

Assessment of Ammonia Emissions from Broilers Using Respiration Chambers

X. D. Zhang, Q. P. Lu[#], H. F. Zhang, L. H. Meng, X. F. Tang

The State Key Laboratory of Animal Nutrition, Institute of Animal Sciences, Chinese Academy of Agricultural Sciences, Beijing 100193, China

#Email: luqingping@sina.com

Abstract

This study was conducted to investigate ammonia (NH₃) emission factors and characteristics from broilers using respiratory chambers. Three hundred 1-day-old healthy Arbor Acres broilers with similar body weights were randomly allotted into three respiratory chambers. The broilers were reared on the net, and manure was not cleared until day 42. A continuous monitoring system for ventilation rate and NH₃ concentration was used in this research to measure NH₃ emissions. Total NH₃ emissions from day 1 to day 42 were estimated at 2777.78±55.58 mg per bird, the mean emissions rate (ER) was 66.14±1.32 mg/bird/d, and body weights averaged 2530.95±57.74 g. The daily ER showed a trend of increasing relative to the age and weight of the broiler before decreasing. The rise in estimated NH₃ emission rates occurred along with an increase in ventilation rate. From day 22 to day 42, NH₃ emissions increased with the thickness of broiler manure first and then decreased.

Keywords: *Broiler; Ammonia; Emission Rate; Emission Characteristic*

1 INTRODUCTION

Broiler production has become increasingly concentrated in recent years, which has resulted in more waste products emitted into the atmosphere. In the poultry industry, ammonia (NH₃) volatilization is a major environmental concern. The high concentrations of NH₃ produced from broiler houses can affect the health of workers and animals (Zhang et al., 1998; Charavaryamath et al., 2006; Singh et al., 2004). NH₃ emissions can increase nitrogen deposition into ecosystems, which causes acidification of soils and reduces species diversity in native ecosystems (Schuurkes et al., 1988). Reasonable estimates of NH₃ emissions are needed by the poultry industry in order to participate in discussions about the industry's impact on local and regional air quality. Quantitative estimates of the effectiveness of the various major abatement strategies for reducing NH₃ emission from facilities are also required to provide guidance to the industry on the most effective strategies for managing NH₃ emissions. Measurement of emission rate requires the simultaneous measurement of ventilation rate of the house and the gradient of pollutant concentration between the building and the environment (Phillips et al., 2000; Heber et al., 2001). The principle looks very simple; however, in practice, both values are difficult to determine accurately within commercial poultry house conditions. The objective of this study was to measure NH₃ emissions from poultry production. The experiment was carried out in respiration chambers, which have advanced ventilation equipment and gas monitoring systems. Through the quantitative analysis of NH₃ emissions, we have provided the basic data necessary to assess the impact of broiler breeding on the environment.

2 MATERIALS AND METHODS

2.1 Broiler and Diets

Three hundred (150 females, 150 males) 1-day-old commercial broiler chicks (Arbor Acres) were randomly allotted to 1 of 3 respiration chambers. The broilers were reared on the net, and manure was not cleared until day 42. Continuous lighting was provided.

The environmental factors were consistent. Throughout the 42-d experimental period, feed and water were offered ad libitum. A 2-phase feeding program was used: days 0 to 21 and days 22 to 42. The feeds were analyzed for crude protein and were found to contain 21.27% and 19.94%, respectively.

2.2 Gas Monitoring System

Each chamber has an air inlet pipe and an exhaust pipe. The air was circulated with fans. Oxygen was supplemented when the pressure fell below atmospheric pressure. Ventilation of each chamber was detected by a TH100 flow meter. Before the experiment, the flow meters were calibrated and sealing performance was evaluated.

The air in inlet pipe and exhaust pipe was sampled by the gas monitoring system. When sampling, the system worked continually. Gas was transported to the INNOVA 1412. Each gas sample was measured three times for 1 min per measurement. The data were recorded by computer.

