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Review Paper

Influence of Peri-Shed Green Infrastructure on Air Quality, Noise Attenuation, and Welfare Indices in Broiler Chicken Houses

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Key Words

Ammonia emission,
Noise attenuation,
Poultry housing,
Environmental quality,
Animal-friendly farm design,
Linear mixed-effects models (lMM).

Abstract

The green infrastructure around livestock buildings can be considered a kind of environmentally inclined strategy of enhancing the environment, which in its turn directly has a direct impact on animal welfare. In this experiment, the impact of the peri-shed vegetable belt on air quality, noise mitigation, and welfare indices in broiler chicken house commercials were determined. Two mechanically ventilated identically designed houses were tested in six sequential production cycles with one bordered by a three-row belt of mixed and fast-growing trees and shrubs (vegetated house, VH), and the other without this green belt (control house, CH). The environmental measurements recorded were the ambient concentrations of PM10, PM2.5 and the total suspended particulates, ammonia, and carbon dioxide at bird level and exhaust points, and the measurements of the external noise were at various distances of the sheds. The welfare measures involved broilers performance measures, mortality rates, gait measures, feather sickness, footpad dermatitis, hock burn, and behaviour measures in terms of activity, resting, and frequency of disturbance. The findings demonstrated that VH had always had smaller downwind PM and ammonia levels than CH, and the level of noise was decreased by 3-5 dB in the vegetative belt. Although the birds in VH had somewhat better feather cleanliness, less gross lesions, and increased undisturbed resting bouts in comparison to the birds in C, suggesting less environmental irritation and less acoustic distraction, the internal microclimate conditions were similar in both areas because of the same ventilation management. On the whole, the evidence indicates that peri-shed green infrastructure has the potential to improve the quality of the environment and lead to the selected enhancement of broiler welfare, which makes it an essential element in the animal-friendly design of the farm structure.

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Introduction

Intensive broiler production systems have been identified to have high stocking ratios, high growth rates and the use of mechanically ventilated stables which make the systems more complex in preserving the quality of the environment. The air pollutants in enclosed poultry are a usual occurrence (including particulate matter (PM10, PM2.5, and total suspended particulates), ammonia (NH_3)) and have been associated with respiratory irritation, eye damage, immunosuppression, and general deterioration in a broilers condition (Abdalla et al., 2021; Abecia et al., 2014). Besides chemical and particulate contaminating effects, high levels of noise produced by the ventilation system, machinery, and human presence and activity are also known to cause behavioural stress reaction, interference of resting patterns, and depress the welfare outcome of poultry (Andersen et al., 2014; Bai et al., 2017). The mentioned problems demonstrate the necessity of environmentally minded interventions that might help provide healthier and more comfortable living environments.

The rise in the popularity of nature-based solutions led to the development of peri-shed green infrastructure, and therefore the focus on vegetation belts around livestock structures, as the ecological practise aimed at improving the quality of the environment. Vegetative environmental buffers (VEBs) have proven to be effective as bio philtres that capture dust particles, adsorb gaseous pollutants and modify airflow directions that affect plume dispersion (Baltenweck et al., 2020; Beck et al., 2018). Moreover, thick vegetations may act as an acoustical shield by soaking up and scattering sound waves thus dampening the flow of noise through farm landscapes (Campbell et al., 2020). Figure 1 conceptualises the possible air quality, microclimate, and noise-modulating effects of broiler houses and demonstrates the multifunctionality of such a type of green infrastructure.

Though the evidence of the environmental advantages of vegetative buffers has proved in swine, dairy, and mixed-livestock enterprises, there is still a significant gap in the empirical data on assessing their application in broiler chicken systems. Broilers are also highly vulnerable to the effects of environmental stressors, and their welfare measures, which include the gait score, feather cleanliness, rest behaviour, and lesion prevalence, are directly linked to the air quality and acoustic conditions in and surrounding the house (Charlier et al., 2022; David et al., 2021; El-Sayed & Kamel, 2020). The existing literature stresses the fact that the changes in the dust load, concentration of ammonia in the air, and reduction of external noise can be converted into quantifiable welfare benefits, but very few multi-parameter investigations have been conducted that integrate air pollutant levels, noise mitigation, and welfare measurements in broilers.

