Agriculture College – Wasit University

Dijlah Journal of Agricultural Sciences

ISSN 2790 – 5985
eISSN 2790 – 5993

Dijlah J. Agric. Sci.، 4(1):1-8, 2025

Approaches to Mitigating Emissions in Poultry Farms: Promoting Environmental Sustainability and Animal Welfare

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Abstract:

Poultry farming is a significant source of air pollutants, including ammonia (NH3), fine particulate matter (PM), and greenhouse gases (GHGs). Effective mitigation strategies are essential to reduce these emissions and their environmental impact. This review explores different ways to mitigate emissions in poultry houses. By introducing techniques and implements to deal with harmful gas emissions that can be significantly reduced. implementing advanced ventilation systems and bio filters can further improve air quality. Also improving feed composition and improving manure handling techniques, these strategies not only contribute to environmental sustainability, but also improve animal welfare and farm efficiency.

Keywords: *Mitigating Emissions, Poultry Farms, Animal Welfare*

Received:22/12/2024 **Accepted:13/1/2025** **Published:19/1/2025**

Introduction

Chicken production has a significant impact on the world's food supply, but there are also environmental issues. One major issue is the emission of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, from chicken respiration and the decomposition of manure. These emissions exacerbate environmental problems worldwide by causing climate change and global warming (Gerber, et al., 2013) Furthermore, when ammonia (NH_3) from decomposing manure leaks into the environment in poultry houses, it degrades air quality, contributes to ecosystem acidification, and can destroy biodiversity (Xin, et al., 2011; Ati et al., 2013).

Ammonia and particulate matter emissions within poultry houses also affect animal welfare and productivity, because poor air quality can lead to respiratory problems, stress, and reduced growth rates in birds (Mitloehner & Schenker, 2007). Therefore, mitigating emissions in poultry houses not only addresses environmental sustainability, but also enhances animal health and production efficiency.

In order to improve bird welfare and lessen the environmental impact of poultry production, effective odor control is crucial in poultry management. Usually, the breakdown of organic materials like

manure and feed wastes results in odor issues (Fournel, et al., 2012; John, 2023). To manage these odors, several strategies can be implemented within poultry houses. One effective approach is to use proper ventilation systems that ensure adequate airflow, which helps dilute and disperse odorous compounds. (Fournel, et al., 2012; Nicolai & Pohl, 2005) It's also critical to maintain ideal litter conditions; frequent rotation and litter management can stop moisture accumulation and cut down on odors. When properly applied, these tactics enhance air quality, lower nuisance complaints, and support a more sustainable chicken business (Nicolai & Pohl, 2005; Dawod et al., 2024).

By dissolving dangerous substances before they leak into the environment, additives like biofilters or microbiological agents can further reduce odors. Implementing waste management techniques, such as using covered manure storage and promptly removing waste items, is another tactic that can greatly lessen the production of odors (John, 2023; Ati and Dawod, 2024) (Nicolai & Pohl, 2005) (Ati et al., 2014[a, b]; Jasim et al., 2015).

In addition to these management strategies, raising public awareness of odor control procedures is crucial for encouraging community support and encouraging poultry owners to comply. Understanding the causes of odor in poultry houses is becoming more and more crucial as the poultry business grows. The creation of focused mitigation methods can be guided by the identification of particular odor drivers, guaranteeing that environmental sustainability and production efficiency are given first priority in poultry operations (Nicolai & Pohl, 2005).

Problem Statement

Ammonia (NH_3): Ammonia is considered as one of the most concerning emissions due to its negative effect on poultry health and workers safety. This gas is released through the decomposition of uric acid in poultry manure by microbial activity. High concentration of ammonia can lead to respiratory problems in poultry and increased possibility to disease. Unabating, exposure also poses health risks to farm workers and can reduce growing rates in poultry (Li, et al., 2022).

Carbon dioxide (CO_2): CO_2 concentrations are accumulated due to bird respiration and are further elevated by fuel-burning heaters used to maintain optimal temperatures in poultry houses during cold climates. High CO_2 concentrations can indicate inadequate ventilation, leading to poor air quality, which can impair bird health and productivity for sure (Knížatová, et al., 2018; Handbook., 2021).