2.3 Emissions Calculation

NH₃ emission was calculated as follows:

$$ER = VR \times \frac{(NH_{3out} - NH_{3in})}{N} \times T \times \frac{M}{22.4} \times \frac{273}{273 + t} \times 60 \times 10^{-6}$$

Where

ER: g/bird/d; emission rate of NH₃

VR: L/min; ventilation rate of the building

NH_{3out}: NH₃ concentration of building exhaust air (ppm)

NH_{3in}: NH₃ concentration of building inlet air (ppm)

N: the number of broilers in each chamber

T: the ventilation time, 24h

M: molar weight of NH₃ (17.031 g mole⁻¹)

t: the chamber temperature (°C)

2.4 Fecal pH, Temperature and Thickness

In the early morning of days 7, 14, 21, 28, 35, and 42, broilers were weighed after fasting 12h. Fecal pH was measured beginning at d5. Using five-point diagonal sampling, each point represented 2 g. After mixing, 5 g was added to 50 ml deionizer water (boiled to get rid of CO₂) in a 100-ml beaker. The mixture was stirred for 15 min, incubated for 30 min, and assessed using an IQ150pH pH meter.

On each morning beginning at d22, fecal temperature was measured using a JM222 thermometer. Using five-point diagonal sampling and a site 2 cm below the excreta surface, thickness was measured with a ruler.

3 RESULTS

3.1 Ventilation and Ammonia Concentration

The minimum ventilation rate was set according to the amount of oxygen that broilers required at different ages. The setting values from 1 to 6wk are 300, 700, 1000, 1500, 1800 and 2000 L/min/100birds, respectively. The detected values are shown in Figure 1.

During days 1–9, the ventilation increased to 500 L/min/100bird gradually and remained at around 600 L/min/100 birds in during days 10–17. From d18, the ventilation increased gradually, and reached 2000 L/min/100 birds. During days 38–42, it remained at around 2000 L/min/100 birds. Throughout the growing period, the ventilation complied with the needs of broilers.