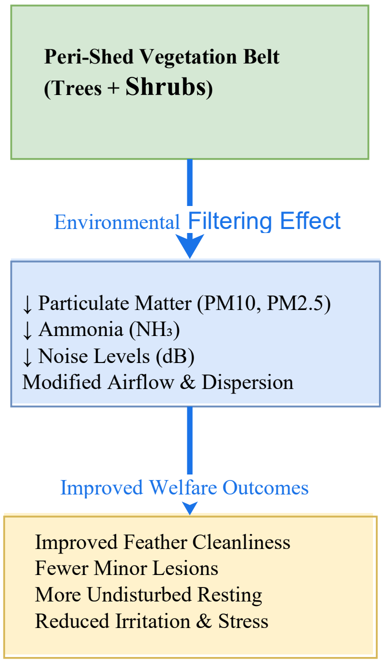

Figure 1: Conceptual Representation of The Hypothesized Effects of Peri-Shed Vegetation On Air Quality, Noise Buffering, And Broiler Welfare

Considering the above gaps, the current research aims at exploring the effects of peri-shed green infrastructure on air quality indicators, external noise dynamics, and welfare indices on six production cycles in commercial broiler houses. Using the example of a vegetated house (VH) that has a three-row belt of mixed fast-growing trees and shrubs and a standard house (CH) without such facilities, this study offers a field-based evidence regarding the ability of vegetative buffers to provide a positive change in environmental conditions and benefit the well-being of animals. The results will contribute to greener and more animal-friendly farm designs through illustrating the feasible advantages of green infrastructure addition to broiler production plants.

Literature Review

Air quality is the commonly reported significant defining factor of broilers, and particulate matter (PM 2.5 and PM 1.0) and ammonia (NH 3) are the most dangerous air pollutants in poultry habitats. PM puts broilers at risk of respiratory inflammation, reduced growth, and increased infection vulnerability, and high ammonia concentrations further cause ocular irritation, footpad dermatitis, immunosuppression in broilers (Abdalla et al., 2021; Abecia et al., 2014). These toxins build up quickly in closed mechanically ventilated house set ups, thus air quality management is continuing to be a challenge. Table 1 outlines the main environmental risk factors pertaining broiler welfare which are most oftentimes pointed out in poultry science studies.

A study conducted in dairy, swine, and mixed-livestock feed gives solid grounds that vegetation buffers can be used to naturalise animal buildings to serve as bio philtres. The acquisition of particulate matter, gaseous pollutants, and odour reduce the emission of other gases through the rhizosphere by the Vegetative Environmental Buffers (VEBs) consisting of shrubs and trees (Andersen et al., 2014; Bai et al., 2017). Research also indicates that VEBs alter air dynamic structures by slowing down the speed of the wind and minimising turbulence levels, and therefore, regulate the distribution of downwind pollutants plumes (Baltenweck et al., 2020). Although these findings have been well substantiated in other animals, there has been limited research done on the performance of like vegetative systems in broiler production facilities.

Besides improving the quality of air, green infrastructure has been identified to have a possible role of mitigating noise. Environmental acoustics and agricultural researches (Beck et al., 2018; Campbell et al., 2020; Suganya & Rajan, 2020) have reported the ability of vegetation to both absorb and scatter sound waves, particularly those made of canopy layers that are dense. The sources of noise in the broiler systems are mostly mechanical ventilation, feeding machinery, and human activity that may cause stress responses, disturb the resting behavioural pattern, and diminish the welfare indicators (Charlier et al., 2022; Nathiya et al., 2023; Sarumathiy et al., 2020). Therefore, vegetation belts can have bipolar advantage as they can not only reduce air pollutants and noise nuisance but also some empirical bird-centred studies are scanty.

