Research Progress on the Impact of Indoor Air Quality on Broiler Chicken Health: Postprint

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Abstract

With the development of large-scale livestock and poultry production, the impact of environmental factors on animal health has become increasingly prominent. High-density, intensive rearing leads to elevated concentrations of microorganisms, dust, harmful gases, and other pollutants within housing facilities, resulting in continuous deterioration of air quality. Prolonged exposure to poor air quality contributes to high incidence of respiratory diseases such as broiler tracheitis and broiler respiratory syndrome, indirectly compromising growth performance and immune function. Enhanced research on the detrimental effects of air pollutants in livestock housing on animal health, and exploration of effective measures to improve air quality in livestock facilities, holds significant importance for the healthy development of China' s animal husbandry sector. This paper primarily provides a theoretical basis for in-depth investigation into the mechanisms by which air pollutants affect broiler health and for rational control of air quality within housing facilities, through a comprehensive review of pollutants including microorganisms, dust, and ammonia, along with their associated hazards and mitigation strategies.

Full Text

Research Progress on the Effects of Air Quality in Poultry Houses on Broiler Health

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Abstract

With the development of large-scale livestock and poultry production, environmental impacts on animal health have become increasingly prominent. High-density, intensive farming leads to elevated concentrations of airborne microorganisms, dust, and harmful gases, resulting in continuously deteriorating air quality. Prolonged exposure to poor air quality environments causes frequent respiratory diseases such as tracheitis and broiler respiratory syndrome, indirectly reducing growth performance and immune function. Strengthening research on the hazards of air pollutants to livestock health and exploring effective measures to improve air quality in animal houses are of great significance for the healthy development of China' s animal husbandry. This paper primarily reviews pollutants such as airborne microorganisms, dust, and ammonia, their harmful effects, and countermeasures, providing a theoretical basis for further investigating the mechanisms by which air pollutants affect broiler health and for rationally regulating air quality in poultry houses.

Keywords: air quality; broiler; health

Livestock growth requires a suitable environment, and housing conditions directly affect animal health and economic benefits. In modern broiler production, environmental factors have become increasingly prominent influences on livestock health. Research reports indicate that genetics, nutrition, and environment are the three main factors affecting animal production, with environment accounting for as much as 25% of the impact. Insufficient attention to farming environments makes chickens susceptible to disease, and once disease occurs, it is difficult to control, causing severe economic losses. Prevention is more important than treatment, and farms must strengthen environmental control to achieve good economic benefits. Among these factors, air quality in poultry houses is critical for healthy broiler growth. Air quality directly affects production performance and economic returns. Harmful gases such as ammonia and hydrogen sulfide, pathogenic microorganisms, and dust in poultry house air can reduce broiler immune function, cause respiratory diseases such as tracheitis and respiratory disease syndrome, and decrease economic efficiency. Improving air quality can enhance product quality and economic benefits to a certain extent. Therefore, strengthening research on the relationship between air quality and animal health and actively improving air quality in livestock houses are important for the development of China' s animal husbandry. This paper summarizes major air quality indicators in poultry houses, their effects on broiler health, and measures to improve air quality, aiming to provide theoretical support for promoting green broiler production, improving quality and efficiency, and developing air quality evaluation models and standards for poultry houses.

1 Overview of Air Quality

Healthy broiler growth depends on air quality in poultry houses, which directly affects growth performance, immune function, and product quality. Poor air quality reduces broiler immune function and triggers respiratory diseases. In particular, harmful gases such as ammonia and hydrogen sulfide, microorganisms, and their metabolic products like endotoxins can easily cause airborne infectious diseases, seriously harming animal health and productivity. Respiratory diseases that frequently occur in broilers during winter and spring have become a thorny problem for large-scale farms, with high incidence rates that are difficult to control, primarily due to poor air quality in houses. Air quality in livestock houses has received increasing attention. The Ministry of Agriculture's "Environmental Quality Standard for Livestock and Poultry Farms" (NY/T 388-1999) clearly stipulates that ammonia concentration should not exceed 10 mg/m^3 and hydrogen sulfide should not exceed 2 mg/m^3 in chick houses, while in adult poultry houses ammonia should not exceed 15 mg/m^3 and hydrogen sulfide should not exceed 10 mg/m^3. Carbon dioxide concentration should not exceed 1,500 mg/m^3; inhalable particulate matter (PM) should not exceed 4 mg/m^3; and total suspended particulates (TSP) should not exceed 8 mg/m^3. In 2006, the United States launched the "National Air Emissions Monitoring Study" to systematically investigate air pollutants and their hazards at livestock facilities. Investigating the relationship between air quality in livestock houses and animal health and exploring effective and practical ways to control air quality, reduce harmful gases, dust, and pathogenic microorganisms, and improve environmental air quality in chicken houses are of great significance for healthy livestock growth in China.