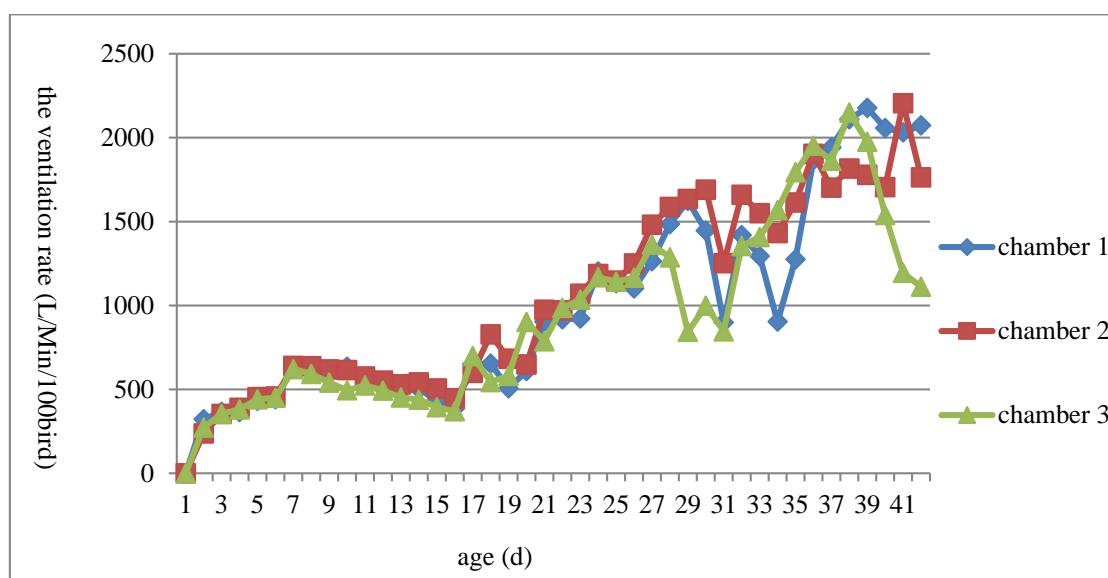


FIG. 1 THE MEASURED VENTILATION RATE OF CHAMBERS

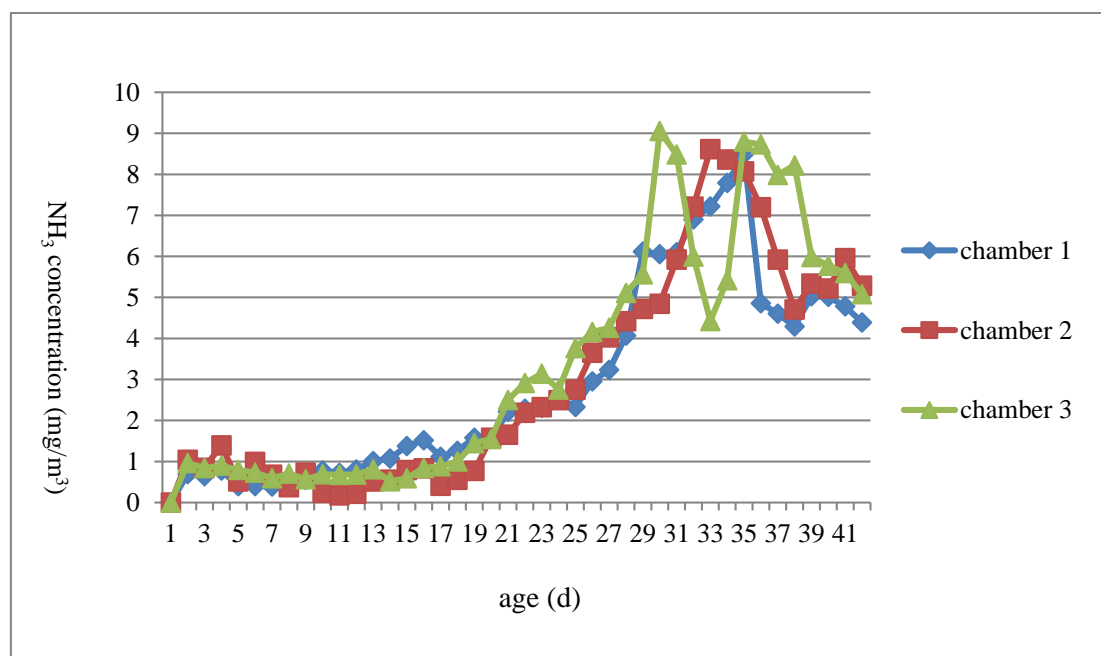


FIG. 2 THE AMMONIA CONCENTRATION IN CHAMBERS

On the condition of setting ventilation, the NH_3 concentration in each chamber is shown in Figure 2. During days 1–15, the concentration remained at 0–2 mg/m^3 . From d16, it began to increase and reached 9 mg/m^3 at d36. Then, it appeared to follow a decreasing trend and, by d42, the concentration was between 4 and 6 mg/m^3 .

3.2 NH_3 emissions

Based on the results of ventilation and concentrations measured above, the weekly accumulated emissions from 1 to 6 wk are (27.92 ± 8.84) , (40.52 ± 8.21) , (99.96 ± 4.72) , (424.81 ± 40.55) , (960.21 ± 124.92) , and (1146.39 ± 100.68) $\text{mg}/\text{bird}/\text{week}$, respectively. The daily NH_3 emission is shown in Figure 3.

During days 1–17, the emission was low, below 10 $\text{mg}/\text{bird}/\text{d}$. At d18, it was 10.19 $\text{mg}/\text{bird}/\text{d}$. Beginning at d19, NH_3 emissions began to increase and reached 203.86 $\text{mg}/\text{bird}/\text{d}$ at d36. During days 37–42, the emission rate declined slowly and, at d42, was 135.00 $\text{mg}/\text{bird}/\text{d}$.

During the growing period, total NH_3 emissions were estimated to 2777.78 ± 55.58 mg per bird, mean ER was 66.14 ± 1.32 $\text{mg}/\text{bird}/\text{d}$, and body weight averaged 2530.95 ± 57.74 g .

