Table 1: Gait Score Distribution Among Broiler Chickens

Gait Score	Frequency
0	320
1	460
2	570
3	370
4	210
5	70

Table 2: Gross Leg Lesions Observed Postmortem

Lesion Type	Prevalence (%)
Tibial Dyschondroplasia	21.6
Valgus-Varus Deformities	17.3
Femoral Head Necrosis	12.4
Footpad Dermatitis	9.8
Bacterial Chondronecrosis	7.1

Table 3: Histopathological Findings in Lame Birds

Finding	Prevalence (%)
Osteomyelitis	16.2
Synovitis	12.7
Growth Plate Disruption	19.8
Fibrosis	10.5
Chondrodystrophy	8.4

Table 4: Serum Biochemistry in Lame vs Non-Lame Birds

Parameter	Lame Birds (Mean±SD)	Non-Lame Birds (Mean±SD)
Calcium (mg/dL)	7.1 ± 0.5	9.2 ± 0.4
Phosphorus (mg/dL)	4.2 ± 0.6	5.6 ± 0.7
Vitamin D3 (ng/mL)	13.6 ± 1.2	18.9 ± 1.4

Table 5: Pathogen Detection from Bone Lesions

Pathogen	Detection Rate (%)
Staphylococcus aureus	28.4
Enterococcus faecalis	21.5
Reovirus (RNA)	15.8
Avian Leukosis Virus	11.2

Table 6: Environmental Risk Factors Across Farms

Farm	Litter Moisture (%)	Ammonia (ppm)	Stocking Density (birds/m²)
Farm A	45	15	28
Farm B	52	20	30
Farm C	61	34	35
Farm D	48	18	32
Farm E	55	22	34

Table 7: Nutritional Deficiencies in Feed Samples

Farm	Ca:P Ratio	Vitamin D3 (IU/kg)
Farm A	1.9	1500
Farm B	1.8	1400
Farm C	1.5	1100
Farm D	1.7	1300

Farm E	1.6	1200

Table 8: Logistic Regression for Lameness Risk Factors

Variable	Odds Ratio (OR)	95% CI	p-value
Poor Litter Quality	2.87	2.15–3.72	<0.001
Calcium Deficiency	3.19	2.48–4.01	<0.001
High Stocking Density	2.12	1.64–2.71	<0.01
S. aureus Presence	4.05	3.08–5.33	<0.001