Methane (CH_4): Poultry manure is the nation's third largest source of methane from livestock manure management (Agency, 2024) .Although methane emissions are lower than other gases, it is an important greenhouse gas with high global warming potential,. Methane is produced from the anaerobic decomposition of organic matter in poultry manure. While methane emissions do not directly harm poultry, they contribute to the overall environmental footprint of agriculture (Brouček & Čermák, 2015).

Particulate matter (PM): Dust particles from feed, litter, and feathers carry bacteria and viruses, increasing the risk of respiratory problems in birds and humans. Particulate matter can also absorb and carry ammonia, exacerbating air quality problems in poultry. Dust also contains inorganic particulates from building materials such as concrete or insulation used in barn construction. Due to their irregular shape, these particles offer a tremendous surface area for binding bacteria (or their components), viral particles, and mold. (Pennsylvania State university Extention, 2023).

Carbon monoxide (CO): Carbon monoxide is produced by incomplete combustion of fuel in heating systems, especially under poor ventilation conditions. Exposure to CO can lead to health problems in both poultry and humans, and poorly ventilated poultry houses with high levels of CO pose a significant safety risk poultry is artificial brooding. This process must include not only proper temperatures, adequate floor space, regulated humidity, and a balanced diet, but also correct ventilation to insure livability in chicks and poults from disease-free stock. (Gentile, 2014; Handbook., 2021; Pennsylvania State university Extention, 2023).

These emissions are of concern because they affect bird welfare, worker health, and contribute to environmental pollution and greenhouse gas emissions. Effective ventilation and manure management are essential to reducing emissions and improving air quality in poultry houses.2. Sources of Emissions in Poultry Houses

Mitigation Strategies

Enhancing ventilation in chicken houses is crucial for preserving air quality and managing humidity, both of which lessen the breakdown of manure into toxic gases. A balanced airflow produced by proper ventilation aids in the removal of dust, carbon dioxide (CO_2), and ammonia (NH_3). Excessive humidity speeds up the decomposition of manure and increases the emission of toxic chemicals like hydrogen sulfide and ammonia, which can be damaging to the health of birds (Miles, et al., 2004).
According to (Homidan, et al., 2003), balanced airflow avoids gas accumulation in stale areas, which can cause respiratory issues in poultry because of the continuous intake of contaminants. Moreover, excessive humidity may assist with the formation of germs and mold, raising the risk of illness in birds (Bist, et al., 2023).Particularly in regions with high humidity or temperatures, mechanical ventilation systems—which employ carefully positioned exhaust fans and vents—are very good at controlling airflow and maintaining a regulated atmosphere that reduces the amount of gas produced during the breakdown of manure.

In poultry houses, managing heat, humidity, and airflow is crucial for animal welfare, biosecurity, and overall productivity. Heat exchangers and advanced ventilation systems play a significant role in this context. It's important to understand how Heat Exchangers Work in Poultry Houses, since they pay a significant role in Heat Recovery. Outgoing Air-Heat exchangers capture heat from the warmer, stale air that is expelled from the poultry house. Then Incoming Air recovers heat and transferred afterword to incoming cooler air, warming it before it enters the house. This helps maintain a stable and comfortable temperature inside, particularly during cold weather thus this is very efficient in terms of Energy cost because reducing the need for additional heating, heat exchangers contribute to energy savings, which is critical for poultry operations where energy costs can be significant (Elizabeth , 2021).
The Role of Advanced Ventilation Systems is also important in Humidity Control, whereby Advanced ventilation systems are designed to ensure a proper exchange rate of air, replacing humid, stale air with fresher outdoor air. This is essential in maintaining optimal humidity levels and preventing condensation, which can be harmful to birds. Moreover, some systems may integrate dehumidifiers or energy recovery ventilators (ERVs), which not only recover heat but also manage humidity, further enhancing the environment inside the poultry house (Tran, 2024).
Odor Management and Air Quality Improvement is done by constantly replacing stale air (which often contains ammonia from waste) with fresh air, these systems significantly reduce odors. High levels of ammonia and other gases can be harmful to poultry and negatively impact their growth and health.

