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An Approach to the Ammonia Inventory in the Poultry Production in Colombia: Antioquia Case

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The understanding of the inventory and control of ammonia (NH_3) emissions to the atmosphere is very important, due to ecological effects of emissions when deposited in soils biodiversity and by its direct relation with NH_3 concentrations. High levels of NH_3 in the air also have a negative effect on health and productivity of animals and people. This research had as objective to estimate the ammonia inventory in Antioquia State of Colombia, generate in poultry broiler production. Thirty facilities that have been working with natural or mechanical ventilation were chose. The daily ammonia factors (fNH_3) in facilities working with natural ventilation, was used the Saraz Method for Determination of Ammonia emissions (SMDAE) and for mechanical ventilation was used the equation proposed by wheeler. The results shown the potential to generate ammonia emission per sub region, where the natural ventilation facilities have been generating 8.41 KT NH_3 year $^{-1}$and mechanical ventilation 0.14 KT NH_3 year $^{-1}$. The ammonia emission factors (fNH_3) estimated in this study are very close to the results that were found in other studies in countries like Brazil.

1. Introduction

In modern animal agriculture, especially on poultry, cattle, and swine farms, animals are raised in concentrated animal feeding operations (AFO) and large quantities of manure are generated on the farms. Ammonia (NH_3) is produced from the manure during microbial processes that convert nitrogen in the manure into ammonia, which can be released from the manure and emitted from animal buildings to the outdoor atmosphere. High densities of animals in AFOs can result in high aerial ammonia concentrations in and large quantities of ammonia emissions from the animal buildings (Qin et al., 2011).
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 (Lima et al., 2011).
According to Broucek et al. (2015), the poultry farms can bring many pollution problems. Therefore, it is important to maintain optimal conditions for poultry production and also it should not impair the human and animal environment through emission of harmful gases. To be profitable, farmers must use the best practices and technological advances in order to achieve the most advantageous environment. The impact on the ecological systems may result from direct release of detrimental constituents into the atmosphere or indirect deposition of these constituents into ground water.
The quality of air within facility and its vicinity cannot only affect the health of confined animals but also of workers which spend 4 to 8 hours a day in this environment. Given that birds are now raised under high densities, the thermal comfort of these animals is easily compromised. It is recognized that for intensive poultry production to be sustainable in tropical and subtropical countries, there must be significant

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improvement of housing facilities to improve poultry performance, reduce production costs and reduce environmental impacts (Osorio et al., 2013).
It is very important to understand ammonia emission rate in poultry facilities not only because of ammonia's effect on the environment, but also because of the direct impact of gas concentration upon the health and productivity of both chickens and workers, as well the acute exposures NH_3 can result in visible foliar injury on vegetation. The ammonia emission rate is approximately proportional to the product of gas concentration and building ventilation rate (Osorio et al. 2015).
The understanding and control of ammonia (NH_3) emissions to the atmosphere is very important, due to ecological effects of emissions when deposited in soils and by its direct relation with NH_3 concentrations. High levels of NH_3 in the air also have a negative effect on health and productivity of animals and people. In general, NH_3 emissions generated from enclosed livestock confinements have been evaluated as the NH_3 concentrations measured at the exhaust fans multiplied by air exchange rate through the installation. However, despite this being a simple concept, both measured concentrations and ventilation rates are difficult to precisely quantify in poultry buildings due to their size and the non-homogeneous nature of factors such as litter moisture content, pH, temperature, etc., that affect those variables both in space and time (Osorio et al, 2009).
Regions with tropical and subtropical climates such as Colombia and Brazil are populated with intensive broiler chicken production facilities that utilize open curtain-sided sidewalls for ventilation to exploit favorable wind conditions and use assisted mechanical ventilation when this is not possible. However, owing to the openness of these buildings in windy conditions there is often significant lack of precision in ventilation control within because wind direction and velocity has a big impact on ventilation uniformity (Menegali et al., 2009). Therefore, in the case of open installations, such as those often encountered in Colombia and Brazil, the quantification of NH_3 emission becomes more complex. One of the aspects of greatest importance in regards to NH_3 emissions is calculation of the ventilation rate in the specific type of installation. Determination of this variable in naturally ventilated buildings, as well as in curtain-sided housing with mechanical ventilation, can be complicated due to its instability and variability, the latter due to strong opposing natural air currents contrary to flow of the fans, generating different flow rates at each moment (Osorio et al., 2013).
A considerable amount of published literature on ammonia (NH_3) emissions from poultry production is devoted to the quantification of NH_3 emissions from mechanically and natural ventilated, environmentally controlled poultry houses (Xin et al, 2011).
Different concepts have incorporated new elements related to climate change into their checklists based on measurements of Greenhouse Gas (GHG) emissions, which obliges producer countries to have their GHG inventories, with the purpose of making them more competitive and positioning them much more in the international market, giving an added value to the internal and external production, as is the case of Colombia.
Based on the above, this research had as objective to estimate the ammonia inventory in Antioquia State of Colombia, generate in poultry broiler production, as this is one of the largest producers in the country.