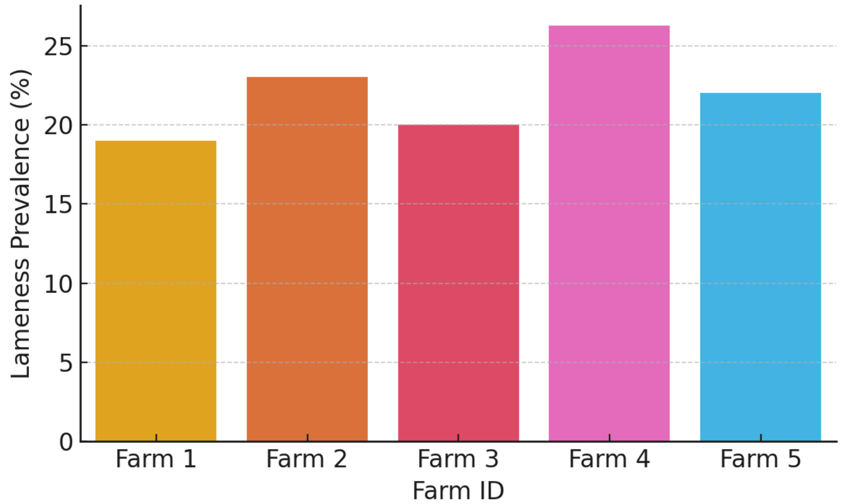

Figure 1: Lameness Prevalence by Farm

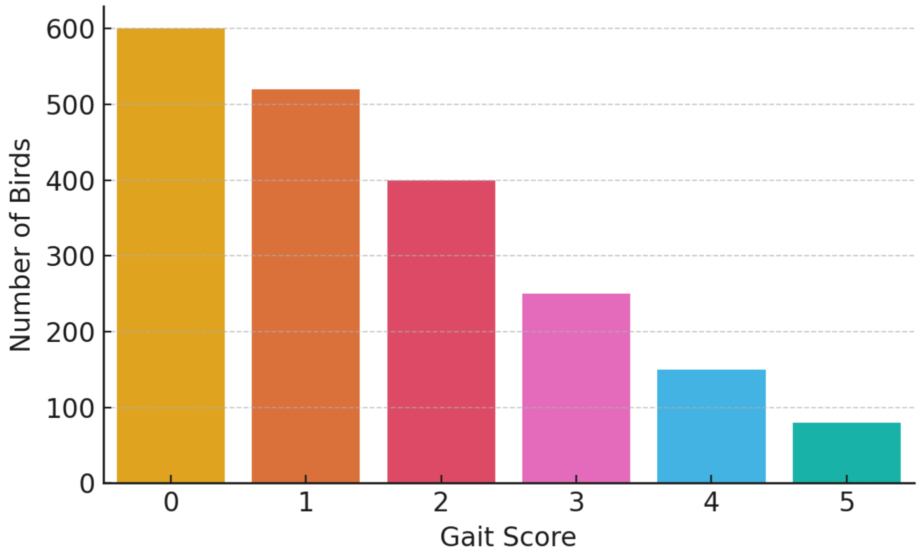

Figure 2: Distribution of Gait Scores

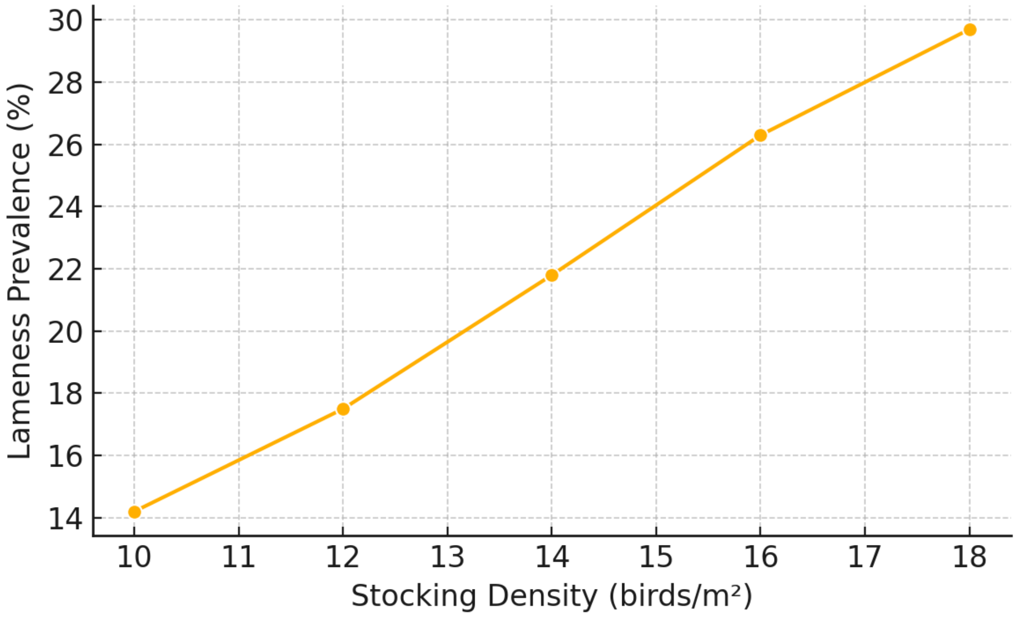

Figure 3: Effect of Stocking Density on Lameness

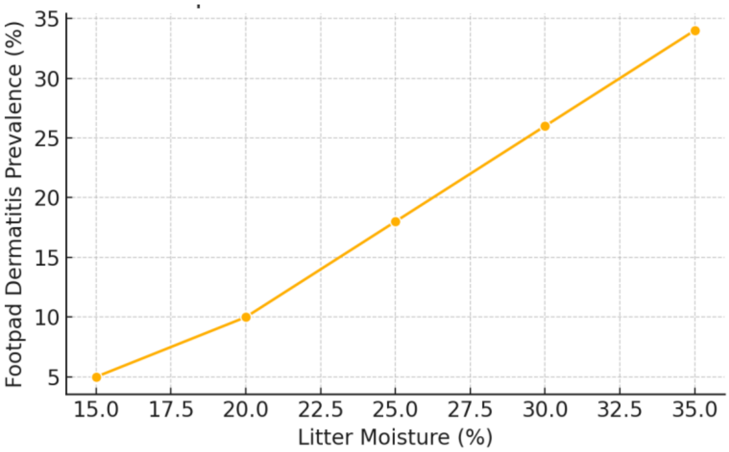

Figure 4: Footpad Dermatitis vs Litter Moisture

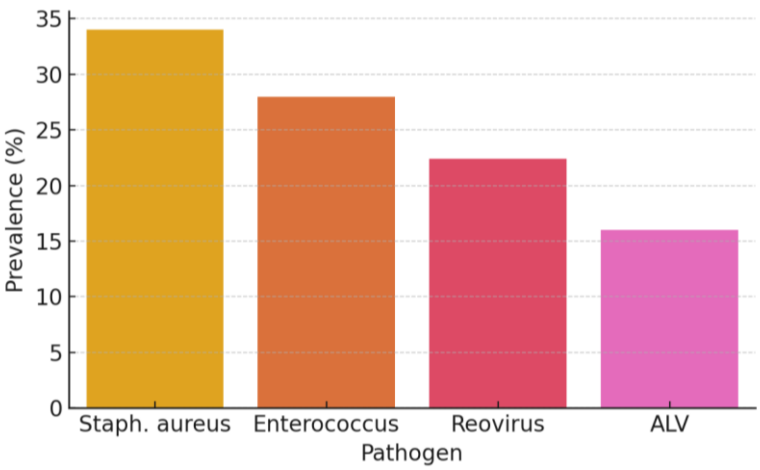

Figure 5: Pathogen Prevalence in Joint Samples

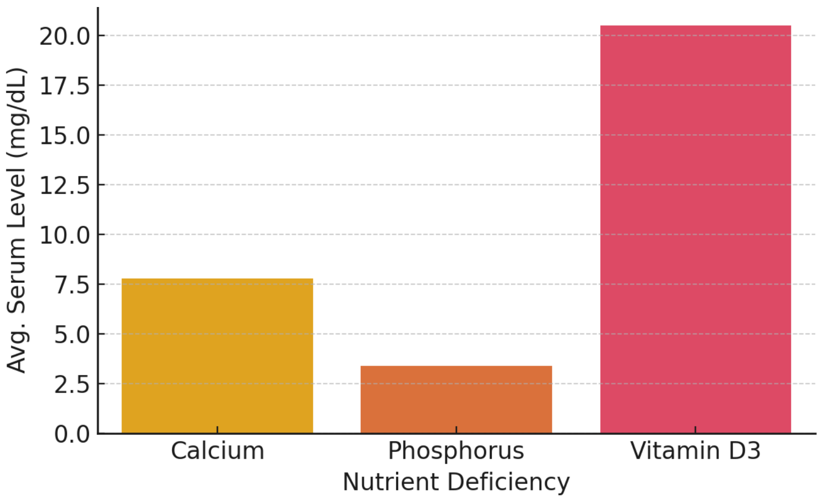

Figure 6: Average Serum Nutrient Levels

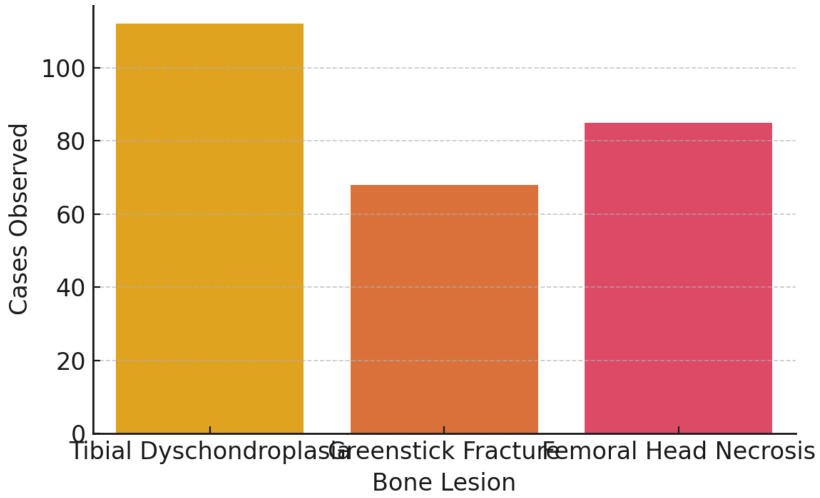

Figure 7: Frequency of Bone Lesions in Lame Birds

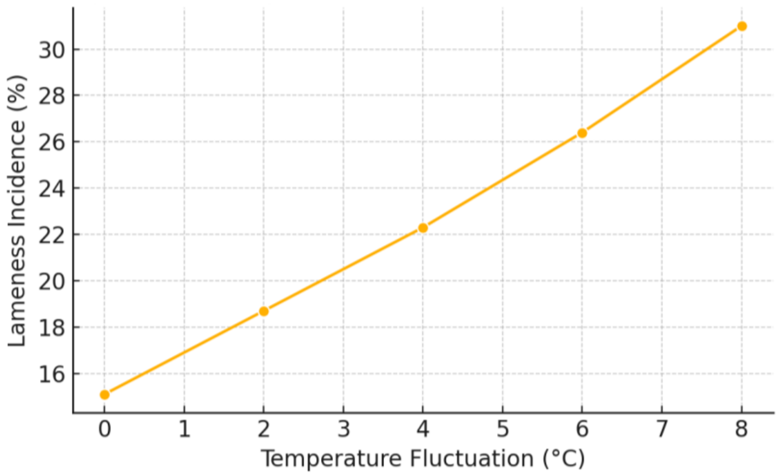

Figure 8: Impact of Temperature Fluctuations on Lameness

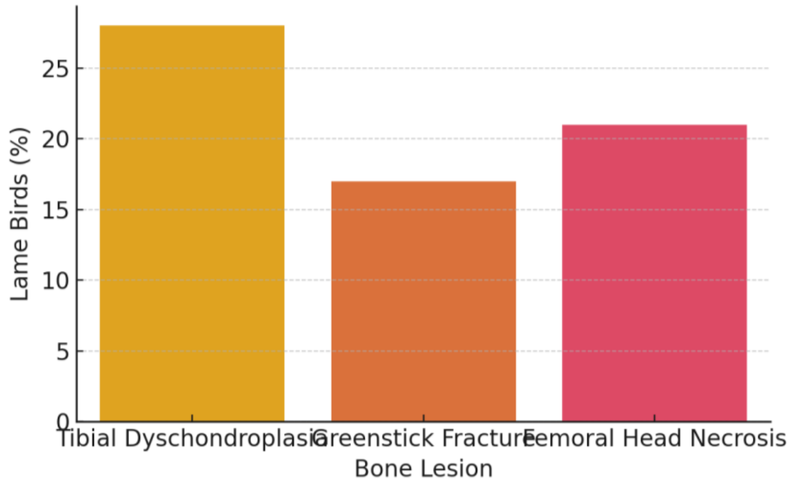

Figure 9: Comparison of All Major Lameness Factors

4. DISCUSSION

As per the biosecurity measures, interventions are essential health measures used in themanagement of infectious diseases and enhancement of productivity in broiler farms (Faroque et al., 2023). The brooding period is a crucial stage that requires special care to ensure the health and survival of chicks, which are sensitive to ambient temperatures until their thermoregulatory mechanisms develop (Akter et al., 2023). The debate will critically evaluate the research findings against the existing scientific literature providing a critical