AMMONIA: A SILENT ENEMY IN POULTRY FARMING

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ABSTRACT: Ammonia (NH_3) is the most critical air pollutant among those related to animal husbandry, especially poultry farming. This gas can cause injuries to humans and animals, particularly in the respiratory tract, and even inflammation in the trachea and lungs. However, the damage extends further, affecting the cornea, liver, and intestines as well. NH_3 is also considered responsible for increasing serum levels of inflammatory mediators and uric acid, in addition to causing changes in the DNA of breast muscle cells, thereby reducing their quality. Therefore, a comprehensive and up-to-date understanding of the effects of this gas is crucial for all those involved in poultry farming.
KEYWORDS: Air pollutant; Broiler chicken; NH_3; Tracheitis.

AMÔNIA: INIMIGO SILENCIOSO NA AVICULTURA

RESUMO: Dentre os poluentes atmosféricos relacionados à criação animal, em especial a avicultura, o gás amônia (NH_3) é o maior deles. Esse gás pode causar lesões em seres humanos e nos animais, principalmente no trato respiratório, podendo gerar até inflamação na traqueia e nos pulmões. Sabe-se que os danos vão para além disso, afetando

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também córnea, fígado e intestino, por exemplo. O NH_3 também é apontado como responsável por aumentar índices séricos de mediadores inflamatórios e ácido úrico, além de causar modificações no DNA de musculatura de peito, diminuindo a qualidade desse. Assim, torna-se primordial a todos os envolvidos na avicultura uma compreensão aprofundada e atualizada sobre a ação desse gás.
PALAVRAS-CHAVE: Frango de corte; NH_3; Poluente atmosférico; Traqueíte.

AMONÍACO: ENEMIGO SILENCIOSO EN LA AVICULTURA

RESUMEN: Entre los contaminantes atmosféricos relacionados con la cría de animales, especialmente la avicultura, el gas amoníaco (NH_3) es el mayor de ellos. Este gas puede causar lesiones en humanos y animales, principalmente en el tracto respiratorio, pudiendo incluso generar inflamación en la tráquea y los pulmones. Se sabe que los daños van más allá, afectando también la córnea, el hígado y el intestino, por ejemplo. El NH_3 también se señala como responsable de aumentar los índices séricos de mediadores inflamatorios y ácido úrico, además de causar modificaciones en el ADN de la musculatura pectoral, disminuyendo su calidad. Así, se vuelve primordial para todos los involucrados en la avicultura, una comprensión profunda y actualizada sobre la acción de este gas.
PALABRAS CLAVE: Contaminante atmosférico; Pollo de engorde; NH_3; Traqueítis.

1. INTRODUCTION

Brazilian poultry farming ranks second globally, reaching 14.972 million tons of chicken meat in 2024 (ABPA, 2025). In this sense, this activity requires a reasonable investment, with the possibility of a return proportional to the company's administrative quality, as the profit margin is narrow (Oliveira *et al*., 2024).

Concerns about pollutant emissions are prevalent in animal farming, and poultry farming is no exception. Animal waste (rich in nitrogen) that accumulates in the litter is the main cause of ammonia (NH_3) emissions (Sousa *et al*., 2016), the most important atmospheric pollutant in poultry farming (Yi *et al*., 2016a). NH_3 is a colorless, corrosive, volatile gas with a repugnant odor (Hao and Yan, 2013). Its production is directly related to the pH, environmental temperature, and litter moisture (Bandeira *et al*., 2023; Ferreira and Bertolosi, 2024).

The NH_3 effect is widely cited in poultry farming (Wu *et al*., 2017; Xiong *et al*., 2016; Zhang *et al*., 2015a,b; Bandeira *et al*., 2023), including its impact on the DNA of birds, which can induce mutations (Yi *et al*., 2016). This has led to the search for methods capable of reducing the emission of this gas (Ezenwosu *et al*., 2024; Van Wagenberg; Koerkamp, 2024).

Therefore, constant updating and understanding of this gas is essential for those who intend to work and/or study in the various branches of poultry farming. This literature review is intended to contribute to scientific advancement.

2. DEVELOPMENT

2.1Definition

Ammonia is an alkaline, colorless gas that can also be found in liquid form (Davis *et al*., 2015). It has a repugnant and suffocating odor, is highly soluble in water, and occurs naturally in the environment, mainly resulting from the decomposition of organic material and forest fires or volcanic eruptions (Toxnet, 2018). It is the most worrying air pollutant in poultry farming (Davis *et al*., 2015).

2.2 Origin

Ammonia is released from the fermentation of organic compounds present in poultry litter, together with bird waste, which is rich in nitrogenous components such as uric acid (80%), ammonia (10%), and urea (5%) (Davis and Morishita, 2005; Davis *et al*., 2015). Once excreted, urea and uric acid are rapidly converted into ammonia by the enzymatic action of the excreta and degradation by the microbiota (mainly *Bacillus pasteurii*) (Davis *et al*., 2015).