2.1 Airborne Microorganisms

Poultry houses contain large numbers of microorganisms, mainly including *Staphylococcus*, *Enterococcus*, *Campylobacter*, *Salmonella*, *Clostridium perfringens*, and *Escherichia coli*. Studying the concentration of airborne microorganisms or the composition and concentration of certain pathogenic bacteria is an effective indicator for evaluating air quality. Vučemilo et al. reported that airborne bacterial concentration in poultry houses increases with broiler age, with microbial contamination significantly increasing during the later growth stages, reaching 6.40 × 10 CFU/m^3 at 5 weeks of age. Agranovski et al. reported that airborne bacterial concentrations in broiler houses range from (0.11–6.38) × 10 CFU/m^3, with Gram-positive bacteria accounting for 85%; fungal concentrations range from (4–620) × 10^3 CFU/m^3, mainly including *Cladosporium*, *Aspergillus*, *Penicillium*, and *Fusarium*. Although Gram-negative bacteria account for a smaller proportion, they contain numerous conditional pathogens such as *E. coli*, *Pseudomonas*, *Pasteurella*, and *Neisseria*. Microorganisms attach to dust particles and aerosols to form microbial aerosols, which can spread and transmit through air media, invading the body through respiratory mucosa and causing excessive immune load, reduced vaccine response, decreased disease resistance, and enhanced susceptibility. Zhang et al. reported that increased concentrations of bacteria and fungi in chicken house air significantly reduced Newcastle disease antibody titers and impaired broiler vaccine response capacity. Xue et al., using an Anderson-6 microbial sampler to study microorganisms in broiler houses, found that bacterial aerosols were primarily collected in stages I, II, and III of the sampler, indicating that bacteria mainly affect the upper respiratory tract of broilers, though some microorganisms in stages IV, V, and VI could enter the lower respiratory tract and damage the lungs. Additionally, many pathogenic bacteria can produce endotoxins, and long-term exposure to high concentrations of airborne endotoxins can cause poultry poisoning, growth retardation, reduced immune function, and various respiratory diseases. Zuker et al. reported that endotoxins can cause respiratory diseases in poultry such as malignant pneumonia and airway obstruction.

2.2 Dust

Dust and particulate matter (PM) in chicken houses mainly originate from feed, feces, droplets produced during respiration, coughing, and vocalization, skin and feather shedding, and airborne microorganisms and fungi. Zhao et al. monitored traditional cage systems and found daily average PM and fine particulate matter (PM .) concentrations of 0.57-0.61 mg/m^3 and 0.033-0.037 mg/m^3, respectively. Particulate matter in poultry houses has complex composition, containing heavy metals, ammonia, hydrogen sulfide, volatile organic compounds, endotoxins, bacteria, and viruses. Dust enters the respiratory system through animal inhalation; particles larger than 10 m are blocked in the nasal cavity and irritate nasal mucosa, most PM adheres to tracheal or lung walls, while PM . can reach deep into alveoli and deposit, entering blood circulation and potentially causing lung diseases such as emphysema and lung cancer. Dust serves as a carrier for harmful gases like ammonia and hydrogen sulfide, as well as microorganisms like bacteria and viruses, forming microbial aerosols that enter the respiratory system, stimulate respiratory mucosa, cause inflammation, and continuously carry pathogenic microorganisms into inflamed areas, triggering upper respiratory diseases, chronic bronchitis, and other respiratory infections. Studies show that coarse particles mainly cause inflammatory responses through Toll-like receptor-4 (TLR4), while PM . primarily induces macrophage expression of tumor necrosis factor- (TNF-) and interleukin-6 (IL-6) through Toll-like receptor-2 (TLR2). Particulate matter can also directly affect respiratory mucosal barriers, reducing expression of antimicrobial peptides defensin-2 and defensin-3, locally lifting inhibition of pathogenic microbial growth. Qu reported that PM . can cause lung tissue cell and biofilm damage in rats, induce humoral immune response and local mucosal immunity changes, and suppress non-specific immune function through various pathways. Shi et al. reported that fine particulate matter causes oxidative stress and inflammatory responses in trachea and lungs of animals like rats, damages mitochondria and cellular structures, and causes cell injury. Additionally, dust can adsorb ammonia and odor mixtures, exacerbating harm to broilers.

