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Ammonia Emissions in Tunnel-Ventilated Broiler Houses

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ABSTRACT

Gas production in broiler houses and their emissions are closely related to the microclimate established inside the house according to air temperature, humidity, and velocity. Therefore, the internal house environment is influenced by building typology and ventilation system. The objective of the present study was to evaluate ammonia emission rates in broiler houses equipped with different ventilation systems (negative or positive pressure) and litter conditions (new or built-up). The environment of six commercial broiler houses was evaluated internal and external NH_3 concentrations. Ventilation rates were recorded to estimate ammonia emission rates. The efficiency of circulation and exhaust fans was assessed, and higher ventilation rates were determined in negative-pressure houses due to the higher flow of the fans. Houses with new litter increased ammonia emission rates along the rearing period, indicating the relationship between gas emissions, bird age and ventilation rates, and presented a typical curve of NH_3 emission increase. Negative-pressure houses with built-up litter presented higher emission rates during the first rearing week due to the high NH_3 concentration during the brooding period, when the ventilation rates required to maintain chick thermal comfort are low. Although the results of the present study indicate an advantage of the positive-pressure systems as to gas emissions, further research is needed reduce gas emissions in broiler houses with negative-pressure systems.

INTRODUCTION

The broiler industry is one of the most technology-intensive and automated livestock activities. Its rapid progress during the past 50 years was allowed by improvements in the field of nutrition, which has promoted higher broiler weight gain in increasingly shorter periods, and in genetics, with the development of high-yield strains. Moreover, advances in the environmental control of broiler houses, providing thermal comfort, has allowed broilers to express their genetic potential.

Despite the advances in ventilation systems, it is difficult to analyze their performance, mainly due to changes in ventilation patterns and the use of different equipment in a same house, as reported by several studies (Vranken *et al.*, 2005; Casey *et al.*, 2008; Calvet *et al.*, 2010). The inaccuracy in the evaluation of gas emissions is probably due to factors such as long ventilation systems inside the poultry houses, and the complexity of measurement of air renewal in naturally-ventilated houses (Hinz & Linke, 1998; Calvet *et al.*, 2010). Ventilation rate was identified as a major source of uncertainty when evaluating gas emissions from livestock production (Gates *et al.*, 2009). Moreover, the understanding of some relations generated inside poultry houses, such as gas concentration and emission, may be a challenge.



Despite the large number of studies published on this subject in poultry production (Harper *et al.*, 2010), gas emission rates are difficult to compare due to differences in geographic locations, management practices, and litter material (Vergé *et al.*, 2009), leading to wide variations in the estimation of greenhouse gas emissions, according to Pescatore *et al.* (2005). Other authors also mention bird age, nutrition, and litter conditions as sources of variation in gas emission estimation (Fergusson *et al.*, 1998; Casey *et al.*, 2004 and Wheeler *et al.*, 2006).

Broilers houses present substantial differences in mechanic ventilation systems. The positive-pressure system is based on circulation fans, and most houses with this system are equipped with yellow curtains. Houses with negative-pressure systems use exhaust fans and blue curtains (blue houses) or are completely closed, and are called dark houses, which are also characterized by low lighting intensity.

These differences among broiler houses must be considered when evaluating the relationship between commonly used ventilation systems and the house environment. Based on this knowledge, improvements can be made in house air quality and litter conditions, thereby reducing health problems, carcass downgrading, and consequently, improving meat quality.

This study aimed at evaluating ammonia emissions in broiler houses with different ventilation systems and litter conditions (new or built-up litter).

MATERIALS AND METHODS

The study was carried out between 2008 and 2009 in three commercial broiler farms located in Capivari, Pedreira and Monte Alegre do Sul, state of São Paulo, Brazil. Six commercial broiler houses with mechanic ventilation were monitored during the rearing period of two flocks. The broiler houses presented two air renewal systems: negative pressure (houses B1, B2, D1 and D2) and positive pressure (C1 and C2). Table 1 shows the description of the broiler houses.

Houses were 3.5m high under the dropped ceiling,

and were equipped with fans with diameters between 0.91 and 1.29 m. Negative-pressure houses were also equipped with a cooling pad placed on the opposite wall of the exhaust fans. Litter materials were a mixture of rice and coffee hulls or wood shavings.

Adiabatic evaporative cooling was also provided by foggers distributed throughout the house. In all six broiler houses, two ventilation management systems were used to maintain the recommended environmental temperature: natural ventilation with side ventilation or tunnel ventilation. In the positive-pressure houses C1 and C2, ventilation rate was controlled by opening of side curtains. In the negative-pressure houses B1, B2, D1 and D2, ventilation rate was controlled by intermittently turning on the exhaust fans.

Straight-run Cobb® broilers were reared to a market age of 42-49 days. Birds were fed a commercial diet and water was supplied in nipple drinker. Feed and water were supplied *ad libitum* during the entire rearing period.