2. Material and methods

2.1 Locations

The research was carry on in the nine (9) sub regions in the Antioquia state, where were chose thirty (30) broiler chickens facilities that have been working with natural or mechanical ventilation, fifteen (15) for natural and fifteen (15) for mechanical ventilation.

2.2 Description of the experimental

Collection of experimental data was done during three consecutive days of each distinct week in the life of the birds. The experiment was performed while the poultry houses were maintained open and with natural ventilation.
The daily ammonia factors (fNH_3) in facilities working with natural ventilation, was used the Saraz Method for Determination of Ammonia emissions (SMDAE) proposed by Osorio et al. (2014).
The daily ammonia factors (fNH_3) in facilities working with mechanical ventilation, was used the proposed method proposed by Wheeler et al. (2006) (equation 1).

$$ER_1 = Q_1 M \left(NH_{3e} - NH_{3i}\right) 10^{-6} \frac{W_m}{V_m} \frac{T_{std}}{T_a} \frac{P_a}{P_{std}} \qquad (1)$$

Where:

ER1 = Emission rate (g NH_3 h^{-1} $bird^{-1}$).

Q1 = air flow inside the confinement, measured five centimeters in front of each sponge positioned on the upwind side, at atmospheric temperature and pressure ($m^3\ h^{-1}\ kg^{-1}$).
M = average body weight of the birds ($kg\ bird^{-1}$).
NH_{3i} = NH_3 concentration of building inlet air (ppm).
NH_{3e} = NH_3 concentration of building exhaust air (in this case near the internal lateral wall of the poultry house) (ppm).
W_m = molar mass of NH_3 (17.031 g $mole^{-1}$).
V_m = molar volume of NH_3 at standard temperature (0°C) and pressure (101.325 kPa), the STP (0.022414 $m^3\ mol^{-1}$).
T_{std} = standard temperature (273.15 K).
T_a = absolute temperature (K).
P_{std} = standard barometric pressure (101.325 kPa).
P_a = atmospheric barometric pressure at the experimental site (kPa).

2.3 Experimental data acquisition

The 1-WireTM technology was used to monitor temperature inside the installation at 1-s intervals, using 36 sensors distributed inside the installation and located at three different heights above the floor (0.2, 1.2 and 2.2 m). The software STRADA (Rocha et al., 2008) was adopted for experimental data acquisition and control. A DS9490R USB adaptor was connected to a laptop computer with an Intel Pentium® 100 Mhz processor and 64 Mb of RAM for data transfer from the 1-WireTM network.
Relative humidity of the air inside and outside the poultry house was obtained at diverse points, representing the entire poultry house, using twelve independent datalogger systems (Hobo H8-032) with accuracy ± 0.7, at 21°C. Data collection was performed every second.
Aerial NH_3 concentration data were monitored by means of a handheld sensor (BW electrochemical detector, “Gasalert Extreme NH_3 Detector”), with a measurement range from 0 – 100 ppm, operating temperature between -4 and +40°C and relative humidity (RH) from 15% to 90% and with an accuracy of ± 2%.
Air speed ($m\ s^{-1}$) was measured with a digital wind gage (Testo 425) inside the experimental barn, ranging between 0 - 20 $m\ s^{-1}$, precision of 0.1 °C ± 0.5%, accuracy of ± 1% (pressure) and 2.5% ($m\ s^{-1}$). External air temperature and air relative humidity (RH) values were registered with a model HO8, HOBO datalogger, installed in a meteorological station located near the poultry house at 1.5 m off the ground, with resolution of 0.5 °C ± 1% and collecting data once at every second. Temperatures of the roof and lining were measured with a TD95 model ICEL infrared thermometer, ranging between -20 and +270ºC, with resolution of 1°C and accuracy of ± 2%.

2.4 Statistical analyses

The results obtained from the different sub regions were compared using a non-parametric one-way analysis of variance (ANOVA, Kruskal-Wallis test).

3. Experimental results

In Antioquia state according with the FAO (2015) were produced approximately twelve millions of broilers of almost 30 millions that existed in the Country, with the follow distribution found in this study in the 9 sub regions (Table 1).