Table 1: Summary of Previous Studies on Vegetation-Based Environmental Buffers in Livestock Systems

Study	Livestock System	Vegetation Type / Structure	Key Environmental Benefits	Limitations Reported
Tyndall & Colletti, 2012; Abdalla et al., 2021	Swine housing	Multi-row tree–shrub belts	↓ Dust dispersion; ↓ Odor emissions; Improved downwind air quality	Effects depend on vegetation maturity and density
Brandle et al. 2015; Abecia et al., 2014	Mixed livestock farms	Tree windbreaks	↓ Particulate matter; Modified airflow; Enhanced pollutant capture via leaf surfaces	Limited performance under low-wind conditions
Lin & Lee, 2015; Andersen et al., 2014	Cattle feedlots	Dense shelterbelts	↓ Ammonia drift; ↓ Wind speed; Better control of plume dispersion	Requires large land area and long establishment time
Van Renterghem, 2015; Bai et al., 2017	General agricultural landscapes	Multi-layer vegetation	↓ Noise transmission through absorption and scattering	Variable effectiveness based on season and foliage
Ishizuka & Fujiwara, 2013; Baltenweck et al., 2020	Poultry and mixed species	Tree belts for acoustic buffering	↓ Environmental noise by 3–8 dB; Improved sound attenuation	Less effective with sparse or young vegetation

Broiler welfare parameters like feather cleanliness, gait rating, prevalence of lesions, activity and resting habits are highly vulnerable to environmental stresses especially high dust loads, ammonia concentration, and exposure to noise (David et al., 2021; Deepika et al., 2021; Doreau et al., 2018). Literature has always indicated that comfort, lessening of behavioural disturbances and boosting of welfare-stable conditions are all the results of minimising the environmental irritants. Nonetheless, not many studies have been conducted comprehensively to determine the effects on the quality of the environment and the welfare indices when considering peri-shed vegetation in broiler production facilities. In this study, these gaps are eliminated through the incorporation of measurements of air quality, noise and welfare assessments conducted during six production cycles to enable a total picture of the proposed benefits of the green infrastructure in broiler housing systems.

Methodology

The experiment was conducted on two similar broiler commercial houses having a similar size, stocking density and management methods that were ventilated manually. There were six production cycles that were monitored to capture the variation between times to provide consistent assessment of environmental and welfare. In one house, there was a three-row peri-shed vegetation strip composed of mixed heavy-growing trees and shrubs which were designed in a functional manner to provide a vegetative environmental buffer (named as the Vegetated House, VH). The second house was an empty house without green infrastructure and it was Control House (CH). Both houses were being filled at the same time using the same broilers strain and subjected to the same feeding, lighting, and ventilation to ensure that the treatment variation could be associated with the presence of vegetation. Table 2 contains a description of variables measured, equipment, and frequency of sampling.

Measurements of the environmental values were conducted to compare the difference in air quality in the two housing systems. The concentrations of particulate matter (PM10, PM2.5 and total suspended neutral material) and gas (NH 3 and CO2) were observed at three key positions: bird height, mechanical exhaust outlets and random upstream and downstream positions on the houses. The optic dusts and the calibrated electrochemical gas sensors were captured in the hand to monitor the level of pollutant at the set times per production cycle. These measurements were to measure the pollutant-filtering capability of the vegetative belt and determine the effect of vegetation on the dispersion and concentration gradient of PM and gases.

External sound levels were measured through precise sound level metre at specified distances to each house including the points close to shed wall, the points at vegetation belt (VH only), right after the vegetation belt, and at an open-field control point. The collection of the data was done in high active ventilation periods and maximum daily operations in case of that operation to represent realistic acoustic exposure. This setup enabled making a comparative analysis of the noise of the vegetation belt to absorb mechanical and ambient noise that was produced by farms under normal working conditions.

Welfare measurements were carried out after every cycle and a standardised score was applied on gait, feather cleanliness, footpad dermatitis, and hock burn. The data about mortality were presented on a daily basis. Structured scan sampling was used to conduct behavioural observations based on where patterns on activity, resting behaviour, and disturbance events were to be documented. These indicators gave an idea of how the welfare outcomes can be measured through improvements in the environment achieved by a reduction of pollutants and noise buffering. Linear Mixed-Effects Models (LMM) were used to analyse continuous errors like PM, gas concentrations, noise levels and behavioural measures, whilst Generalised Linear Mixed Models (GLMM) were used to analyse discrete measures like lesion prevalence and scores on cleanliness. Cycle, treatment and sampling location were considered as a fixed effect with house and repeated measures between cycles as a random effect. The statistical significance level was $p < 0.05$ and an estimated marginal means was used to generate post-hoc comparisons to show differences that were specific to VH and CH.