As gas emission rates are a combination of air pollutant concentrations and ventilation rates, measurement techniques were based in gas concentrations and on ventilation flow to calculate house ventilation rates. Emissions were estimated using the following equation, adapted from Zhang *et al.* (2005) and described as:

$$AER = Q (NH_{3,air, house} - NH_{3,air, out}),$$

where: AER = ammonia emission rate (kg h⁻¹), Q = ventilation rate (m³ h⁻¹), NH_{3,air, house} = air ammonia concentration inside the broiler house (kg m⁻³) and NH_{3,air, out} = air ammonia concentration outside the house (kg m⁻³). The estimates obtained from the equation were then calculated for a 24h cycle (day), and units were transformed into grams per bird.

The concentration of NH₃ was measured using a portable gas analyzer (BW Technologies®), which monitors atmospheric levels of up to five gases, including carbon monoxide (CO), oxygen (O₂), ammonia (NH₃), hydrogen sulfide (H₂S), and combustible gases (LEL).

Table 1 - Information on broiler houses monitored for ammonia emissions in the presente study.

Houses	Ventilation system	Dimensions (m)	Number of fans (diameter in m)	Housing density (bird m ⁻²)	Total n. birds housed	Litter condition
B1	Negative pressure	13x125	8 (1.22)	14.1	23000	New
B2	(Blue Houses)	22x90	10 (1.22)	15.1	30000	Built-up
C1	Positive pressure	12x120	10 (0.91)	13.8	20000	New
C2		12x120	10 (0.91)	14.0	20200	Built-up
D1	Negative pressure	18x120	10 (1.29)	15.8	34000	New
D2	(Dark Houses)	18x120	10 (1.29)	15.6	22500	Built-up



Ventilation rate was measured using a vane thermoanemometer (Model 451126, EXTECH, Waltham, MA). The anemometer was used to measure air velocity at 18 points on the fan surface at a distance of approximately 5 cm from each fan. Mean velocity was calculated and multiplied by the fan area to obtain the estimated ventilation rate (ASHRAE, 2009). Total ventilation rate was calculated as the sum of the flow rates of each fan.

The evaluated broiler houses were divided in six equally distant points, where measurements were weekly made at bird height (0.30 m). Gas concentration and ventilation rates were measured at four different times: 9h00min, 11h00min, 14h00min and 16h00min. Emission data were also weekly evaluated to estimate mean emission per bird in both ventilation systems and in both litter conditions (new or built-up litter).

Statistical analyses were performed with the aid of Statgraphics Plus 5.1® software program. Ammonia emission rate data were submitted to analysis of variance.

RESULTS AND DISCUSSION

Ammonia emission rate was calculated by multiplying ammonia concentration by ventilation rate, which was measured according to the performance of the fans. Fan average capacities were 21538, 23381, 13012, 13761, 34147 and 34807 m³ h⁻¹ in houses B1, B2, C1, C2, D1 and D2 respectively. House ventilation rates are shown in Figure 1.

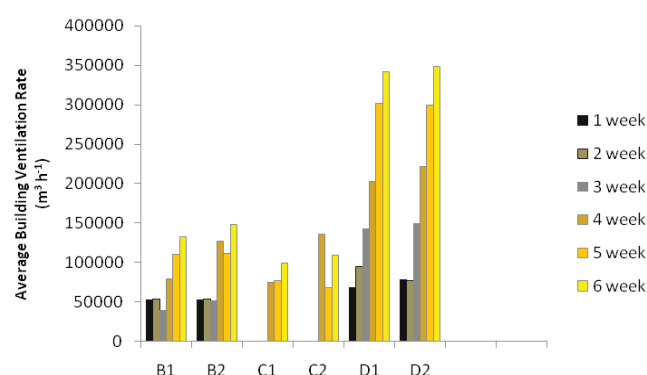


Figure 1 – Average building ventilation rate from week 1 to 6 of the rearing period.

Figure 1 shows higher ventilation rates in dark houses D1 and D2 due to the higher air flow of the exhaust fans. However, the differences in ventilation rates can also be attributed to differences in flow caused by shutters, engine capacity, and by the wear

of the fan components caused by time of use. The average ventilation rates of 1.22m diameter exhaust fans in houses B1 and B2 were lower than those reported by Calvetet *et al.* (2010), who obtained 34,000 m³ h⁻¹ for exhaust fans of the same diameter. According to Casey *et al.* (2008), the ventilation efficiency of identical exhaust fans can vary up to 24%.

