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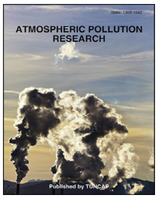

Assessment of ammonia and greenhouse gas emissions from broiler houses in Portugal

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ABSTRACT

Broiler husbandry is a significant source of ammonia (NH_3), nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) emissions but scarce studies have been made under Mediterranean conditions. The aim of this study was to evaluate the NH_3, N_2O, CO_2 and CH_4 emissions on commercial broiler houses under Portuguese winter conditions. The study was made on a commercial broiler farm located in central Portugal. Three tunnel ventilated broiler houses with similar equipment and production practices were selected. The outdoor and indoor environmental conditions, gas concentrations and ventilation rates of each broiler house were measured during 42 days of growing cycle. Results showed that the maximum concentrations of NH_3, N_2O, CO_2 and CH_4 did not exceed the threshold values recommended to maintain indoor air quality on broiler houses. The average emission rates from broiler houses under winter conditions were 0.13 ± 0.04, 0.041 ± 0.002, 96.2 ± 8.8 and 0.226 ± 0.013 g day^{-1} $bird^{-1}$ (22.0 ± 7.3, 6.7 ± 0.3, 16,028 ± 1465 and 37.7 ± 2.1 g day^{-1} LU^{-1}) for NH_3, N_2O, CO_2 and CH_4, respectively. Furthermore, NH_3 and N_2O emission rates of this study are in the same range than measurements from most European countries, but CH_4 emission rate seems higher to those reported for Mediterranean countries.

1. Introduction

The broiler production in Portugal accounted about 17.1 million places and 253,238 t of meat for consumption in 2015 and ca. 3.5% of total production in the European Union (INE, 2016; PIIR, 2017). Portugal has about 3% of chicken meat surplus and this sector represents ca. 12.5% of animal production. The National poultry production is a very specialized sector with a few number of integrator companies mainly located in the centre of Portugal, and a rearing cycle between 35 and 42 days (2.0–2.4 kg liveweight). Feeding and management techniques are usually provided by the integrator company. The intensive broiler farms have modern mechanically ventilated buildings, equipped with heating and cooling pad systems, and the litter material (rice hulls or wood shavings) is always removed at the end of the cycle. Regarding the National legislation (REAP, 2013), in each farm, is mandatory an environmental licence and inclusion of the best available techniques for manure management.

Broiler husbandry is a significant source of ammonia (NH_3), nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) emissions but scarce data are available for Mediterranean conditions. The NH_3 emissions from the poultry production were 14.2% of the total NH_3 emissions reported in the Portuguese inventory in 2015 (PIIR, 2017). Acidifying pollutant depositions such as NH_3 has a number of negative effects on ecosystems and degradation of materials and existing facilities. Nitrous oxide, CO_2 and CH_4 are greenhouse gases that contribute to increase greenhouse effect (Pereira et al., 2012; Van der Heyden et al., 2015; Xu et al., 2014; Mostafa et al., 2016).

Gases such as NH_3, N_2O, CO_2 and CH_4 are produced by transformation processes in the excreta/bedding mixture (Méda et al., 2015). The production and emission of gases are a result of complex biological, physical and chemical processes. Broiler excretions are rich in uric acid, being decomposed into urea through aerobic

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decomposition and followed by NH_3 and CO_2 volatilisation thorough urease enzyme (Rotz, 2004). Nitrous oxide emission is originated by nitrification and denitrification processes whereas CH_4 emission coming from anaerobic decomposition of litter materials (Sommer et al., 2006; Pereira et al., 2012). Thus, factors such as ventilation rate, temperature and humidity, litter type, stoking density and management affect the gas concentration and emission from broiler houses (Méda et al., 2015).

Previous studies reported (Calvet et al., 2011; Brouček and Čermák, 2015; Eugene et al., 2015) a great variation on gas emission rates between seasons and countries, being related with outdoor climate, housing and diet supplied to broilers. Hence, more studies are needed, mainly in warmer regions because a very limited number of studies have been conducted under these conditions. Portugal lacks information concerning the broiler sector characterization. There is no information on the gas emission rates related to broiler houses. The aim of this study was to evaluate the NH_3, N_2O, CO_2 and CH_4 emissions on commercial broiler houses under Portuguese winter conditions.

2. Material and methods

2.1. Broiler housing and management

The study was made on the commercial broiler farm located in central Portugal (Oliveira de Frades, Portugal). Three tunnel ventilated broiler houses (length = 100 m, width = 11 m, ridge = 4.0 m and sidewall height = 2.7 m) with similar equipment and production practices were selected. The broiler houses are a steel construction (year 2013) with insulation (polyurethane) in roof and walls, being oriented East to West (long axis = 100 m). Each broiler house had box air inlets (height = 0.38 m and width = 0.86 m) along the sidewalls facing East (height = 0.8 m and width = 18.0 m) and exhaust fans facing West (minimum ventilation = 2178 $m^3\ h^{-1}$ at differential pressure = 0 Pa, maximum ventilation = 365,531 $m^3\ h^{-1}$ at differential pressure = 50 Pa), set up within a tunnel ventilation system (Fancom, The Netherlands).

