DETERMINATION OF EMISSION FACTORS OF AMMONIA AND GREENHOUSE GASES FOR GESTATING ROOMS OF COMMERCIAL SWINE HOUSES

Case Study of a Weaning Production Unit in Concordia, Santa Catarina, Brazil

Maria Ana Benoliel Nunes Bonito[1]

Instituto Superior Técnico, Lisboa, Portugal

Abstract:

Population growth, along with rising incomes in developing countries, led to the growth of swine production, increasing atmospheric emissions of ammonia and greenhouse gases - carbon dioxide, methane and nitrous oxide. Brazil, the fourth biggest swine producer in the world, holds the majority of its production in Rio Grande do Sul, Santa Catarina and Paraná. The following study aims to expand and enhance the knowledge in the field of sustainability in livestock production, and to produce scientific information on air quality in swine production units. Specifically, it aims to determine greenhouse gases and ammonia concentrations and emissions factors in gestation rooms of commercial swine houses located on the West side of Santa Catarina, (micro-region of Concordia), considering two different periods of the year (winter period-A and summer period- B), two different collection times (morning and afternoon), two different lodging systems (individual boxes –G1 and collective stalls – G2) and natural ventilation. For each five-week term, two production units were analyzed – model unit and control unit – following the Simplified Methodology suggested by ROBIN et al. (2006) and ROBIN et al (2010). Weekly samples of gas, manure and feed, as well as data for relative humidity, air velocity and temperature were collected inside and outside the units. Measurements were also conducted to determine how widely the blinds were open. The gas samples were read by photo-acoustic measuring with INNOVA 1412, ambient data was processed in Microsoft Excel© and samples of manure and feed were analyzed according to *Standard Methods*. Simultaneously, daily indoor and outdoor monitoring of relative humidity and air temperature was carried out. Emission factors were only measured for the model unit of term A (UPMA). The study concludes that: manure in G1 and G2 has different characteristics; the feeding system in G1 leads to water spillage; concentrations did not go above the legal exposure thresholds and differ according to collection time; comfort conditions inside the rooms are good/very good; gas concentrations lodging systems may affect gaseous concentrations and emission factors; in UPMA, comfort conditions and lodging conditions favour the rapid volatilization of ammonia from manure, the applied methodology is appropriate

Keywords: swine production, gestation, greenhouse gases, ammonia, natural ventilation

Introduction

Population growth and rising incomes in developing countries have led to an increase in consumer demand for agricultural goods, generating the need to increase global food production by 60% in the 2005/7 to 2050 period. (FAO, 2014)

Increased production means increased agricultural activity, and consequently increased environmental pressure on water resources, soil and biodiversity, and increased emissions of greenhouse gases and ammonia to the atmosphere. (FAO, 2014)

In Brazil, livestock production grows as a consequence of growing demand for livestock products. In particular, pork production becomes mainly industrial, operating with higher stocking densities and consequently generating more manure leading to the pollution of water, soil and air (FAO, 2002)

This rapid growth of Brazilian swine production promoted the adoption of intensive farming systems, namely by implementation of concentrated animal feeding operations (CAFO's). (MIRANDA, 2005)

CAFO's, usually efficient from the point of view of productivity control, generate ecological disruption and increase the environmental impact on biodiversity and natural resources (used as agricultural inputs), as well as soil pollution, water pollution and atmospheric pollution problems. More specifically, these systems produce higher daily volumes of manure and intensify daily emissions of dust and gases to the environment. (MIRANDA, 2005; PETERSEN e MILLER, 2006; AMORIM, 2011; TAVARES, 2012)

In this context, it's important to develop defined strategies for the mitigation of environmental impacts and promotion of agricultural sustainability, by controlling and monitoring potentially pollutant activities.

The following study aims to expand and enhance knowledge in the field of sustainability in livestock production, and to produce scientific information on air quality in swine production units. Specifically, it aims to determine greenhouse gases and ammonia concentrations and emissions factors in gestation rooms of commercial swine houses located on the West side of Santa Catarina, (micro-region of Concordia), considering two different terms of the year, two different collection times, two different logging systems and natural ventilation.