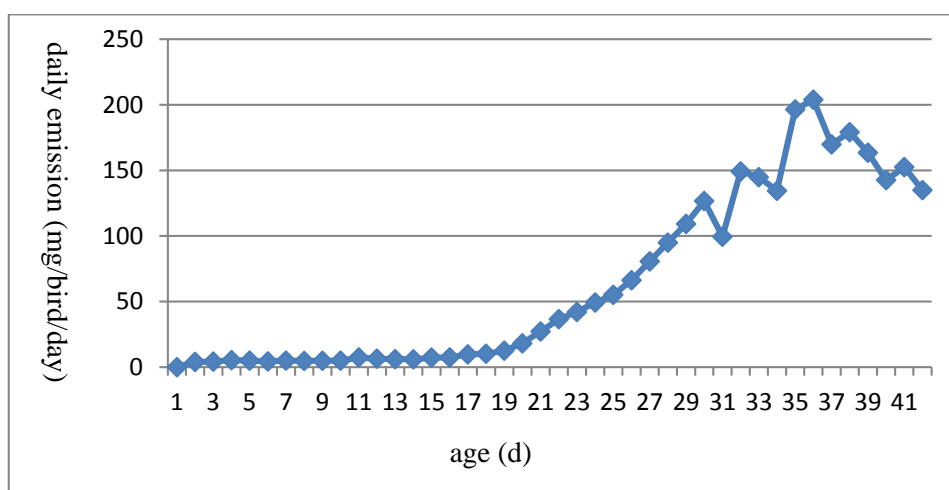


FIG. 3 DAILY NH₃ ER CHANGES IN BROILERS PRODUCTION PROCESS

3.3 Fecal Indicators

Throughout the experiment, fecal pH, accumulated thickness, internal temperature, and moisture were measured. Fecal pH measurements are shown in Figure 4. During days 1–16, the fecal pH was about 6.00, which increased to 6.68 at d40. At d42, the pH decreased to 6.31. During weeks 1–3, the cumulative manure thickness was about 2 cm. At 6 wks, the thickness grew to 6.91 cm.

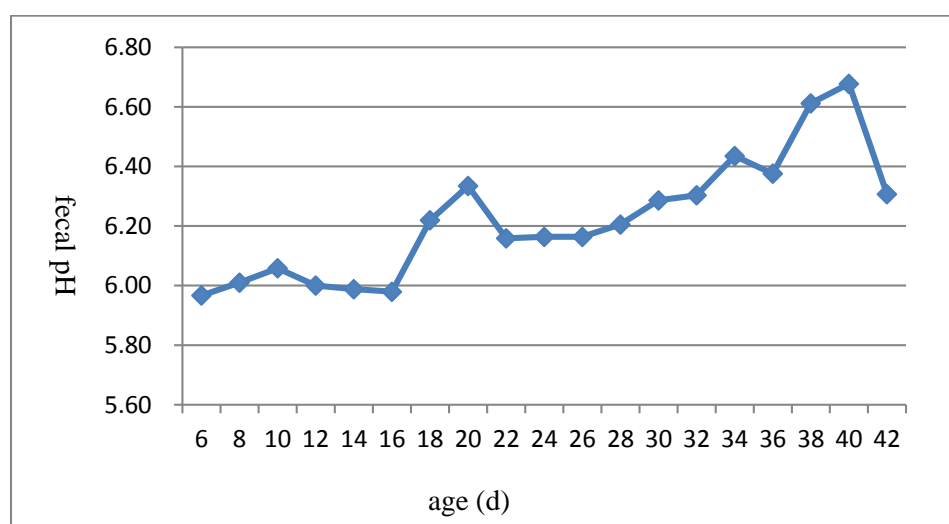


FIG. 4 pH OF BROILER MANURE

The water content of manure began at 24.79% during the first week and increased to just over 60% by week 4, where it leveled off (Table 1).

TABLE 1 WEEKLY MANURE MOISTURE CONTENT

Age (d)	d7	d14	d21	d28	d35	d42
Moisture (%)	24.79	34.45	46.35	61.67	62.65	61.27
SED	6.51	7.13	11.71	6.07	5.57	6.02

3.4 NH₃ Emission Varies with Body Weight

Using the measured weight at each week, we determined the relationship between weight and age by polynomial regression. This relationship was defined by the equation was $y = 0.965x^2 + 17.45x$ ($R^2=0.997$).

The linear regression equation between the NH₃ emission per day and body weight was $y = -59.60x^3 + 222x^2 - 132.5x + 18.71$ ($R^2= 0.967$). The daily emission rate increased with weight.

