AMMONIA IN BROILER PRODUCTION: HARMFUL EFFECTS AND MITIGATION STRATEGIES

Compared to other livestock commodities, poultry is the most consumed in the world and will continue to grow in the coming years. Intensive broiler production plays an important role in meeting the growing demand for animal protein. This sector is mainly characterized by large scale facilities, housing highly efficient and fast growing birds at high stocking densities. Although in general defined by efficiency, intensive broiler production also faces some challenges, for example high ammonia (NH_3) emissions. Ammonia is the main gaseous pollutant produced and emitted from poultry facilities and there are growing concerns with regards to its environmental and health impact. Therefore, strategies need to be implemented to mitigate NH_3 emissions.

How is NH_3 formed?

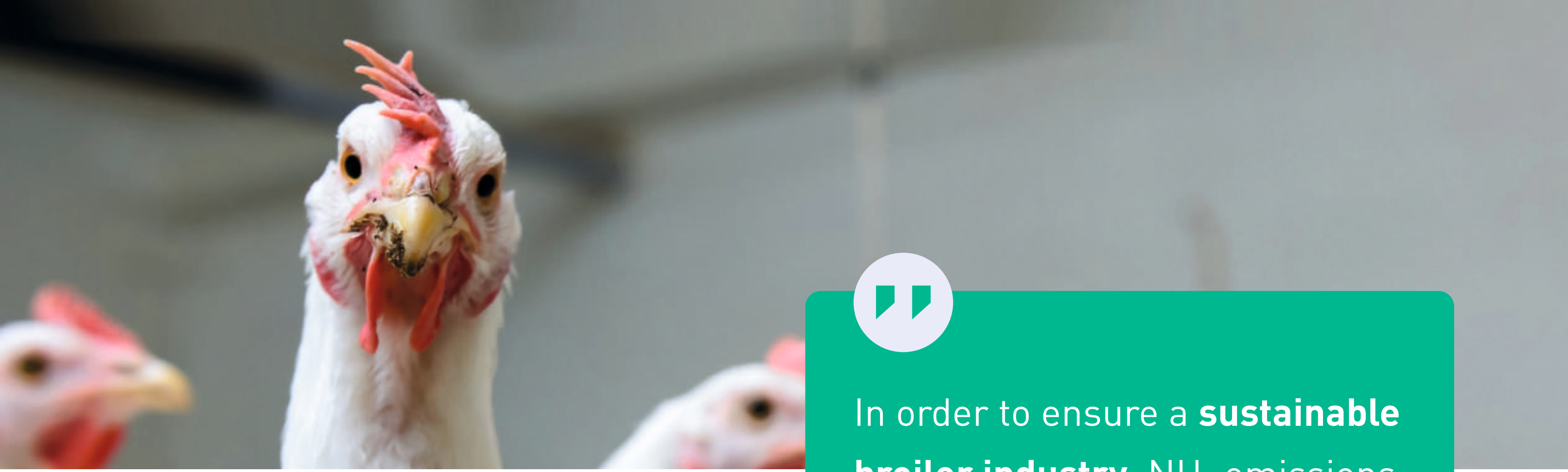
In broiler production, NH_3 emissions can occur during the rearing period, from stored litter removed from broiler houses, and during or after the application of litter to fields as fertilizer. In the litter, NH_3 originates from the microbial degradation of uric acid and undigested feed proteins excreted by the birds. This degradation process requires water and oxygen, while NH_3 and carbon dioxide are generated. In the moist litter layer or excreta, the total ammoniacal nitrogen (TAN) formed exists as an equilibrium between ionised ammonium (NH_4^+) and volatile ammonia (NH_3). Only the volatile NH_3 fraction can be released from the litter to the environment. About 50% to 80% of the nitrogen present in the excreta can be converted into TAN. The formation of TAN and the equilibrium between the NH_4^+ and NH_3 fractions depend on several factors. Moist, aerobic, and alkaline litter conditions as well as high litter temperatures, and a high concentration of substrate (nitrogen) will increase the formation of TAN. At a high litter temperature and pH, nearly all of the TAN will be present in the volatile NH_3 form. In addition to the litter pH, temperature, moisture and oxygen content, the volatilization of NH_3 from the litter layer is also influenced by the near-air floor velocity and the physical condition of the litter.