Methodology

The following study was carried out during gestation, considering two different lodging systems (individual stalls and collective stalls) and two different periods of the year, A and B, each lasting five weeks. Period A was in winter and period B was in summer.

The analysis was carried out for 4 production units (UP), paired in groups of model (UPM) and control (UPC) units according to the period in which they were analysed (one model unit, UPMA, and one control unit, UPCA, for period A; one model unit, UPMB, and one control unit, UPCB, for period B.

To better understand water consumption, feed and gaseous emissions inside each lodging system (individual or collective stalls), these were considered as separate phases of gestation and analysed individually. Individual lodgings were called G1 and group lodgings were called G2.

Gaseous concentrations were analysed for all units; however, due to the complexity and time consumed in modelling each of the studied units, and given the established time-frame for the project, emission factors were calculated only for one selected model unit (UPMA).

Weekly samples of manure and feed were collected in the units. Weekly samples of gas, as well as data for relative humidity, air velocity and temperature were collected inside and outside the units. Also, measurements were conducted to see how widely the blinds were opened.

Manure

Manure samples were collected for five weeks. After mixing the manure, a first sample was collected into a 20L bucket. The sample was mixed again and a second sample of 1L was collected and stored into a specific plastic cup, closed and identified. The sample was then stored in a thermal container and transported to EMBRAPA.

Feed

Weekly samples of feed were collected for each period of five weeks - A and B - and each room. Samples were directly collected from the food tanks or food carts into a plastic bag.

The samples were also carried to EMBRAPA where they were analysed by EMBRAPA laboratories for a series of properties. The procedures followed the *Standard Methods for Examination of Water and Wastewater*. Analyses were confirmed by theoretical calculations described in GIROUX and AUDESSE (2006), for organic matter, carbon/nitrogen ratio and total carbon.

Temperature, Relative humidity and Air Velocity

Temperature and relative humidity were measured by continuous and discontinuous monitoring inside and outside the units.

Continuous daily monitoring of temperature and relative humidity inside and outside the rooms was carried out by TESTO 174 data-loggers, programmed to record measurements every 30 seconds.

Periodically, data-loggers were collected and cleaned by the field team, and the recorded data saved into a specific computer. The data-loggers were then repositioned into their previous location.

The air velocity, relative humidity and temperature data was collected using a high precision probe TESTO 435.

Indoor collection was conducted throughout X predefined points of each room, on both the left side and the right side, so that 2x measurements were made for each room. Measurements always began on the left side of the room. Outdoor collection followed the same pattern, measuring 5 points first on the left side and then on the right side of each building.

Gas

Gas samples were collected inside and outside the units, using an air pump and a pair of TEDLAR bags.

The air pump was connected to each bag through an opening valve and remained on until the bag was full. Once the bag was full, the valve was closed and the pump was disconnected from the bag.

In order to obtain a representative set of samples, indoor collection was held along the main corridors and also near the stalls inside each unit. Outdoor sampling was held within a 3 m radius of the buildings.

The sampling process took up 40 minutes of each collection hour.

The collected gas samples were then transported to EMBRAPA headquarters inside insulated boxes, to be read by photo-acoustic measuring with INNOVA 1412. The bags were kept inside a closed room at a controlled temperature, until all samples had been read.

Blind Width measurement

To see how widely the blinds were opened, a graduated wooden stick, graduated, was used. Scale “0” was positioned on the upper part of the window. The aim was to ascertain the total ventilation area, to be used in flowrate calculations.

Statistical analysis

A statistical analysis for gaseous concentrations inside the rooms was conducted using the SAS software; temperature and relative humidity were plotted in Sigma plot. The calculations, mass balances, energy balances and emission factor determination were also conducted using SAS, for one model unit analysed in period A (UPMA).