Table 2: Summary of Environmental and Welfare Variables, Measurement Instruments, and Sampling Frequency

Variable Category	Measured Parameters	Measurement Instruments	Sampling Locations	Sampling Frequency
Air Quality (PM)	PM_{10}, $PM_{2.5}$, TSP	Portable optical dust monitor	Bird level, exhaust points, upwind/downwind sites	Twice daily per cycle
Gas Concentrations	Ammonia (NH_3), Carbon dioxide (CO_2)	Electrochemical gas sensors (calibrated)	Bird level and exhaust outlets	Twice daily per cycle
Noise Levels	Sound pressure level (dB)	Precision sound level meter	Near wall, within vegetation belt, outside belt, control distance	During active ventilation + peak operation times
Physical Welfare Indicators	Gait score, feather cleanliness, footpad dermatitis, hock burn	Standardized welfare scoring charts	Inside each house (VH and CH)	Once per cycle (end of grow-out)
Behavioral Observations	Activity, resting, disturbance events	Scan sampling using observation checklists	Broiler activity zones in VH and CH	Multiple sessions per week

Results and Discussion

Air Quality Improvements

The peri-shed vegetation belt created a relative, yet steady beneficial effects to the downwind air quality throughout the six production cycles. In comparison to Control House (CH), the Vegetated House (VH) exhibited lower concentrations of PM 0, PM 2.5 and total suspended particulates (TSP) at the downwind sample sites and this could be attributed to the filtering ability of rapid growing tree-shrub systems. The Linear Mixed-Effects Model (LMM) analyses showed that all the measures of particulate had significant treatment impacts ($p < 0.05$), which proved that vegetation acted as an interception of pollutants and decreased the dispersion of the plumes. Internal measurements were conducted at the bird level and exhaust points, however, although no statistically significant differences in VH and CH were obtained, this was anticipated as a result of the same ventilation settings and the equal microclimatic conditions in the interiors. These results show that vegetation plays the main role in the behaviour of external pollutants, it is a protective barrier of nature that mitigates the level of pollution in the surrounding farm environment.

Noise Attenuation

Monitoring of noise showed that vegetative belt around VH dampened sound pressure levels by around 3 5 dB as compared to similar distances around CH. Mixed-model analysis established that attenuation effects were statistically significant, and decreases started getting more intense as the sampling point was further withillowsi, or directly behind vegetation barrier. This forms the conceptual knowledge that foliage and structural density of vegetation act as buffers, scattering, and refraction of sound waves. These findings are in line with other studies regarding environmental acoustics carried out previously, which emphasise the importance of dense level shrubs and trees towards decreasing the mechanical and ambient noise. Despite the fact that the scale of reduction may seem small, even minimal changes in the uninterrupted exposure to noise can have a significant impact on the stress responses and rest in poultry.

Welfare Outcomes

Physical welfare indicators assessment showed a number of positive tendencies in broilers kept in VH. The birds in the vegetated habitat had better scores on feather cleanliness, lower rates of minor lesion on the integument, and greater rates of uninterrupted rest periods. The differences were statistically significant ($p < 0.05$) according to Generalised Linear Mixed Models (GLMM) which supported the hypothesis that the improvements of external environment which was lowering dust drift, less exposure to ammonia, and reduced noise were translated into increased comfort and stability. There was little change in gait score and more devastating categories of lesion between VH and CH, as the internal microclimate and flooring conditions were similar. The changes in cleanliness and resting behavior however are indicators of significant welfare gains that go with buffered environments. Table 3 in the appendix gives a summary of welfare performance indicators.

Integrated Interpretation

Uncovering the results on a big scale, it becomes obvious that the alteration of peri-shed vegetation on the internal house microclimate is completely excluded, whereas the external environmental envelope of broilers housing is changed significantly by this factor. The vegetation will result in a calmer, cleaner buffer zone by means of reduced downwind particulate material and ammonia essence drift and reduced intensity of outer noise, which will have an indirect effect on the birds, through reduced environmental irritation and disturbance. Such cumulative effects can be used to justify the realised advantages to welfare indicators, especially the ones concerning cleanliness and restfulness. This research paper hence confirms the hypothesis that peri-shed green infrastructure is an economical and ecologically viable environmental management intervention, which can be used to improve the welfare of broilers without modifying internal broiler housing systems. The results indicate the importance of considering vegetation in farm structure as a component of an animal friendly integrated and holistic production approach.