2.3 Harmful Gases

2.3.1 Ammonia Under high-density, enclosed housing conditions, broiler houses produce large amounts of toxic and harmful gases, with ammonia being the most hazardous. Amino acids degrade in the body to produce uric acid and urea that are excreted into the gastrointestinal tract, where microbial urease generates ammonia; bedding and other nitrogen-containing materials also produce ammonia under urease action. Zhang et al. found that from 1 to 42 days of age, white-feathered broilers emitted an average of 2,778 mg of ammonia per bird, with an average emission rate of 66 mg/(bird • d). High ammonia concentrations affect cerebral nerve and muscle cell metabolism, cause ammonia poisoning, increase energy consumption for detoxification in organs like the liver, and consequently reduce broiler growth performance. Reports indicate that excessive ammonia concentrations affect broiler welfare and human health, reduce production performance, damage respiratory tracts, and increase incidence of airsacculitis and keratoconjunctivitis. Charles et al. reported that exposing chicken houses to high ammonia concentration of 102 mg/m^3 for one week significantly reduced average daily feed intake and daily weight gain. Zhang et al. reported that 75 mg/m^3 ammonia caused upregulation of 21 proteins related to lipid synthesis, amino acid decomposition, oxidative stress, and liver injury, and downregulation of 17 proteins related to energy metabolism, cytoskeletal structure, immune and inflammatory responses, and detoxification functions. Meng et al. reported that ammonia significantly affected footpad scores, hock joint scores, and gait scores in broilers, with increasing ammonia concentrations raising the incidence and severity of feather soiling, footpad infections, and lameness. Broiler respiratory systems are sensitive to ammonia stimulation; long-term exposure causes pathological changes and even necrosis in tracheal and lung tissues. Li found that as ammonia concentration in chicken houses increased, mRNA expression of tight junction protein 1 (claudin1) and mucin 2 (MUC2) in tracheal tissue significantly decreased, while mRNA expression of cysteine protease 3 (caspase-3) significantly increased, indicating that ammonia stress destroyed the mucosal barrier function of tracheal tissue and induced apoptosis. Animals under long-term ammonia stimulation develop pathological changes and necrosis in tracheal and lung tissues, with severe cases showing bronchiole epithelial blockage, edema, atelectasis, hemorrhage, and alveolar emphysema, leading to respiratory dysfunction. Zhang et al. reported that 0.77 g/m^3 ammonia caused necrosis, shedding, and hemorrhage of tracheal epithelial cells and obvious lung hemorrhage and congestion. Xiong et al. reported that ammonia stimulation caused oxidative stress damage and histopathological injury in broiler trachea, disrupted immune response and muscle contraction processes, increased mucus secretion, and caused respiratory obstruction. These studies demonstrate that ammonia seriously endangers broiler health, making it imperative to reduce ammonia concentration and improve air quality.

2.3.2 Hydrogen Sulfide In anaerobic environments, microorganisms reduce sulfates and decompose sulfur-containing organic matter in livestock feces to produce large amounts of colorless, corrosive, toxic hydrogen sulfide gas with a strong rotten egg odor. Hydrogen sulfide strongly stimulates animal mucosa, causing conjunctivitis, rhinitis, tracheitis, and even pulmonary edema. Hydrogen sulfide combines with sodium ions in mucus to produce sodium sulfide, which stimulates animal mucosa; entering the respiratory tract, it irritates nasal cavities causing rhinitis and damages trachea; entering the lungs, it causes tracheitis and pulmonary edema; chronic inhalation of low concentrations leads to autonomic nervous system disorders; entering the blood, it hinders oxygen transport, causing hypoxia, weakness, and decreased immunity. Meng reported that hydrogen sulfide reduces broiler feed intake and daily weight gain, increases tracheal mucus secretion, damages cilia, ruptures alveoli, and reduces immunity and meat quality.