Table 1: Numbers of broilers in each Antioquia sub regions

Sub region	Number of broilers Natural ventilated (mill)	Number of broilers Mechanical ventilated (mill)
Central-AMVA	1.0	0.5
West	1.5	0.8
East	0.8	0.4
South	1.1	0.7
North	0.8	0.6
South west	1.2	0.4
South east	0.6	0.3
North west	0.5	0.3
North east	0.4	0.1
Total	**7.9**	**4,1**

The daily fNH3 obtained from similar studies performed in Brazil are also presented in Table 2. Unfortunately, not all the emission factors presented in the considered studies were accompanied by an uncertainty estimate, such as a standard error (SE), which makes it difficult to draw comparisons. The emission factor presented by Osorio et al. (2009) of 0.28 g bird^{-1} d^{-1} and Mendes et al (2014) of 0.27 g bird^{-1} d^{-1} were relatively lower than the ones presented in this study for natural ventilated, even the same situation happened for mechanical ventilated.

Table 2: Ammonia emission factors (fNH_3) estimated from this study and other studies

Sub region	Type of ventilation system	NH_3ER (mean ± SE2, g bird ^{1} d ^{1})	Local
This study	Mechanical	0.35 ± 0.18	Antioquia Colombia
This study	Natural	0.30 ± 0.23	Antioquia Colombia
Mendes et al. (2014)	Mechanical	0.32 ± 0.10	MG-Brazil
Mendes et al. (2014)	Natural	0.27 ± 0.07	MG-Brazil
Osorio et al. (2009)	Natural	0.28 ± 0.16	MG-Brazil

The same way, the daily fNH_3 obtained for different sub regions is shown in the Table 3 and 4. It can see that the higher emission factor *(fNH_3),* are presented in the west and south east regions for natural and mechanical ventilation, that may it is due to the wind direction in those regions and the localization of facilities with respect to wind direction, and the number of birds.

Table 3: Ammonia emission factors (fNH_3) estimated from this study to natural ventilation

Sub region	NH_3ER (mean ± SE2, g bird ^{1} d ^{1})
Central-AMVA	0.28 ± 0.22 a
West	0.31 ± 0.26 b
East	0.29 ± 0.11 ab
South	0.27 ± 0.07 a
North	0.32 ± 0.06 b
South west	0.28 ± 0.18 a
South east	0.31 ± 0.13 b
North west	0.29 ± 0.11 ab
North east	0.27 ± 0.07 a

Table 4: Ammonia emission factors (fNH3) estimated from this study to mechanical ventilation

Sub region	NH_3ER (mean ± SE2, g bird ^{1} d ^{1})
Central-AMVA	0.32 ± 0.25 a
West	0.36 ± 0.16 b
East	0.31 ± 0.08 a
South	0.33 ± 0.17 a
North	0.37 ± 0.26 b
South west	0.31 ± 0.25 a
South east	0.34 ± 0.08 b
North west	0.32 ± 0.06 a
North east	0.30 ± 0.09 a

The Table 5 shown ammonia emission (KT NH_3 year $^{-1}$) estimated from this study to natural and mechanical ventilation in the 9 sub regions in Antioquia –Colombia State. In Antioquia State have been generating about 9 KT NH_3 year $^{-1}$ where the higher producer of ammonia comes to the facilities that have been working most of the time during the year with natural ventilated. These results shown as Antioquia is one of the higher producer of ammonia in Colombia Country.

Table 5: Ammonia emission (KT NH_3 year $^{-1}$) *estimated from this study to natural and mechanical ventilation in the 9 sub regions in Antioquia –Colombia State*

Sub region	Natural (KT NH_3 year $^{-1}$)	Mechanical (KT NH_3 year $^{-1}$)
Central-AMVA	1.02	0.02
West	1.70	0.03
East	0.85	0.01
South	1.08	0.02
North	0.93	0.02
South west	1.23	0.01
South east	0.68	0.01
North west	0.53	0.01
North east	0.39	0.01
Total	**8.41**	**0.14**

4. Conclusion

This approach is the first work that have done in Colombia, and reveals that the ammonia emission per sub region and it is potential for production, that is very important for futures environmental policies in Antioquia State and Colombia country.

The Ammonia emission factors (fNH_3) estimated from this study to natural ventilation are higher than others study found in countries as Brazil for natural and mechanical ventilated by Mendes et al. (2014) and Osorio et al. (2009), however, in the case of mechanical ventilated the ammonia emission factors (fNH3) found in USA poultry facilities by Burns et al. (2007) and Wheeler et al. (2006) (0.47 and 0.63 g bird ^{1} d ^{1} respectively), are higher than found in this study.

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