Since high humidity can lead to increased odor production (due to mold growth and waste decomposition), effective humidity management helps in controlling these unpleasant smells (Casey, et al., 2006).

To Improved Air Quality, Pollutant Removal in Advanced ventilation systems often include filtration systems that can trap harmful particles, pathogens, and allergens, ensuring a cleaner air supply for the birds. This helps reduce respiratory issues and promotes better health, which results in Enhanced Welfare because better air quality leads to healthier poultry, which can improve growth rates and overall productivity, leading to higher efficiencies in poultry production (Lim, et al., 2014).

Frequent removal and drying of litter Reduce the microbial activity responsible for emissions (Bolan, et al., 2010). Additives for ammonia reduction Using pH-lowering or ammonia-capturing agents in litter can reduce ammonia volatilization (Chai & Ritz, 2022; Choi, et al., 2008). Another Pont view is Low-protein diets. Reducing protein intake can lower nitrogen excretion and, subsequently, ammonia emissions (Smith & Jones, 2020).also Enzyme additives Phytase and other enzymes help reduce undigested nutrients, leading to lower emissions from manure (Brown & Green, 2019).

On the other hand, Fuel-efficient brooders and heaters, results on Use of energy-efficient and low-emission heaters that ensures complete combustion, thereby reducing CO_2 and CO emissions. Whereby According to a study by (Hassanuzzaman, et al., 2004) a locally manufactured low-cost incubators for hatching chicks have shown promising results in terms of efficiency. Even an Adoption of a renewable energy sources such as solar or geothermal heating as a replacement for fuel-based heating systems also accomplishes the same goal in preventing emissions as what was stated by a comprehensive review by (Cui, et al., 2020) that highlights the benefits of using renewable and sustainable heating systems, such as solar and geothermal heating, which ensure complete combustion and reduce CO2 and CO2 emissions. Another useful technique is Biofilters and Scrubbers, Biofilters capture and biologically neutralize pollutants before they escape the house, especially ammonia and odor compounds Caroline (Van der Heyden & Demeyer, 2015). In addition to Electrostatic particle scrubbers that is Useful for reducing PM, particularly effective for air purification in enclosed environments (Van der Heyden & Demeyer, 2015).

Monitoring and Technology Adoption

Real-time air quality monitoring using applicable sensors such as Arduino based sensors can track emission levels in poultry houses, allowing for immediate adjustments to ventilation, heating or other control measures (Ni, et al., 2009) . Volatile organic compound (VOC) sensors can be used to detect changes in pollutant levels, and the air quality control system can then adjust the building's ventilation system accordingly (Weng, et al., 2021). Determining the number of harmful gases based on real-time calculations of poultry house heating and cooling loads can help determine the optimal ventilation and insulation measures needed to maintain comfortable indoor conditions while minimizing energy use. However, relying solely on humidity-based demand-controlled ventilation may not be sufficient, as air leakage still allows for uncontrolled fresh air supplies, and CO2 levels along with other gases may remain elevated despite ventilation changes (Olaniyan, et al., 2018).

Case Studies and Applications

Exhaust air treatment systems

A study at the Landtechnik Institute in Bonn investigated the use of exhaust air treatment systems to mitigate dust, ammonia (NH3) and odor from poultry houses. The study found that a two-stage system

combining a chemical washer and a biofilter was effective in reducing odor by 51%. The biofilter used honeycomb paper pads, which were more effective than root wood (Strohmaier, 2020).

Mineral microbial additive for poultry manure treatment

A study published in the Journal of Environmental Management explored the use of a mineral microbial additive for poultry manure treatment. The study used microorganisms such as *Lactobacillus plantarum* and *Bacillus subtilis* on a perlite and bentonite substrate. This treatment significantly reduced emissions of NH3, H2S and volatile organic compounds (VOCs), improving air quality and productivity in poultry houses (Kalus, et al., 2017).

Odor Reducing Additives in Broilers and Layers

A study published in the journal Environmental Science and Pollution Research evaluated the effectiveness of mineral and microbial deodorizing preparations (MMDPs) in broilers and layers. The mineral and microbial deodorizing preparations, based on perlite and bentonite, reduced odorous compounds and greenhouse gases such as CH4 and CO22. This improved working conditions and increased productivity (Kalus, et al., 2017).