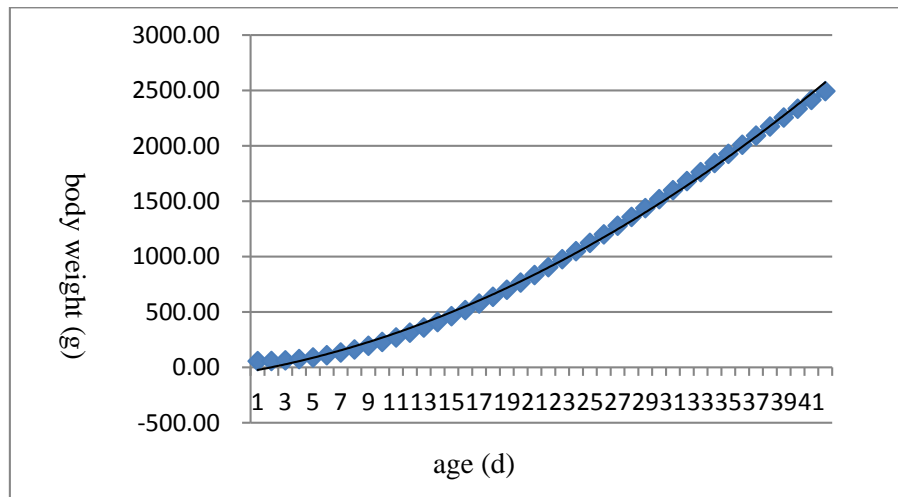


FIG. 5 MEAN LIVE WEIGHT OF BROILERS

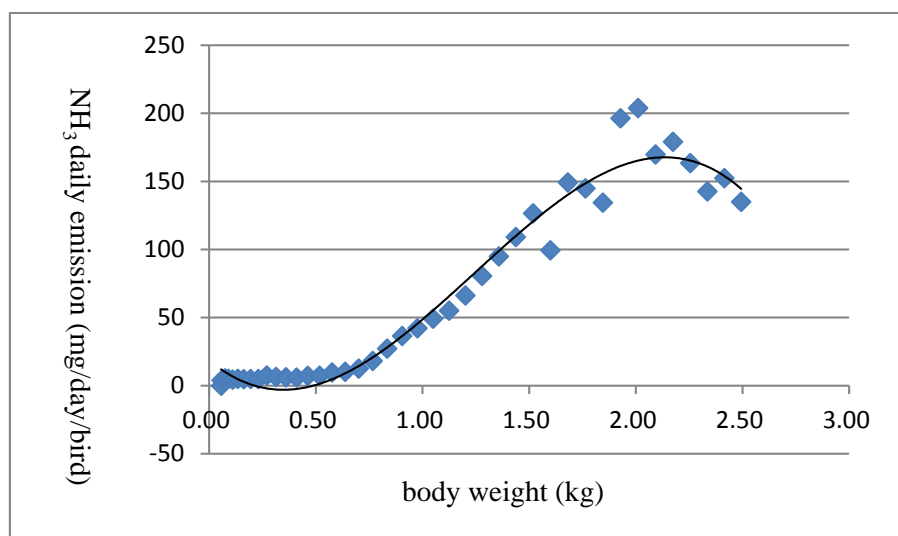


FIG. 6 NH₃ EMISSION RATES VERSUS BODY WEIGHT

3.5 NH₃ Emission Varies with Ventilation

The linear regression equation that relates daily emission and ventilation was $y = 0.117x - 53.64$ ($R^2=0.8715$, $P<0.0001$). The daily emission rate increased linearly with the increase in ventilation.