A biomass-fired boiler (model CVT1000S, Ventil, Portugal) was used to heat the houses of whole broiler farm. The water heated on the boiler was then pumped to the inside of each house and sensible heat was released. The ventilation rate was controlled by a control system (model F37, Fancom, The Netherlands) equipped with one sensor of differential pressure (0–100 Pa, Fancom, The Netherlands), two sensors of temperature (model SF7 Fancom, The Netherlands) and two sensors of relative humidity (model RHM.17 for inside and model RHO.17 for outside, Fancom, The Netherlands) placed indoor and outdoor the broiler house.

The experiment started with 10,500 male and 10,500 female broiler chicks per house on day 0 of the production cycle (18-12-2015) and finished on day 42, with a liveweight of 2.4 kg $bird^{-1}$. New bedding material made with rice hulls (3–5 kg m^{-2}) was used during the experiment. The mortality during the growing cycle was 3.28% and 8000 broilers per house (1.0 kg $bird^{-1}$) were removed on day 27. Birds had ad libitum consumption of feed and water under lighting a period of 20:4 (light:dark) h day^{-1} and a luminance of 20 Lux. Fed was supplied by an automatic feeding system for broilers in line (model Minimax, Roxell, Belgium) with 66 birds per pan, and water was provided by a nipple drinking system (model SPARKnipple, Roxell, Belgium) with 14 birds per drinker. The mean composition (mean ± standard deviation) of the standards diets provided by the integrator was the following: 88.1 ± 0.2% dry matter, 19.2 ± 2.0% crude protein, 4.7 ± 0.5% crude fat, 2.8 ± 0.1% crude fibre and 95.2 ± 0.6% organic matter.

2.2. Gas monitoring and data analysis

The gas concentrations of each broiler house were measured intermittently on days 1, 4, 10, 12, 18, 23, 26, 28, 32, 35 and 40 of growing cycle by using a photoacoustic field gas-monitor (model INNOVA 1412i-5, Lumasense Technologies, Denmark) with detection limits of 152.1, 58.9, 286.4 and 2947.1 $\mu g\ m^{-3}$ for NH_3, N_2O, CO_2 and CH_4, respectively. At each measurement date and at four different times (8 h, 11 h, 14 h and 18 h), were collected individual air samples from the inlet (e.g., from air inlets), middle and outlet (e.g., from exhaust fans) of each broiler house by using an using a field sampling pump (model EW 79200-10, Cole Parmer, USA) to pump a sample of 1.5 L to a gas sampling bag (Tedlar bag, Cole Parmer, USA). The Tedlar bags were stored in plastic boxes under dark and analyzed up to 24 h after sampling.

At each gas sampling campaign, data on ventilation rate, indoor temperature and relative humidity were recorded from the climate controller (model F37, Fancom, The Netherlands) of each broiler house. The outdoor temperature and relative humidity were recorded every 10 min over the growing cycle using a sensor (model CS215, Campbell Scientific, UK) connected to a micrologger (model CR3000, Campbell Scientific, UK).

The emissions of NH_3, N_2O, CO_2 and CH_4 of each broiler house were estimated by a mass balance (Calvet et al., 2011; Alberdi et al., 2016) according Eq. (1).

$$ER = VR \times (C_{\mathrm{inlet}} - C_{outlet}) \quad (1)$$

where, ER was the gas (NH_3, N_2O, CO_2 or CH_4) emission (mg h^{-1}), VR was the ventilation rate in the broiler house ($m^3\ h^{-1}$), and C_{inlet} and C_{outlet} were the outlet and inlet gas (NH_3, N_2O, CO_2 or CH_4) concentrations measured in inlet and outlet air, respectively (mg m^{-3}).

The daily mortality rates as well as the removal of the 8000 broilers were recorded and accounted in the calculation of the average emission rates. The daily estimates of gas emission rates (g day^{-1} $bird^{-1}$) were determinate considering the mean values of the four sampling times of each day (8 h, 11 h, 14 h and 18 h). The cumulative gas emissions were determinate considering the mean gas emission rates and the time interval between two sequential dates of growing cycle. Broiler numbers were expressed in livestock unit (LU), considering that one broiler was 0.006 LU (REAP, 2013).

Data were subjected to one-way analysis of variance and Tukey comparisons of means tests ($p < 0.05$) were carried out using the statistical software package Statistix 7.0 (USA).

3. Results and discussion

3.1. Environmental conditions

The outdoor and indoor air temperature and relative humidity as well as the ventilation rates from each broiler house are shown in Fig. 1A–C and Table 1. During the growing cycle, the outdoor average temperatures ranged from 2.5 to 18.5 °C and the average relative humidity varied between 34.2 and 100% (Fig. 1A–B). Thus, there were significant ($p < 0.05$) on a few days (for indoor temperature) and for a larger period (for indoor relative humidity) between the three broiler houses, being observed an increase of the temperature and a decrease of the relative humidity from day 0 to day 42 (Fig. 1A–B). Hence, during the growing cycle, the indoor average temperatures varied from 31.6 to 20.6 °C while indoor average relative humidity ranged from 30.8 to 69.4% (Fig. 1A–B). The high values of indoor temperature and low values of indoor relative humidity relative to outdoor climatic conditions (Table 1)