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journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Ammonia and greenhouse gas emissions from an enriched cage laying hen facility

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ARTICLE INFO

Article history:
Received 30 April 2015
Received in revised form
4 December 2015
Accepted 20 January 2016
Published online xxx

Keywords:
Diurnal variation
Emission factor
Gas concentration
Hen manure
Seasonality
Ventilation rate

Ammonia, methane, nitrous oxide and carbon dioxide emissions were measured during a complete production cycle in an enriched cage laying hen facility under Oceanic climate conditions. Continuous monitoring of gas concentration, ventilation rate and environmental parameters were conducted from April 2012 to September 2013. The seasonal and diurnal pattern of gas emissions was analysed.

Seasonality effect was found for NH_3 emission, showing an average emission of 144.9 mg d^{-1} hen^{-1} and 90.3 mg d^{-1} hen^{-1} in summer and winter, respectively. On the contrary, diurnal pattern of NH_3 emission did not differ between these seasons. For CO_2, mean emission values did not show seasonality, although the diurnal pattern differed between winter and summer. Results obtained for CH_4 and N_2O emissions did not provide sufficient evidence to determine either seasonality or diurnal effect on these gases.

An NH_3 emission factor of 7% of total N in manure was defined for this system. These losses increased at higher ventilation rates and lower belt cleaning frequencies. Thus, NH_3 mitigation strategies at housing level should consider both parameters. Further studies would be necessary to determine how these factors regulate NH_3 emission at laying hen houses.

1. Introduction

Livestock intensification is associated to concerns on animal welfare and environmental issues such as air pollution. The need to improve the welfare and the productivity together with the mitigation of air pollution has led either governments or producers to the adoption of several international agreements. Regarding egg production sector in EU, intensified laying hen farms had to adopt Directive 1999/74/EC on animal welfare in 2012. According to this regulation, conventional cages (CC) are prohibited across EU since then. Alternative production systems have been implemented at varying levels in different EU countries, and most CC farms have switched to enriched cages (EC). In this sense, Spain, which is the 4th egg producer country in EU (MAGRAMA, 2015), has currently more than 85% of its laying hen population producing through EC production system. From an environmental perspective, EU

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http://dx.doi.org/10.1016/j.biosystemseng.2016.01.009

state members are obliged to reduce NH_3 and GHG losses by adopting Gothenburg and Kyoto protocols together with Directive 2001/81/EC concerning national emission ceilings (NEC). In order to reduce these emissions, EU created Directive 2010/75/EU, known as Industrial Emission Directive (IED). Laying hen farms with more than 40,000 hens are obliged to comply with IED Directive by implementing best available techniques to reduce gaseous losses.

Ammonia (NH_3) is one of the main pollutant gases associated with poultry operations, which also leads to poor indoor air quality that affects the health of animals and workers (Portejoie, Martinez, & Landmann, 2002). It also has an impact on vegetation, water and atmospheric environment (Henry & Aherne, 2014). It has been reported that NH_3 concentrations and emissions in poultry houses are usually higher than those from other livestock categories, e.g., dairy cattle and swine (Groot Koerkamp et al., 1998). In this sense, Nicholson, Chambers, and Walker (2004) concluded that strategies to reduce NH_3 emissions from poultry farming would be most effective if focused on housing and land spreading practices, where the greatest losses occur. On the contrary, methane (CH_4) and nitrous oxide (N_2O) emission from these facilities are lower if compared to other livestock productions, although according to IPCC (2013) both are greenhouse gases with a higher warming potential than carbon dioxide (CO_2).