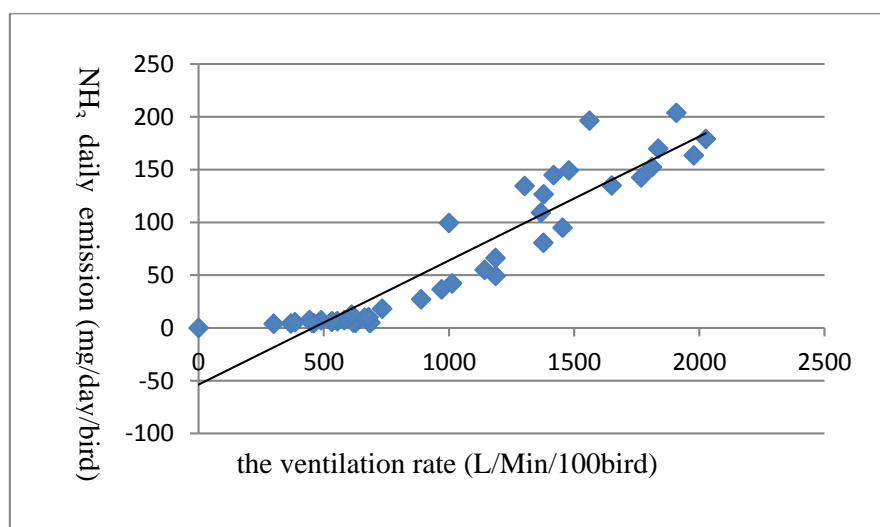


FIG. 7 NH₃ EMISSION RATES VERSUS VENTILATION RATE

3.6 NH_3 Emission Varies with Manure Thickness

By correlation analysis, there was a significant correlation between daily NH_3 and the thickness of manure.

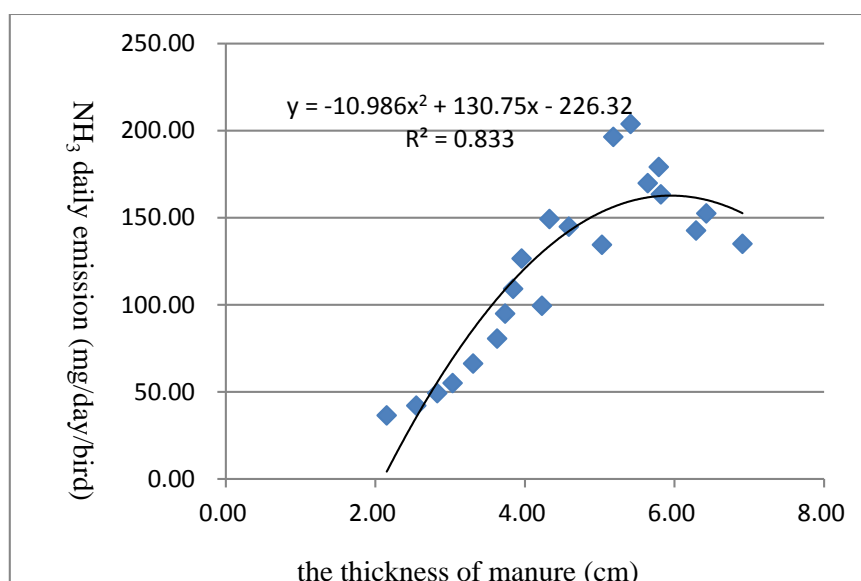


FIG. 8 NH_3 EMISSION RATES VERSUS THICKNESS OF BROILER MANURE

4 DISCUSSION

In China broilers can be reared on the net, with litter, in cages, and so on. Because rearing on the net can reduce the incidence of diarrhea, coccidiosis, and *E. coli* infection, and also improve the value of manure, it has become more popular in recent years. This study was carried out in airtight respiration chambers using advanced ventilation equipment and gas monitoring systems in order to monitor NH_3 emissions from broilers reared on net accurately.

4.1 ER under Different Conditions

Many researchers have studied NH_3 emissions from broilers, and the results have differed. In this paper, total NH_3 emissions during days 1 to 42 were estimated at 2777.78 ± 55.58 mg per bird, and the mean ER was 66.14 ± 1.32 mg/bird/d with an average body weight of 2530.95 ± 57.74 g. NH_3 emission measurements are affected by many factors, such as management practices, geographical location, and climatic conditions (Malone et al., 1992).

Wheeler et al. (2006) monitored 12 commercial broiler houses in the U.S. for 1 year and found that NH_3 emissions from using built-up litter houses were higher than from houses with new litter. Furthermore, the emissions earlier measured in Pennsylvania during cold weather were also consistent with this (Wheeler et al., 2003). Obviously, the broiler NH_3 emissions can be affected by litter usage. Coufal et al. (2006) show that nitrogen loss from built-up litter is higher than from fresh litter because litter usage time can significantly affect its ability to retain nitrogen, thereby affecting the production of NH_3 .