What are the effects of NH_3?

Ammonia not only presents an environmental risk, but high NH_3 concentrations inside the rearing facilities as well as prolonged exposure to this volatile compound, may lead to productivity losses in broilers and broiler breeders. Furthermore, it can create unhealthy working conditions for the farmer or farm workers.

Ammonia emitted from the poultry operations can contribute to the formation of fine particulate matter ($PM_{2.5}$), an air pollutant. In this form, NH_3 can be deposited either close to its source or transported over large distances, also impacting the environment further away. Once deposited in the environment, NH_3 can cause soil and water acidification, shifts in plant species, and loss of plant biodiversity. Eutrophication of water can increase algal blooms in surface waters and damage aquatic ecosystems.

In many countries, the maximum levels of NH_3 in the poultry houses are set at 20 to 25 ppm. Due to adverse health effects, poultry breeding companies recommend that, ideally, NH_3 in the broiler house should remain below 10 ppm. These concentrations can easily be exceeded, however, especially during the winter periods when ventilation is decreased to maintain optimal indoor temperatures.



> In order to ensure a **sustainable broiler industry**, NH_3 emissions should be **reduced**

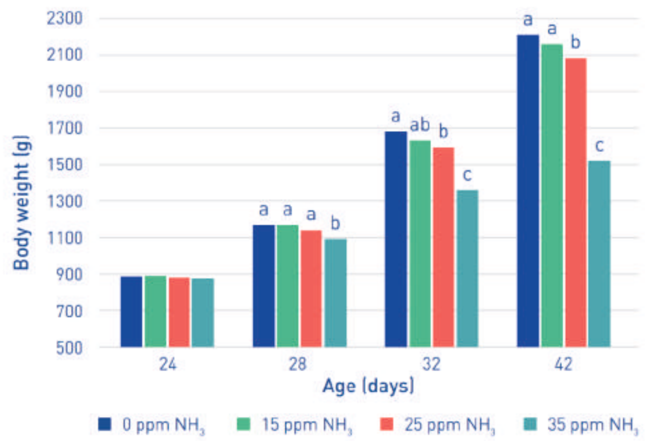


Figure 1: *Effect of ammonia (NH_3) (0, 15, 25, and 35 ppm) on the body weight of broiler chickens between 22 and 42 days of age (Data from Zhou et al., 2020).*

Research shows that exposure to high concentrations of NH_3 (between 50 and 75 ppm) causes reduced weight gain, final body weight, and feed efficiency, and increased mortality rate in broilers. Even a prolonged exposure to lower NH_3 concentrations (25 ppm and 35 ppm) has been shown to reduce broiler weigh gain, body weight (Figure 1), and feed efficiency. In breeding birds, high levels of NH_3 can cause a decrease in egg production, egg weight and eggshell thickness. The negative effects of NH_3 on broiler performance is of economic importance as reduced productivity and increased mortalities directly translates to a lower income for the farmer.

Ammonia is a highly water-soluble gas and can dissolve in the moisture of the eyes and mucous membranes of the respiratory system. Exposure of chickens to relatively low concentrations for 6 weeks resulted in respiratory tract damage. An increase in conjunctival lesions was also reported when birds were exposed to NH_3 concentrations of 30 and 60 ppm. Ammonia is also a corrosive substance and when present in the litter, it can induce lesions to the feet and hocks (Figure 2). Another, less observable, effect reported in chickens is an increased susceptibility to diseases such as Newcastle disease. Studies have shown that NH_3 can also act as a non-infectious trigger to initiate the inflammatory process by activating inflammatory pathways. Excessive inhalation of NH_3 can lead to oxidative stress and induce cardiac inflammatory injury. Furthermore, exposure to NH_3 can also lead to dysbiosis of microbiota in the trachea and intestinal tract, leading to inflammation in the trachea and intestinal tract, respectively.