The emission of NH_3 from poultry houses has been widely investigated although most of the studies on laying hen units have been carried out in Central and Northern European countries (Groot Koerkamp, 1994) and USA (Zhao, Shepherd, Li, & Xin, 2015), where either the environmental conditions or production systems may differ with respect to South European countries. In contrast to NH_3, fewer data on the emissions of CH_4 and N_2O from animal houses are available (Fournel, Pelletier, Godbout, Lagacé, & Feddes, 2012a; Shepherd et al., 2015; Wathes, Holden, Sneath, White, & Phillips, 1997; Zhu, Dong, Zhou, Xin, & Chen, 2011). Moreover, most of the research on air quality in laying hen houses in Europe has been based on short-time measurements (Nimmermark, Lund, Gustafsson, & Eduard, 2009), thus not covering seasonal variations. Long term and continuous monitoring is therefore needed to obtain deeper knowledge on gaseous emissions driving factors. This is a key element when proposing mitigation strategies that would better adapt to specific conditions.

The main objective of this paper was to report a sound baseline characterization of NH_3, CH_4, CO_2 and N_2O concentrations and emissions from a commercial farm of laying hens under Oceanic climatic conditions, located in the Basque Country (northern Spain). A second objective was to analyse the effect of factors such as ventilation, temperature, feeding or manure management on gaseous losses.

2. Material and methods

2.1. Animals and housing

Approximately 52,000 Lohmann-Brown hens were housed in a commercial laying hen unit in a vertical tiered EC system adapted to Directive 1999/74/EC.

The house (Fig. 1) was 17 m wide and 66 m long and enriched cages were arranged in 6 rows of 9 tier cages. The lighting period was 17:7 (light:dark) hours per day. The farm was selected to be representative of the current egg production facilities in the Basque Country in terms of management practices.

The hens were fed on a phase feeding system composed of three phases differing in crude protein (CP) content (Table 1).

Animal live weight (LW) was estimated from data provided by the supplier for a Lohmann Brown hen (Lohmann Tierzucht GMBH, 2013) according to hen age. Bird mortality, laying rate, egg production, feed intake and feed conversion ratio was daily recorded by the producer. Productive parameters of the laying hens during the experiment for different feeding phases are presented in Table 2.

Maximum laying rate (93%) was reached at week 23 and decreased gradually until the end of the cycle (78%). Feed conversion averaged 2.1 throughout the cycle in accordance with the technical datasheet for Lohmann Brown hens.

2.2. Environmental conditions

Outside weather conditions of the location during the study were: average air temperature of 10.7 °C and 20.0 °C, air relative humidity (RH) of 76.0% and 86.3% and rainfall rate of 618 and 101 mm (Euskalmet, 2014) for winter and summer respectively. These climate parameters are within the values recorded during the last 20 years for the Atlantic region, being representative of the Oceanic climate conditions.

Five temperature and RH sensors (Onset, HOBO U12-013, USA, precision ±0.35 °C and ±2.5%, respectively) were installed at the facility. One sensor was placed outside the house, two at the air inlets and the other two close to the fans. Temperature and RH were monitored and recorded every 15 min. An automated system (Tecno Poultry Equipment, Macronew 3, Italy) regulated inside temperature through windows opening, cooling system and the activation of 18 fans (EM50n, Munters, Sweden, air flow rate 42,125 $m^3\ h^{-1}$ at differential pressure = 0 Pa) set up within a tunnel ventilation system (Fig. 1).

Ventilation rate (VR) was measured under the usual rearing conditions at the facility according to the methodology described by Calvet, Cambra-López, Blanes-Vidal, Estellés, and Torres (2010). An electronic data logger (Binary Devices S.L., Datalogger 244, Spain) converted every second the electric signal from each fan into digital data on fan status. The average percentage of operation of each fan was obtained every 5 min.

The airflow rate of each fan was individually calibrated at different static pressures. Air was ducted 30 cm and the velocity measured by a hot wire anemometer (Testo 425, Germany, accuracy ± 0.03 $m\ s^{-1}$) at 25 locations in the section (ASHRAE, 2001). Static pressure was continuously measured and recorded every 5 min by a pressure drop metre (Veris, PX, USA, accuracy ±0.5 Pa). The resulting average airflow rate of fans, associated to each pressure drop recorded in the building during calibration events, were used to create the corresponding linear relationship (Eq. (1))