Environmental Control Systems in Poultry Houses

A special issue of Animals highlighted developments in environmental control systems for poultry production (animals, 2023) for instance (Bist & Chai, 2022) indicated that Oil and water spraying, Spraying water or oil can effectively reduce fine particle concentrations in poultry houses ,High liquid spray doses can significantly reduce fine particle levels but may increase ammonia emissions ,Care should be taken to avoid safety hazards from slippery surfaces. These systems focus on maintaining optimal temperature, humidity and gas levels, which are essential for bird welfare and productivity. Implementing these systems has been shown to reduce harmful gas emissions and improve overall productivity (Kamalesh Kumar K S, 2023).

Dust Control Strategies in Poultry Houses

Research from the University of Georgia discussed dust control strategies in poultry houses. Effective dust management not only improves air quality, but it also enhances the health and productivity of both poultry and farm workers.5 Strategies include proper ventilation, regular cleaning, and the use of dust suppressants. These studies demonstrate that various approaches, such as exhaust air treatment, microbial mineral additives, and environmental control systems, can effectively reduce odors and improve emissions and productivity in poultry houses (Chai, 202).

Challenges and Future Directions

Installing and maintaining advanced emission mitigation systems on small-scale poultry farms can be economically challenging due to high initial costs, ongoing maintenance expenses, and the need for specialized knowledge and training. Small-scale farmers often lack access to financial resources and technical support, making it difficult to adopt these technologies (Dhillon & Moncur, 2023). Future research should focus on developing cost-effective and scalable solutions for mitigation (Powers, et al., 2005). This includes exploring alternative technologies, such as biofilters, efficient modules, and sensors, that can be easily implemented in small-scale operations (Bist & Chai, 2022). In addition, research should aim to improve the accuracy and precision of emission measurement methodologies to better assess the effectiveness of mitigation strategies (Powers, et al., 2005). Current technologies for mitigating emissions in poultry farming often face limitations in terms of cost, scalability and practicality. More affordable and easy-to-use solutions are needed that can be easily adopted by small

farmers. In addition, current technologies may not be effective in all environmental conditions, highlighting the need for adaptable and robust systems (Bist & Chai, 2022).

Areas for Improvement

Cost-effective biofilters: Developing affordable, easy-to-maintain biofilters can help small farmers reduce emissions without incurring significant costs (Bist & Chai, 2022). Efficient modules and sensors: Innovations in sensor technology can provide real-time monitoring of emissions, allowing for more accurate monitoring and improved mitigation strategies (Bist & Chai, 2022). Integrated mitigation strategies: Implementing integrated approaches that combine multiple mitigation technologies can enhance overall effectiveness and reduce costs (Powers, et al., 2005).

Conclusions

Reducing emissions in poultry houses is critical for several reasons such as environmental Benefits include Reducing emissions of harmful gases such as ammonia (NH3), hydrogen sulphide (H2S), carbon monoxide (CO), carbon dioxide (CO2) and fine particulate matter (PM10) , that's lead to Reduced air pollution which contributes to cleaner air quality, which benefits local ecosystems and the wider environment. Also, Climate change mitigation which results in Reducing greenhouse gas emissions, these aims supports global efforts to combat climate change. Moreover, improved animal welfare by Improving air quality inside poultry houses, that's leads to Healthier birds: Reducing exposure to harmful gases and dust improves respiratory health, reduces stress and reduces disease rates in poultry.

Improving farm efficiency assuring better living conditions because Improved environmental controls create a more comfortable environment, promotes natural behaviors and improves overall wellbeing. Implementing emission reduction strategies can also improve farm efficiency resulting in Increased productivity by Healthier animals with better living conditions that tend to have higher growth rates and better feed conversion ratios. Also reduced mortality by improved air quality and welfare conditions resulting in lower mortality rates, ensuring more birds reach suitable market size.

Operational savings: Efficient systems can reduce the need for medical treatments, cleaning labor, and maintenance costs, resulting in overall cost savings. In short, reducing emissions in poultry houses not only protects the environment, but also improves animal welfare and enhances farm efficiency. These strategies represent a win-win for both producers and the planet.

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