The formation and release of this gas depend on several factors such as temperature, pH, and moisture of the litter (Brainer *et al*., 2022). However, low or very high levels of moisture in the litter have been shown not to interfere with ammonia emissions (Ferreira; Bertolosi, 2024; Wei *et al*., 2015) (Figure 1).

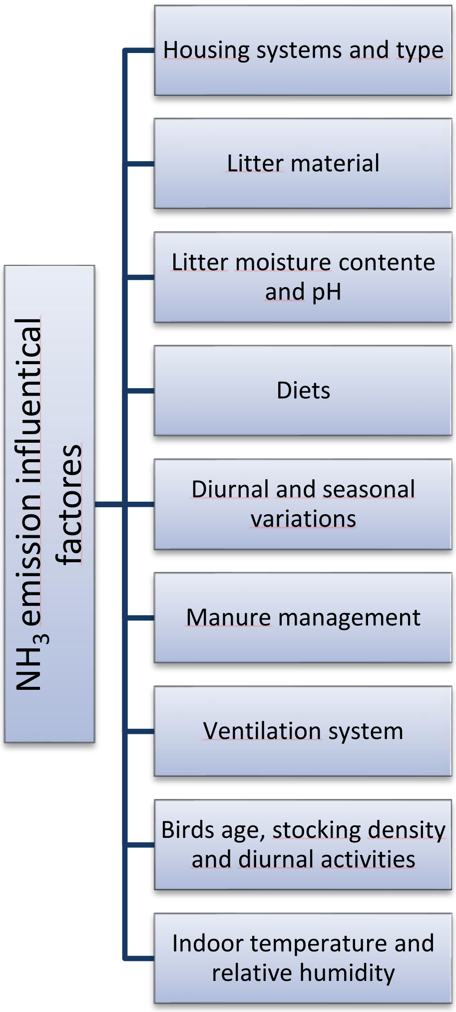

Figure 1: Key factors influencing ammonia (NH_3) emissions in poultry production. These include housing systems and type, litter material, litter moisture content and pH, dietary composition, diurnal and seasonal variations, manure management, ventilation systems, bird age, stocking density, diurnal activities and indoor temperature and relative humidity. Each factor plays a critical role in determining the level of ammonia volatilization and its impact on environmental and animal health. Adapted from Chai, 2023.

Bandeira *et al.* (2021) demonstrated that ammonia emission exhibit cyclical patterns, peaking around noon, in both winter and summer in the Northeast region of Brazil. The authors also found higher ammonia emissions during winter, a time when the average temperature is lower. It suggests that the considerable variation in temperature during this season favors this phenomenon, as this variation stimulates the microbiota present in the litter to metabolize more nitrogen compounds.

Chicken litter is an absorbent material that covers the floor of poultry housing, receiving the excreta of these animals (Campos *et al*., 2018). The expected function of this litter is to absorb moisture from bird feces, as well as other organic materials that mix with it, to provide a soft surface that prevents mechanical injuries to the birds, and creates thermal insulation (Campos *et al*., 2018; Carvalho *et al*., 2011). The materials most commonly used as litter in poultry farming are rice husks, shavings, sawdust, paper and shredded grass (Campos *et al*., 2018; Carvalho *et al*., 2011).

The type of litter to be used will also influence the emission of this gas. Freitas *et al.* (2011) tested six types of litter for ammonia emissions (sugarcane bagasse, shavings, rice husks, Napier grass, sugarcane bagasse + rice husk, and sugarcane bagasse + shavings) and observed a change in gas emissions only occurs after the 28th day when litters with sugarcane bagasse + shavings and Napier grass presented the lowest and highest gas emission rates, respectively. Although moisture is a major influencer of NH_3 emissions, there is a limit to its participation, that is, when litter moisture becomes very high, ammonia levels do not necessarily increase accordingly (Bandeira *et al*., 2021).

2.3 Harmful effects of high ammonia concentration

The presence of ammonia is a problem not only for animal health but also for employee health and is one of the main environmental problems related to animal husbandry (Douglas *et al*., 2018; Medeiros *et al*., 2008). Cattle, pig, and poultry farming produce increasing amounts of air pollutants, especially ammonia, which affects the health of humans exposed to it and can cause eye and skin irritation, respiratory tract injuries, headaches, and vomiting and these changes can worsen and even lead to the death of the individual (Iversen *et al*., 2000; Schiffman, 1998).

Humans can detect the presence of ammonia at concentrations as low as 10 ppm, mainly due to the repugnant odor and the irritating action of the gas on the eyes and respiratory mucosa. It can cause chronic sinusitis when exposure is chronic, consequently desensitizing the person to the presence of ammonia, allowing its-presence to persist in places with high levels of ammonia (Davis *et al*., 2015).