2.3.3 Odor Livestock farm odors refer to gaseous substances harmful to animals and humans that cause olfactory aversion, mainly including volatile fatty acids, indoles and phenols, ammonia and volatile amines, volatile sulfur compounds, and skatole. Intensive farming models with high stocking density, poor ventilation, and delayed manure removal combined with microbial decomposition produce excessively strong odors. Most of these odorous substances are water-soluble gases that easily adsorb to respiratory mucosa of humans and animals, reducing immune function and causing respiratory diseases.

2.3.4 Carbon Dioxide and Others Carbon dioxide mainly originates from broiler respiration, with some produced by microbial decomposition of feces and bedding. Carbon dioxide itself is not toxic, but high concentrations lead to low oxygen levels, and chronic oxygen deficiency can cause chronic poisoning, reduced immune function, and decreased feed intake. Carbon dioxide release depends primarily on broiler numbers; high concentrations indicate poor ventilation and air quality, reduced oxygen content, and affect metabolism. Carbon dioxide concentration indicates ventilation status and air pollution levels, and when it increases, other harmful gas concentrations also rise, making it a reliable indicator for monitoring air pollution. Additionally, in enclosed houses, incomplete coal combustion during winter heating may produce large amounts of carbon monoxide, which is toxic to the nervous and blood systems. Carbon monoxide entering broilers combines with hemoglobin, hindering oxygen transport, causing acute hypoxia, and leading to dysfunction of the nervous, circulatory, and respiratory systems, even death.

3.1 Strengthening Air Quality Monitoring and Environmental Management

Understanding air quality conditions is essential for timely and reasonable regulation. Modern livestock house environmental monitoring systems combine multiple environmental sensors for continuous multi-point monitoring, enabling real-time tracking of air quality indicators such as carbon dioxide, ammonia, and hydrogen sulfide, which is crucial for promptly improving air quality. Wang et al. designed a wireless transmission-based remote monitoring system for chicken house environments that can monitor carbon dioxide, ammonia, and other indicators in real time, providing scientific management basis for farm managers and improving management efficiency. Zhu et al. developed a harmful gas monitoring system for chicken houses based on ZigBee and GPRS technology that can monitor carbon dioxide, ammonia, and hydrogen sulfide conveniently, quickly, and accurately. Through air quality monitoring, managers can promptly understand conditions; when air quality declines, management should be strengthened to improve it. Ventilation reduces harmful gases, dust particles, and microorganisms in chicken houses and is the most direct and effective way to improve air quality, though house temperature must also be considered. Timely removal of excreta avoids long-term accumulation and fermentation, reducing emissions of ammonia and hydrogen sulfide. Proper disinfection of livestock houses can reduce airborne microorganisms and dust concentration, thereby improving air quality. Wang et al. showed that disinfection with chickens present significantly reduced airborne bacterial concentration, with bacterial levels significantly decreasing one hour after disinfection.

3.2 Adjusting Dietary Structure

Incomplete digestion and absorption of nutrients in feed is the main cause of harmful gases and odors in livestock houses. Reasonably adjusting dietary structure and improving nutrient utilization can reduce ammonia and hydrogen sulfide production, thereby improving air quality. Ferket et al. showed that using ideal protein patterns and synthetic amino acid additives to balance dietary amino acids improves protein utilization and reduces ammonia and hydrogen sulfide in excreta. Ferguson et al. found that reducing dietary crude protein content decreased chicken house ammonia concentration by 31%. Roberts et al. reported that feeding laying hens high-fiber diets reduced ammonia volatilization from excreta. These studies demonstrate that adjusting dietary structure can effectively improve air quality.