As ventilation rate is highly dependent on weather and bird size, there is a high potential for high gas emissions even in poultry houses with low NH₃ concentrations due to the high ventilation rates used to provide thermal comfort and environmental control in these houses. According to Demmerset *et al.* (1999), the ventilation rates in broiler houses can increase from 4000 m³ h⁻¹ up to 42000 m³ h⁻¹, particularly during periods of temperature extremes in the summer. However, independently of season, 60% of the negative-pressure systems can be operated to maintain thermal comfort after the second week of rearing (Czarick, 2006). On the other hand, in positive-pressure systems, curtain management is commonly used as minimal ventilation for air renewal during the first week of rearing, as observed in houses C1 and C2, which fans were not turned on during brooding.

These differences in fan management make ventilation comparisons between positive and negative pressure systems difficult. As mentioned by Casey *et al.* (2008), the main source of uncertainty in the assessment of gas emissions is related to house ventilation rates, possibly due to sampling error, effects of wind dynamics, and to replacement and maintenance of equipment during the experiment.

Ammonia emission rates increase with bird age (Elwinger & Svensson, 1996, Redwine *et al.*, 2002, Liu *et al.*, 2006) due to the increase in nitrogen excretion during rearing, which is significant as birds approach market age. The ventilation rates required to maintain thermal comfort according to bird age should also be considered. Figure 2 shows ammonia emission rates in the studies broiler houses during the entire rearing period.

Ammonia emission in houses with new litter (B1, C1 and D1) increased along the rearing weeks, demonstrating the effect of the correlation between broiler age and ventilation rate on gas emission. The graph shows a typical growth curve of NH₃ emission rate.

Houses B1 and B2, B2 presented the highest emission rate during the first week. This is related to high NH₃ concentration during brooding, when low ventilation rates are applied in order to maintain pullets



thermal comfort. Similar conditions were observed in the dark house D2, where minimal ventilation was not sufficient for air renewal.

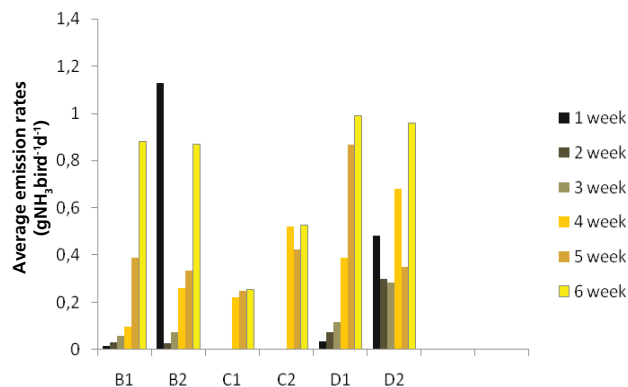


Figure 2 – Average ammonia emission rates (AER) from week 1 to 6 of the rearing period.

The graph also shows that there were no emission rates in houses C1 and C2 in the first weeks of rearing. The estimate of ammonia emission was virtually zero in these houses during brooding due to the low ventilation rates, and therefore, it was not possible to collect emission data. Total emission rate in the houses was low during the entire rearing period. This indicates the linear relationship between gas emissions, bird age, and litter condition, as described in literature (Casey *et al.*, 2004; Wheeler *et al.*, 2006 and Gates *et al.*, 2008; Casey *et al.*, 2010).

Taking that relationship into account, a model was developed to estimate emission rate as the product of a factor (0.031) multiplied by the variable, which would be bird age lower than seven days and new litter (Wheeler *et al.*, 2006), when ammonia emission would be considered as zero. However, in the present study, this happened only due to the lack of ventilation in both positive-pressure houses (C1 and C2), indicating that the lack of ammonia emission was influenced only by ventilation rate, independently from litter conditions. In addition, the model considers that it is possible to evaluate emissions after the first week in houses both with new and built-up litter. However, it was not possible to confirm this assumption in the present experiment.

The analysis of variance (ANOVA) of the collected data is presented in Table 2 and the comparison of means is shown in Figure 3. As the p-value was significant (<0.05), the null hypothesis that all data belonged to populations with equal means was rejected.

The graph in Figure 3 allows identifying which means were significantly different. It shows the presence of three homogenous, i.e., statistically similar groups, as well as the influence of negative-pressure ventilation systems on ammonia emissions.

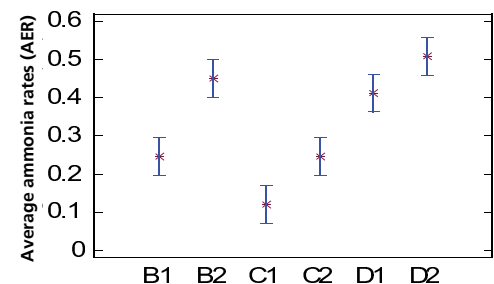


Figure 3 – Interval plot showing mean ammonia emissions (gNH₃ bird⁻¹ d⁻¹) in the evaluated broiler houses.