Table 3: Comparison of Key Welfare Indicators between Vegetated House (VH) and Control House (CH)

Welfare Indicator	Vegetated House (VH)	Control House (CH)	Observed Trend
Feather Cleanliness Score	Higher cleanliness; fewer dust deposits	Lower cleanliness; more dust accumulation	VH better
Minor Lesion Incidence (skin/abrasion)	Reduced minor lesion frequency	Slightly higher lesion frequency	VH better
Footpad Dermatitis (Mild Cases)	Comparable or slightly lower	Similar to VH	No major difference
Gait Score	Mostly normal gait; no significant deviation	Similar gait scores	No major difference
Undisturbed Resting Bouts	More frequent, longer resting periods	Shorter, more disturbed resting	VH better

Future Research

Future research should be aimed at investigations in long-term tracking of peri-shed vegetation belt interactive use in order to comprehend the development of environmental buffering capacities of peri-shed vegetation belts with maturity. The structure of vegetation, the density of the canopy, the development of roots and the changes of foliage seasonally could have a significant impact on the particulate filtration, absorption ammonia and silence. Long-term researches would consequently contribute to the discovering stability and long-term viability of these advantages in various weather and functioning circumstances and create a better perspective on the lifetime of vegetation and its connexion to the quality of the environment inside broiler houses.

There is also need to do further research to compare the performance of various vegetation species and structural combination. The variety of combinations of trees and shrubs differ on the allowance of leaf surfaces, growth rates, porosity of the canopy and acoustics. The optimal combinations of species could be discovered through comparative trials, which would enable producers to design vegetation belts according to the ecology of the region, land accessibility, and outputs targets. Also, the evaluation of vegetation management practises (intensity of pruning, rows spacing, and understory) would assist in establishment of the standard legal guidelines to recommend on the optimality of performances by buffers.

Another way forward is the integration of sophisticated modelling tools. The movement of pollutants, patterns of airflow and the transmission of noise around broiler houses can be simulated using their respective models; Computational Fluid Dynamics (CFD) and dispersion modelling that are highly spatial. Such models would enable the researcher to experiment with a variety of vegetative designs virtually eliminating the need to have expensive field experiments. Integrating the outputs of coupling models with empirical evidence in commercial farms may generate strong predictive models to environmental management in the poultry production systems.

Lastly, a study to be undertaken in the future ought to involve an assessment of the financial sustainability of implementing vegetation belt with other technologies that can improve the environment at large. Cost-benefit studies are crucial in deciding the financial self-sufficiency of mass adoption especially in farms where the ground resources or investment scale is low. Moreover, there should be synergistic benefits of green infrastructure with other related interventions, natural lighting, environmental enhancements or better ventilation strategies to deliver extra welfare. Knowledge about interactions of these measures would aid in the design of holistic and animal-friendly production entailing sustainability and welfare objectives.

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Conclusion

This research offers practical facts to that the peri-shed green infrastructure can be a practical tool of environmental management in commercial broilers production systems. The existence of a vegetation belt around the broiler house had a continuous positive influence on the decreased levels of downwind concentration of the particulate matter and ammonia as well, which proved not only the potential of mixed tree-shrub buffers as bio filters but also indicated the benefits of bio filtering vegetation belts. The vegetative barrier was also associated with the objective noise reduction, which minimized the external noise levels up to 3 to 5 dB, which supports the multifunctional nature of green infrastructure as an environmental buffer. Although there are no significant variations in internal microclimate, which can be explained by the same ventilation conditions of the houses, the external environmental additions were transferred into a number of welfare improvements. Birds established near the vegetation belt were more feather clean and less affected by minor integumentary lesions and had more time to rest undisturbed, meaning with less irritation and reduced disturbance of the acoustic environment. These results indicate that the external environment can give significant positive changes with small improvements. These findings justify the consideration of peri-shed green infrastructure as a feasible, inexpensive, and environmentally sound method of improving the quality of the environment in poultry production. Vegetative buffers provide a simple and natural way of minimising blanketing systems in alignment with animal welfare and environmental conservation in the livestock industry. These green elements integrated into the designing of the farm are not only available to help in enhancing the well-being of birds but also to support the overall aim of ecological sustainability and climate-adaptable agricultural development.

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