3.3 Using Feed Additives

Common feed additives include probiotics, prebiotics, and synbiotics; plant extracts; Chinese herbal additives; enzymes; acidifiers; and minerals. Probiotics, prebiotics, and synbiotics improve feed conversion and intestinal microbial structure, reducing harmful gas emissions. Hossain et al. reported that adding 0.1% compound probiotics (containing *Bacillus subtilis*, *Clostridium butyricum*, *Lactobacillus acidophilus*) significantly reduced ammonia emissions. Wang et al. showed that adding 0.3% fructooligosaccharides and 0.1% *B. subtilis* significantly reduced ammonia and hydrogen sulfide emissions. Tong et al. reported that spraying compound *Bacillus* solution significantly reduced airborne *E. coli* and *Staphylococcus aureus* in broiler houses. Luan et al. showed that spray preparations significantly reduced total aerobic bacteria, *E. coli*, and *S. aureus* in air and excreta, purifying the microbial environment.

Using plant extracts to reduce harmful gas concentrations has become a research hotspot. Plant extracts can inhibit urease activity and block microbial urease synthesis pathways, reducing urease secretion and thereby inhibiting urea decomposition and ammonia production. Yu et al. showed that extracts from Lauraceae and Yucca species reduced ammonia and hydrogen sulfide emissions from livestock excreta. Li et al. reported that dietary phytoncide significantly reduced ammonia emissions, with a significant linear decrease as phytoncide concentration increased. Bostami et al. reported that adding 0.5% pomegranate fermented byproducts significantly reduced ammonia and hydrogen sulfide concentrations. Enzymes such as protease and phytase supplement endogenous enzymes, reduce antinutritional factors, promote nutrient digestion and absorption, and decrease nitrogen and sulfur content in feces. Zhang showed that adding different levels of enzymes to broiler diets significantly reduced airborne microorganisms and ammonia concentration. Acidifiers reduce gastrointestinal pH, provide suitable environments for digestive enzymes and microorganisms, promote pepsin synthesis, improve protein digestibility, and reduce odor from intestines and excreta. Additionally, many minerals with large specific surface area and pore volume have strong adsorption capacity for ammonia, hydrogen sulfide, carbon dioxide, and water, improving air quality. Minerals such as zeolite, bentonite, attapulgite, and montmorillonite are currently used to improve livestock house environments by adsorbing ammonia, hydrogen sulfide, carbon dioxide, and water molecules, inhibiting production and volatilization of harmful gases.

3.4 Utilizing Air Electro-Purification Technology

High-voltage electrodes in space electric fields discharge to produce high-energy charged particles and trace ozone that can oxidize and decompose harmful gases, while the electric field and high-energy particles inhibit gas production. High-energy charged particles and trace ozone produced by discharge can effectively kill or inactivate pathogenic microorganisms attached to dust particles and droplets. Ritz et al. reported that electrostatic space charge systems (ESCS) significantly reduced dust and ammonia concentrations in chicken houses. Yang et al. reported that high-energy photoelectric deodorization equipment and photoelectric deodorizers significantly reduced ammonia concentration, particulate numbers, and microbial concentration, improving air quality. Negative air ions carry negative charges, easily attracting, colliding with, and combining with positively charged pollutants in air to form larger molecules that settle, providing bactericidal, dust-reducing, and air-purifying effects. Jiao et al. installed artificial negative ion generators in houses, significantly reducing total aerobic bacteria and dust concentration, showing that artificial negative ions improve air quality and promote healthy livestock growth. These studies demonstrate that electro-purification technology has become an effective measure for poultry house air purification worthy of further research and promotion.

4 Summary

Air quality in broiler farms not only affects broiler disease prevention, health, and product quality, but also relates to human health. Strengthening research on the relationship between air quality and health and improving air quality are important for promoting healthy development of the broiler industry. Future research should combine advanced technologies such as high-throughput sequencing, proteomics, transcriptomics, and metabolomics to deeply investigate the hazards and mechanisms of airborne microorganisms, dust, and harmful gases. Additionally, meta-analysis methods should be used to integrate the effects of microorganisms, dust, and harmful gases, providing references for establishing air quality evaluation models and standards for broiler houses.

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