There was no difference ($p > 0.05$) in mean ammonia emissions among houses D1 with new litter and D2 and B2, both with built-up litter. This was probably caused by the relationship between ventilation rate and NH₃ concentration in these houses, despite the significantly higher ventilation rates in the dark houses (D1 and D2) as compared to the blue house (B2). However, the low ventilation rate in B2 was compensated by the high NH₃ concentrations, whereas the low ammonia concentration in D1 was compensated by its high ventilation rate.

According to Fairchild *et al.* (2009), during the summer, exhaust fans run approximately 96% of the rearing period in broiler houses. This explains the obtained results, as blue houses were monitored during the winter and dark houses were monitored during the summer, and therefore their ventilation rates were higher than in the other monitored houses.

The second homogenous group included houses B1 and C2, which AER were not significantly different.

This emphasizes the importance on ventilation when comparing new with built-up litter.

House C1 is in the third group, which means AER was statistically different than those determined in

Table 2 – ANOVA of ammonia emission rates in the evaluated broiler houses.

Cause of variation	Sum of squares	Degrees of freedom	Meansquare	F	p-value
Treatment	15.9852	5	3.19704	17.62	0.000
Residue	155.709	858	0.1814		
Total	171.694	863			



the other houses. This result may be explained by the combination of new litter with low ventilation rate in that house.

In general, the mean ammonia emission rates obtained in the present study are consistent with the range reported by Gates *et al.* (2008), who found 17.4 gNH₃ bird⁻¹ flock⁻¹ on new litter and 25.4 gNH₃ bird⁻¹ flock⁻¹ on built-up litter. Other values were reported by Redwine *et al.* (2002), of 632 mgNH₃ bird⁻¹ flock⁻¹, and by the NRC (2003), of 99.7 gNH₃ bird⁻¹ flock⁻¹.

The variability in ammonia emission estimates is related to bird age and litter conditions, as well as to bird nutrition, particularly in terms of dietary protein and amino acid content (Casey *et al.*, 2004 and Wheeler *et al.*, 2006). Houses with built-up litter (B2, C2 and D2) presented higher emissions per bird. According to Brewer and Costello (1999), built-up litter has high nitrogen content, and may present six times more ammonia emissions than new litter, even during the first weeks of rearing.

Table 3 presents mean AER obtained in the present study compared with the results of other studies. The AER results of the present study were lower than those obtained in the other studies shown in Table 3, but were comparable with the European research results reported by Groot Koerkamp *et al.* (1998) of 0.21, 0.27, 0.44, 0.48 gNH₃ bird⁻¹ flock⁻¹ for broilers reared in Germany, the Netherlands, United Kingdom and Denmark, respectively.

However, it is difficult to compare results as the data presented in Table 3 were obtained under different conditions, such as different numbers of evaluated flocks and housing density. Harper *et al.* (2010) also

reported that it is complicated to compare AER results, and concluded that, despite presenting the same ranges, European AER could not be compared with AER obtained in the U.S. due to different management practices, housing types, and climate.

The assessment of gas emissions from broiler production should include all factors related to their management as well as specific characteristics and key parameters involved. Despite all obstacles, it is evident that gas emission inventories are required to evaluate the impact of animal production on the environment, and to be used as foundation of future plans for justified control and abatement measures (Seedorf, 2004).

CONCLUSION

Negative-pressure broiler houses presented higher emission rates related to the higher ventilation rates. In the present study, positive-pressure systems presented lower emission rates when new litter was used. As Brazilian climate and characteristics allow the use of positive-pressure systems in different regions, the information generated in this study could be used to reduce the impact of broiler production on the environment. Independently of ventilation system, the use of new litter for every flock housed could significantly reduce ammonia emissions, but it should be taken into consideration that it also increases production costs.

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Table 3 – Ammonia emission rates obtained in the present study and in studies published in the US.

Reference	Rearing period (days)	Housing density (bird m ⁻²)	N. flocks	Litter condition	Mean NH ₃ emission (g bird ⁻¹ day ⁻¹)	Local
Current Study	42	15	2	New	0.25	SP/Brazil
	42	15	2	Built-up	0.45	
	42	14	2	New	0.12	
	42	14	2	Built-up	0.25	
	42	16	2	New	0.41	
	42	16	2	Built-up	0.51	
Burns <i>et al.</i> (2007)	52	12.7	3	New	0.49	KY/EUA
	52	12.2	9	Built-up	0.62	
Wheeler <i>et al.</i> (2006)	42	14.7	10	New	0.47	KY & PN/ EUA
	42	14.7	12	Built-up	0.65	
	49	13.4	24	Built-up	0.76	
	63	10.8	20	Built-up	0.98	
Seifert <i>et al.</i> (2004)	42	20	1	Built-up	1.18	TX/EUA
Lacey <i>et al.</i> (2003)	49	13.5	12	Built-up	0.63	DE/EUA



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