Results

Manure

The manure pH and ammonia fraction of nitrogen are higher for G1 than for G2; however, results show that a higher percentage of dry matter can be found in manure for G2.

Feed

Analytical and theoretical values estimated for dry matter, carbon/nitrogen ratio and total carbon presented errors of 2%, 5% and 7%, which attest to the reliability of laboratory findings.

Thermal Environment

Period A

Indoor Temperature in period A was about 19 ºC and external temperature was on average 16 ºC. G1 and G2 have the same temperature evolution; differences between indoor and outdoor temperatures vary by 3 ºC.

The temperature is within the limits of thermal comfort for gestating sows, not being higher than the higher critical temperature, Tcs =24ºC. (PANDORFI, 2005; MENDONÇA, 2010)

Relative humidity is high inside the buildings, with mean indoor values of about 71%. Outdoor relative humidity is around 78%. Evolution is similar for G1 and G2.

Relative humidity is within the thresholds for thermal comfort for gestating sows.

Period B

Minimum and maximum temperatures are closer than those found for period A, and indoor and outdoor temperatures vary by 1 ºC.

Values are slightly above the threshold for thermal comfort for gestating sows, however, they are not higher than the superior critical temperature.

Gaseous Concentrations

Differences in gaseous concentration between indoor and outdoor measurements were higher in morning collection hours, for all analysed gases.

The regulatory mechanism of opening or closing the blinds might act as a barrier to the passage of air fluxes from the inside to the outside or vice versa, preventing air from the two environments from mixing together.

Therefore, differences in concentration can be explained by such an opening and closing mechanism: in the hours when openings are smaller (morning time, colder), concentration differences are higher. On the other hand, in the hours where openings are bigger (afternoon time, hotter), concentration differences are smaller.

The gaseous concentrations were also higher in G2 than in G1, for all analysed gases.

Although pH and the ammonia fraction of nitrogen are favourable to higher ammonia concentrations for G1, the higher values for ammonia concentrations found in G2 can be explained by the higher dry matter content presented in manure for this stage.

Ammonia mean levels place the evaluated UP's in between a very good (19ºC for term A and indoor ammonia levels around 2-3ppm) and good (23ºC for term B, and indoor ammonia levels around 2-3ppm) classification for comfort conditions.

Gaseous concentrations were within the exposure limits established by the literature.

Case Study. Model Unit, Term A

In UPMA 161 matrixes were lodged in G1 and 49 matrixes were lodged in G2.

Ambience Evaluation

Data for relative humidity, temperature and wind velocity was collected weekly.

An indoor temperature of 20ºC, relative humidity of 66,6% and air velocity of 0,1m/s were obtained. Outdoors, temperature was measured at 18,1ºC, relative humidity at 61,7% and air velocity at 0,4m/s.

Air velocity is very difficult to measure in natural ventilated buildings because it depends on wind direction and velocity, which may vary greatly.

Temperature-relative humidity relations classify UPMA as having very good lodging conditions.

Similarly, indoor wind velocity values are within the optimal values established by MENDONÇA (2010) – 0.1m/s for colder and 0.4m/s for hotter terms.

Gaseous concentrations inside the unit were within established exposure limits. These concentrations are presented in Table 1.

Table 1 – Gaseous concentrations (ppm-v) inside the rooms (except methane)

Room	CO_2	NH_3	N_2O
G1	969,6	4,8	0,434
G2	990,9	6,6	0,434
External	508,9	0,9	0,364

Obs.: CO_2 – carbon dioxide; NH_3 – ammonia; N_2O – nitrous oxide

Carbon dioxide concentration varied from G1 to G2. Considering the amount of animals lodged in each stage (161 for G1 and 49 for G2), it should be expected that concentrations of carbon dioxide would be higher for G1, given that carbon dioxide is mainly produced by animal breath. However, results show that G2 presents higher values of carbon dioxide. Air mixing inside the room might help explain this disparity.

External values for ammonia reached 1ppm, which can be explained by a possible contamination of air samples due to the location of the analysed rooms, adjacent to the treatment cesspool and maternity rooms.