The signs in birds are similar to those seen in humans. Oyetunde *et al*. (1978) described that the birds presented respiratory difficulty moments after the emission of ammonia, characterized by head movements and redness of the eyes and skin under the wing feathers. Subsequently, the birds started panting, stumbling, and lying down next to the door. This behavior stopped after a while and returned every time the gas was injected into the chamber.

It is well-documented in the literature that even at low concentrations, such as 25 ppm, ammonia can cause lesions in the respiratory tract of birds (Anderson; Beard;

Hanson, 1964; Al-Mashhadani; Beck, 1985; Ansari *et al*., 2016). Excess mucus in the trachea (Anderson; Beard; Hanson, 1964; Al-Mashhadani and Beck, 1985) and edematous, inflamed lungs with hemorrhagic points (Anderson; Beard; Hanson, 1964) are among the macroscopic lesions.

Microscopic lesions in the respiratory tract show areas with loss of cilia, mainly in the upper portion of the trachea (Oyetunde *et al*., 1978), which appear to have a higher number of goblet cells, which makes sense due to the higher presence of mucus (Al-Mashhadani; Beck, 1985), which may present hypertrophy and depletion (Bandeira *et al*., 2023). It also presents deterioration of the tracheal tissue structure, which may lead to severe deformation of the mucous layer (or even mucosal detachment), inflammation in the lamina propria (tracheitis), edema in the submucosa, and congestion (not associated with inflammation) (Zhou *et al*., 2021; Bandeira *et al*., 2023).

Bandeira *et al.* (2023) found that temperature also directly influences the appearance of tracheal lesions, with more lesions and higher spacing of the tracheal mucosa being observed at higher temperatures. The authors also inferred that the reuse of poultry litter in broiler production may be a contributing factor to the increase in these lesions associated with ammonia.

The mechanisms of action of the gas on the trachea have been the subject of several studies. It has been suggested that levels of 15 ppm of ammonia are sufficient to cause severe lesions in the upper portion of the trachea (Zhou *et al*., 2021). Moreover, most of the appearance of these lesions is believed to be due to the alkalinization of the tracheal mucosa, which leads to an imbalance in the microbiota present there, leaving the epithelium more vulnerable to the action of various pathogens, including those with systemic action (Xiong *et al*., 2016).

There is evidence of an increase in the thickness of the alveolar wall in the lungs, reducing the lumen of the alveolus, sometimes with areas of atelectasis (Al-Mashhadani; Beck, 1985). It also leads to an increase in capillarity, hyperemia, and higher chemotaxis of inflammatory cells (Liu *et al*., 2024). On the contrary, Curtis *et al.* (1975) suggested that the lower respiratory tract would not be affected by the action of ammonia because this gas is highly soluble in water and would, therefore, bind to the mucus in the upper respiratory tract, without reaching the lungs.

These lesions may initially seem small but end up leaving the birds susceptible to pathogens that can cause great economic losses (Anderson; Beard; Hanson, 1964;

Oyetunde *et al*., 1978). In this case, they depress the immune response of the birds (Wei *et al*., 2015) and increase the levels of several inflammatory mediators (An *et al*., 2019; Xiong *et al*., 2016; Zhou *et al*., 2021), mainly TNF-α (Liu *et al*., 2024).

In addition to the respiratory tract, irritation of the photoreceptor apparatus is also reported, causing corneal lesions, marked photophobia, eye redness, and tearing (Anderson; Beard; Hanson, 1964). However, these lesions appear to be transient from the 28th day of exposure to NH_3 at constant concentrations of up to 25 ppm (Miles *et al*., 2006).

Lesions in the bird's pads have also been described, although the emission of ammonia cannot be directly related to the appearance of foot disease. The ammonia produced by the bacteria present in the litter is mainly mixed with litter moisture, causing this microenvironment to become alkaline and, consequently, acting as an irritant in the pads (Stojcic *et al*., 2016).

There are also reports of liver changes, resulting in reduced performance (Liu *et al*., 2024; Zhang *et al*., 2015a). The described lesions include inflammatory infiltrates, hyperemia, fracture of the splenic cords, and atrophy of the red pulp, increased lymphocytes, and amyloidosis surrounding the muscular layer of the arterial wall (An *et al*., 2019). Macroscopically, liver pallor has been reported (Zarnab *et al*., 2019), probably due to increased cholesterol deposition in the organ (Sa *et al*., 2017).

A reduction in breast muscle (Yi *et al*., 2016b), as well as changes in fat deposition, quality, and palatability of this cut, mainly due to the expression of several genes responsible for controlling lipid metabolism in birds, has also been reported (Yi *et al*., 2016a).