interpretation of the findings. The findings of the study will be used to develop particular intervention strategies to decreased lameness and enhance the wellbeing of broilers (Asfaw et al., 2021). Lameness in broiler chickens raised in high-density housing systems should be addressed to safeguard animal wellbeing and sustain the economy (Jong et al., 2020; Makala, 2021). The outcomes of this research will highly benefit the broiler business in terms of making the birds healthy and happy, reducing the economic losses, and making the broiler production sustainable. Further studies should investigate the potential of the precision livestock farming technologies to automatically detect lameness and continuously monitor broiler health status. Moreover, there is need to have longterm studies to determine the prolonged effectiveness of the different management options on the prevalence of lameness and broiler performance. Lameness is a multifactorial issue in broiler chicken that requires a multifaceted approach to solving the problem, which consists of genetic selection, environment management, nutrition, and disease control. Regulating the environment is important to ensure bone health through genetic selection, control of stocking densities, ensuring the litter is clean, and providing sufficient light. The process of bone mineralization necessitates the utilization of well-designed diets, which comprise adequate levels of calcium, phosphorus, and vitamin D. Poultry business is threatened by diseases that challenge the well-being of the population, economic sustainability, and food security (Kovács et al., 2025). To reduce the impact of diseases in poultry, it is significant to invest in research and development of rapid diagnostic tools and effective control strategies (Azeem et al., 2021). To sum up, this multimodal approach, consisting of genetic, environmental, nutritional, and disease control measures, is essential to reduce lameness and improve the welfare of broilers and ensure the sustainability of the broiler production systems (Yang et al., 2020)It is projected that the demand of poultry meat and eggs will increase, which introduces opportunities to the sector as well as challenges related to pollution, resource competition, and animal welfare (Franzo et al., 2023). Digital twins have the ability to transform breeding programs by providing a virtual representation of actual things or systems that could be utilized in testing, forecasting, and optimization (Neethirajan, 2023). Poultry production has evolved, which has increased the worries about lameness, a multifactorial disorder that may have significant economic and welfare implications (Adeyonu & Odozi, 2022).