Emission Factors

Emission factors were obtained applying the Simplified Methodology proposed by ROBIN et al. (2006).

Table *2* - Emission Fluxes for *N* gases based on latent heat (g/animal.day), by room

Room	N_2O Flux	NH_3 Flux	Total N Flux
G1	0,4	7,3	7,7
G2	0,5	12,1	12,6

Obs.: NH_3 – ammonia; N_2O – nitrous oxide; N- nitrogen

Table 3- Emission Fluxes for C gases based on latent heat (g/animal.day), by room

Room	CO_2 Flux	CH_4 Flux	Total de C Flux
G1	743,9	16,9	760,8
G2	919,9	11,7	931,6

Obs.: CO_2 – carbon dioxide; CH_4 methane; C - carbon

Emission factors were higher for G1 than for G2, except for methane, which is higher once again.

The ammonia fraction of nitrogen in the manure is compatible with the production of gas inside the rooms.

Emission factors were very similar to those found in literature for European gestation rooms of commercial swine production buildings.

Validation

Validation was made using mass balances for phosphorous, nitrogen and carbon and by calculating the errors associated to nitrogen losses and carbon losses to the atmosphere.

Errors were close to 10-15% for phosphorous mass balance, which confirms the presupposition of phosphorous conservation. Errors were between 11% to 20% for carbon and nitrogen losses. Considering the maximum error suggested by ROBIN (2006) – 30%, the model can be assumed as appropriate.

Conclusions and Discussion

For the first part of the study, the following conclusions can be drawn:

- Manure in G1 has very different characteristics from manure in G2;
- The rooms can be classified as having very good thermal comfort conditions for term A and good conditions for term B.
- Temperature in G2 is higher than comfort temperature; however it is not above critical superior temperature.
- Gaseous concentrations in G1 are higher than gaseous concentrations in G2, for all analysed rooms;

- Concentrations are higher in morning collection times than in afternoon collection times.

The second part of the study led to the following conclusions:

- UPMA can be classified as having good to reasonable thermal comfort conditions;
- The common water-feed system used in G1 led to water spillage; sows apparently drink 3 times as much as sows in G2;
- Management in UPMA, naturally ventilated and with no ambiance control, led to emission factors close to those found in the literature for commercial buildings kept in rigorously controlled environment conditions and mechanically ventilated;
- Emission factors are higher in G1 than in G2.
- Air velocity is difficult to measure in naturally ventilated buildings;
- The error found for P mass balance is compatible with the assumption that P is conserved;
- N content found in manure and N excretion calculated by mass balance present an error of 58% for G1 and 54% for G2.
- Rooms in UPMA have conditions for the rapid volatilization of ammonia
- The applied methodology is appropriate;
- The hypothesis can be answered as follows:
- Collection time and temperature difference are closely related, which might influence gaseous concentrations inside the rooms;
- Different lodgings account for a set of parameters such as stage of pregnancy, animals' live weight, metabolic activity, quantity and quality of the feed, volume, retention time and management of manure, which have an influence on atmospheric emissions of ammonia and greenhouse gases.

Further work is being conducted by a PhD project in EMBRAPA. In this context, further work could include:

- Extending calculations made for UPMA to other UP followed in the study, so as to establish a more significant population;

- Repeating procedures so as to be able to obtain more concrete data that allow solid conclusions about greenhouse gases and ammonia emissions to the atmosphere.

For future work, it might be of interest:

To conduct similar studies in livestock units in Portugal and to o apply the Simplified Methodology in Portugal;

To promote more scientific partnerships between Portugal and Brazil, similar to those established between Brazil and France, to promote a joint enhancement of livestock production and established world patterns for environmental quality in agriculture. Namely, it might be interesting to conduct comparative studies between Portugal and Santa Catarina, due to their proximity in territorial area and agricultural background.

To conduct further studies for this particular physiological stage (gestation) in order to obtain sustainability throughout production chain.

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