In addition, climatic conditions are main factors affecting NH_3 emissions. In different seasons and weather conditions, ventilation, temperature, and humidity differ significantly, which leads to differences in NH_3 emissions. Cheng et al. (2011) have found that NH_3 emissions in a Taiwan broiler house were 0.66 g/bird/d during the summer and 0.41 g/bird/d during the winter. Casey et al. (2004) studied NH_3 emissions from Kentucky broiler houses in winter, spring, and summer. The results showed that NH_3 emissions were between 0.14 and 1.92 g/bird/d, and were highest in the summer and lowest in the winter.

In China, Zhu et al. (2010) show that NH_3 emissions from broilers reared in cages was 140 mg/bird/d. This result differed substantially from the level found in the present study 66.14 ± 1.32 mg/bird/d. Compared with the above results, the NH_3 emissions rate found within this study is lower. The experiment is small-scale, and environmental parameters were controlled accurately. These results should reflect a NH_3 emission typical of broilers reared on the net.

From comprehensive studies, we can see that management practices, geographical location, and climatic conditions all affect broiler NH₃ emissions. Typically, NH₃ emissions from using built-up litter houses were higher than those from using houses with new litter and were higher in summer than in winter. NH₃ emissions were also different under different rearing styles.

4.2 NH₃ Emission Trend during Growing Period

NH₃ is mainly produced by the degradation of nitrogenous compounds. Uric acid, urea, and undigested protein in excreta are the main sources of NH₃ (Krogdahl et al., 1981). Body weight, fecal accumulation conditions, and other factors can affect NH₃ emissions.

In some reports, NH₃ emission increases linearly with age during the entire growth period (Wheeler et al., 2003; Wheeler et al., 2006; Lacey et al., 2003; Hayes et al., 2006). In this study, NH₃ emissions remained stable between d1 and d18. Furthermore, it appeared to linearly increase from d19 to d36. In some countries, broilers are usually reared on built-up litter, which allows the NH₃ to volatilize from litter continuously. In this experiment, there was no manure at the beginning. At the same time, there is less manure and accumulated feces when broilers are young. The high temperature of the chambers made the moisture content of the manure low. All of these factored contributed to the reduction in NH₃ emissions. With the increases in body weight and excretion starting at d19, the accumulation of manure increased rapidly, and NH₃ emissions increased significantly. This trend was consistent with the above reports. On the matter of rearing on litter or net, the accumulation of excretion is the reason for the increased emissions from litter rearing (Lacey et al., 2003; Hayes et al., 2006).

At the end of the breeding, the emission rate appeared to fluctuate and drop, which may relate to variations of fecal moisture and pH. Studies have shown that the degradation of uric acid into NH₃ requires water at many steps. The activity of microorganisms that provide enzymes to accelerate these reactions increases when water content is high (Kim et al., 2004). Thus, NH₃ production was reduced when fecal moisture was low.

At the end of the experiment, fecal pH fell to 6.31 from 6.68, which may have also reduced NH₃ production. Canh et al. (1998) showed that a slight change in fecal pH has a significant impact on the volatilization of NH₃. Fecal pH affects the balance between NH₃ and ammonium. When pH is low, the ammonium content is high, and NH₃ volatilization is low. In addition, broiler activity may also underlie this change. Studies have shown that in the final phase of the growth period, broiler activities were mainly lying and included less walking, and excretion was reduced (Newberry et al., 1990; weeks et al., 2000). This feature may also reduce NH₃ production.

Total NH₃ emissions during days 1–42 were estimated at 2777.78±55.58 mg per bird, and the mean ER was 66.14±1.32 mg/bird/d with an average body weight of 2530.95±57.74 g.

The daily ER during days 1–18 remained stable and then showed a trend of increasing with broiler age. The daily ER increased relative to broiler age and weight first but then decreased.

The rise in estimated NH₃ emission rates occurred along with an increase in ventilation rate. During days 22–42, the NH₃ emission rate increased with the thickness of broiler manure first and then decreased.

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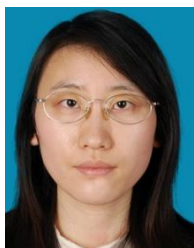
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AUTHORS



¹X.D. Zhang (1987-) Master and the major study field is animal nutrition and environment.

Email: zhangxd@kbimed.com.

²Q.P. Lu Corresponding Author. Associate Professor.

Email: luqingping@sina.com

³H.F. Zhang Professor. Email: zhanghf6565@vip.sina.com