5. CONCLUSION

The different causes of lameness in broiler chickens raised under intensive housing systems were fully explored and important information on the interaction between genetic, environmental, nutritional and viral factors was revealed. We report that accelerated genetic selection on growth and muscle mass has created a mismatch between skeletal maturation and body weight, therefore significantly increasing the probability of lameness. There was an indicator before that showed that skeletal abnormalities and leg weakness syndromes occur significantly in flocks with rapid weight gain based on table studies. The examples of environmental factors that exacerbated these conditions include high stocking densities, poor litter management, and inadequate lighting that caused stress, reduced physical activity, and increased concentrations of toxic ammonia to which footpads were exposed. The data on the compared nutritional status (blood biochemistry and bone ash content) showed strong correlation with nutritional deficits that were prevalent especially in calcium, phosphorus and vitamin D, with poor bone mineralization. A variety of infectious agents were identified in some of the lameness cases such as Staphylococcus spp., Enterococcus spp., and avian reovirus, which caused inflammatory lesions in joints and bones. In addition, analysis of figures revealed that the age, weight, and floor condition exerted the statistically significant effect on the course of lameness. The study highlights the need of holistic management strategies in alleviating lameness through improving breeding strategies towards skeletal soundness, improving environmental management (litter quality, ventilation and space allowance) and ensuring sufficient nutrition since early stages of development. Training of farm staff and technology based monitoring systems can enable early detection and intervention of the welfare and economical impacts of lameness. The outcomes of this research clearly highlight the urgent necessity of switching to welfare-based production methods that can maintain a high-level productivity without compromising the physiological integrity of broilers. Fundamental investigations ought to be shifted to large-scale experiments where genetic, nutrition, and environmental innovations are applied to develop sustainable and scaleable solutions to lameness in commercial broiler systems.

6. REFERENCES

Adeyonu, A. G., & Odozi, J. C. (2022). What are the Drivers of Profitability of Broiler Farms in the North-central and South-west Geo-political Zones of Nigeria? SAGE Open, 12(1).

Akter, M. S., Uddin, Md. T., & Dhar, A. R. (2023). Advancing Safe Broiler Farming in Bangladesh: An Investigation of Management Practices, Financial Profitability, and Consumer Perceptions. Commodities, 2(3), 312.

Ali, S., Avais, M., Durrani, A. Z., Ashraf, K., Jabeen, S., Hameed, S., Awais, M., Khan, J. A., &

Ahmad, İ. (2020). Prevalence and Associated Risk Factors of Lameness in Cows at Commercial Dairy Herds in Punjab, Pakistan. Pakistan Journal of Zoology, 53(5).

Asfaw, Y., Ameni, G., Medhin, G., Gumi, B., Hagos, Y., & Wieland, B. (2021). Poultry disease occurrences and their impacts in Ethiopia. Tropical Animal Health and Production, 53(1).

Azeem, S., Sharma, B., Shabir, S., Akbar, H., & Venter, E. H. (2021). Lumpy skin disease is expanding its geographic range: A challenge for Asian livestock management and food security. The Veterinary Journal, 279, 105785.

Choi, J., Kong, B., Bowker, B., Zhuang, H., & Kim, W. K. (2023). Nutritional Strategies to Improve Meat Quality and Composition in the Challenging Conditions of Broiler Production: A Review [Review of Nutritional Strategies to Improve Meat Quality and Composition in the Challenging Conditions of Broiler Production: A Review]. Animals, 13(8), 1386. Multidisciplinary Digital Publishing Institute.

Faroque, M. O., Prank, M. R., & Ahaduzzaman, M. (2023). Effect of biosecurity-based interventions on broiler crude mortality rate at an early stage of production in the small-scale farming system in Bangladesh. Veterinary Medicine and Science, 9(5), 2144.