Zhang *et al.* (2015b) identified a decrease in growth rate, a reduction in intestinal villi and crypts, delayed development of lymphoid organs such as the cloacal pouch, and serum indicators of oxidative stress, including increased CK (creatine kinase) and low T-SOD (total superoxide dismutase). Liu *et al.* (2024) detected a significant increase in serum uric acid in birds exposed to ammonia levels above 15 ppm.

In addition, there is a decrease in the appetite of birds and a consequent decrease in productivity, both for broilers and layers (Charles; Payne, 1966; Lu *et al*., 2016). Up to 14.4% reduction in chicken carcass weight has been recorded when under conditions of up to 25 ppm of ammonia (Zarnab *et al*., 2019).

2.4 Mitigation strategies for reducing ammonia emissions

Ammonia emissions in broiler production pose significant environmental, economic, and animal welfare challenges. There are two main strategies to control air pollutant emissions in animal houses: pre-excretion (reducing emissions at the source, such as through diet manipulation and feed additives) and pre-release (removing pollutants from gas flow before dispersal, using methods like litter additives, improved management, or innovative housing designs). Mitigation technologies can be categorized into microbiological, biochemical, chemical, managerial, physical, and physiological methods (Chai, 2023).

Key strategies to control ammonia emissions in broiler houses include dietary manipulation, such as reducing crude protein levels and incorporating feed additives like enzymes, probiotics, and yucca extract to improve nitrogen utilization (Orffa, 2024). Additionally, interference in the nitrogen cycle can be achieved by incorporating zinc into poultry diets, which may prevent uric acid formation. Furthermore, a separate analysis of broilers demonstrated that inhibiting microbial uricase activity through dietary zinc supplementation can significantly mitigate nitrogen losses (Swelum *et al*., 2021). Li *et al.* (2025) indicates that oxychar pellets exhibit a 393.6% increase in NH_3 uptake compared to powder, primarily due to the formation of C–N covalent bonds, which reduces NH_3 volatilization from poultry litter by 77.6%. The compacted structure of the pellets results in higher bulk density and enhanced water resistance, while simultaneously minimizing the risk of self-heating, dustiness, and weight. Furthermore, the formation of amine and amide compounds contributes to the high stability of adsorbed NH_3.

Improved litter management techniques, including the use of absorbent bedding materials and chemical additives like alum and zeolites, help reduce ammonia volatilization (Orffa, 2024). Litter additives have shown mitigation efficiencies of 50% in broiler houses and 80-90% in cage-free hen litter with higher application rates (0.9 kg/m²) (Chai, 2023). The use of sulfuric acid and oxalic acid can significantly reduce ammonia emissions (Xue *et al*., 2025).

Ventilation optimization and advanced air-filtration systems, such as multi-stage acid scrubbers, can significantly reduce ammonia concentrations in poultry houses, achieving up to 95% efficiency in NH_3 mitigation (Orffa, 2024). However, the high costs associated with these technologies may hinder their adoption by farmers, highlighting the need for government assistance or subsidies to facilitate broader implementation (Chai, 2023). Nevertheless, when employed in conjunction with other environmental preservation strategies, such as biogas production through the fermentation of organic waste, it proves to be a viable economic alternative (Cimpean *et al*., 2024).

Additionally, innovative technologies such as biofiltration and acid scrubbers provide promising solutions for large-scale operations (Chai, 2023). Manure management, such as chemical treatment (addition of Al2(SO4)3, manure treated by $FeCl_2$, Fe_2SO_4, $CaCl_2$, CaO, and $Ca(OH)_2$), microbial manipulation, or biological nitrification, is being studied to reduce this problem (Salim *et al*, 2014). Adopting these strategies not only improves animal health and welfare but also enhances sustainability in broiler production by mitigating the environmental impact of ammonia emissions (Chai, 2023).

3. FINAL CONSIDERATIONS

The emission of ammonia is an inevitable byproduct of poultry farming, but its harmful effects on animal health, productivity, and the environment underscore the urgency for effective mitigation strategies. This review highlights that a multi-faceted approach encompassing dietary manipulation, optimized litter management, advanced ventilation systems, and innovative technologies such as biofiltration and acid scrubbers can significantly reduce ammonia levels. However, successful implementation requires balancing cost-effectiveness and efficiency, necessitating government subsidies or support to make these solutions accessible to farmers. By addressing ammonia emissions, the poultry industry can enhance animal welfare, improve environmental sustainability, and ensure long-term productivity. Continued research and collaboration among scientists, policymakers, and industry stakeholders are essential to developing and implementing these strategies on a global scale.

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AUTHORSHIP CONTRIBUTION

All authors contributed significantly to the conception, development, and writing of the article, fulfilling the authorship criteria established by the journal.