The numerous negative effects of NH_3 on the environment as well as on animal and human health highlights the need for solutions to reduce the formation and subsequent emissions of NH_3 from broiler operations.

Figure 2: *Ammonia is a corrosive substance and its presence in the litter can induce foot pad dermatitis.*

Nutritional strategies to mitigate NH_3 in broiler production

To achieve a reduction in indoor NH_3 concentrations, various interventions are possible. Good ventilation management can act to remove NH_3 from the broiler house, but this does not prevent the formation of NH_3 inside of the broiler house. Nutritional strategies are the key to decrease the indoor concentration of NH_3 and subsequently NH_3 emissions by reducing the amount of nitrogen excreted by the broilers or limiting the amount of NH_3 volatilized from the litter.

Nitrogen excretion is highly correlated to nitrogen intake. Reduced crude protein diets (supplemented with synthetic amino acids to maintain optimal amino acid ratios) have been shown to reduce nitrogen excretion and NH_3 emissions in broilers and broiler breeders. By avoiding the overfeeding of crude protein and amino acids, the fraction of uric acid excreted by the bird will be reduced. This can significantly impact NH_3 formation and volatilization as uric acid nitrogen is degraded more rapidly than nitrogen that is excreted via the faeces. Furthermore, a lower uric acid excretion by the bird will also cause a lower water intake (leading to drier litter) and may reduce the incidence foot pad dermatitis and hock burn in broilers. Another approach to reduce the protein intake of broilers is by implementing phase feeding. This involves the adjustment of the dietary nutrient content closer to the requirements of the broilers in order to avoid the overfeeding of protein and amino acids. In broilers, the application of a 6- instead of a 4-phase feeding program reduced NH_3 emissions by 22%. A decrease in the dietary crude protein content of broiler feeds generally involves reducing the amount of soybeans and soybean meal in the diet. These feedstuffs are high in potassium and their reduction can decrease the dietary electrolyte balance (Na + K Cl), which in turn can lead to a lower water intake and a reduced litter moisture content. A lower litter moisture content can reduce the formation of NH_3.

The inclusion of a range of feed enzymes and additives is already standard practice in commercial broiler feeds. As enzymes such as amylase, xylanase, protease, and phytase can improve the utilisation of nutrients such as protein, the excretion of nitrogen can be reduced and, as a consequence, the formation and volatilization of NH_3 from the litter. Furthermore, the addition of enzymes to broiler feeds should allow for a dietary crude protein reduction. The water binding capacity of clays such as zeolites can increase the dry matter content of the excreta and, consequently, of the litter. Furthermore, clinoptilolite has a high cation exchange capacity and therefore high affinity toward NH_4^+ and NH_3. The adsorption of NH_3 by clinoptilolite can improve intestinal health and may prevent the volatilization of NH_3 from the broiler litter. Saponin extracts are well-known for their use in reducing NH_3 emissions and odour. Saponins have various modes of action and can act to reduce NH_3 emissions by directly binding to NH_3, improving the digestibility of nutrients such as protein, or inhibiting the enzymes involved in the conversion of uric acid to TAN.

The inclusion of fermentable fibres such as distillers dried grains with solubles (DDGS), wheat middlings, or soybean hulls in the diet may also contribute to reduce NH_3. The microbial fermentation of these fibrous feedstuffs causes the production of volatile fatty acids which can lower the pH of the excreta and increase the non-volatile NH_4^+ fraction of the TAN.

Conclusion

In order to ensure a sustainable broiler industry, NH_3 emissions should be reduced. Nutritional strategies are essential to reduce the NH_3 originating from broiler production at the source. A reduction in NH_3 will have a positive influence on the indoor climate and, consequently, the well-being of the animals and the farmers will be improved.