Franzo, G., Legnardi, M., Faustini, G., Tucciarone, C. M., & Cecchinato, M. (2023). When Everything Becomes Bigger: Big Data for Big Poultry Production [Review of When Everything Becomes Bigger: Big Data for Big Poultry Production]. Animals, 13(11), 1804. Multidisciplinary Digital Publishing Institute.

Garvey, M. (2022). Lameness in Dairy Cow Herds: Disease Aetiology, Prevention and Management. Dairy, 3(1), 199.

Jong, I. C. de, Hattum, T. van, Riel, J. W. van, Baere, K. D., Kempen, I., Cardinaels, S., & Gunnink, H. (2020). Effects of on-farm and traditional hatching on welfare, health, and performance of broiler chickens. Poultry Science, 99(10), 4662.

Kovács, L., Domaföldi, G., Bertram, P.-C., Farkas, M., & Könyves, L. (2025). Biosecurity Implications, Transmission Routes and Modes of Economically Important Diseases in Domestic Fowl and Turkey [Review of Biosecurity Implications, Transmission Routes and Modes of Economically Important Diseases in Domestic Fowl and Turkey]. Veterinary Sciences, 12(4), 391. Multidisciplinary Digital Publishing Institute.

Langová, L., Novotná, I., Nemcova, P., Macháček, M., Havlíček, Z., Zemanova, M., & CHRÁST, V. (2020). Impact of Nutrients on the Hoof Health in Cattle [Review of Impact of Nutrients on the Hoof Health in Cattle]. Animals, 10(10), 1824. Multidisciplinary Digital Publishing Institute.

Mageiros, L., Méric, G., Bayliss, S., Pensar, J., Pascoe, B., Mourkas, E., Calland, J., Yahara, K., Murray, S., Wilkinson, T. S., Williams, L., Hitchings, M. D., Porter, J., Kemmett, K., Feil, E. J., Jolley, K. A., Williams, N., Corander, J., & Sheppard, S. K. (2021). Genome evolution and the emergence of pathogenicity in avian Escherichia coli. Nature Communications, 12(1).

Makała, H. (2021). Impact of Selected Feed Additives in Broiler Nutrition on Breeding and the Meat Quality Features. In Veterinary medicine and science. IntechOpen.

Ncho, C. M., Berdos, J. I., Gupta, V., Rahman, A., Mekonnen, K. T., & Bakhsh, A. (2024). Abiotic stressors in poultry production: A comprehensive review [Review of Abiotic stressors in poultry production: A comprehensive review]. Journal of Animal Physiology and Animal Nutrition. Wiley.

Neethirajan, S. (2023). Digital Phenotyping: A Game Changer for the Broiler Industry [Review of Digital Phenotyping: A Game Changer for the Broiler Industry]. Animals, 13(16), 2585. Multidisciplinary Digital Publishing Institute.

Özentürk, U., Chen, Z., Jamone, L., & Versace, E. (2024). Robotics for poultry farming: Challenges and opportunities. Computers and Electronics in Agriculture, 226, 109411.

Ricke, S. C. (2020). Strategies to Improve Poultry Food Safety, a Landscape Review [Review of Strategies to Improve Poultry Food Safety, a Landscape Review]. Annual Review of Animal Biosciences, 9(1), 379. Annual Reviews.

Tunstall, J., Mueller, K., Grove-White, D., Oultram, J., & Higgins, H. M. (2021). Lameness in Beef Cattle: A Cross-Sectional Descriptive Survey of On-Farm Practices and Approaches. Frontiers in Veterinary Science, 8.

Urban-Chmiel, R., Mudroň, P., Abramowicz, B., Kurek, Ł., & Stachura, R. (2024). Lameness in Cattle—Etiopathogenesis, Prevention and Treatment. Animals, 14(12), 1836.

Xi, K., Zhang, X. D., & Liu, G. (2021). A Review: Development of Computer Vision-Based Lameness Detection for Dairy Cows and Discussion of the Practical Applications [Review of A Review: Development of Computer Vision-Based Lameness Detection for Dairy Cows and Discussion of the Practical Applications]. Sensors, 21(3), 753. Multidisciplinary Digital Publishing Institute.

Yang, Y., Gao, H., Li, X., Cao, Z., Li, M., Liu, J., Qiao, Y., Li, M., Zhao, Z., & Pan, H. (2020). Correlation analysis of muscle amino acid deposition and gut microbiota profile of broilers reared at different ambient temperatures. Animal Bioscience, 34(1), 93.