Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Influence of season and outdoor run characteristics on excretion behaviour of organic broilers and gaseous emissions

Bertrand Méda [a,b,c,*], Mélynda Hassouna [a,b], Marcel Lecomte [a,b], Karine Germain [d], Jean-Yves Dourmad [e,f], Paul Robin [a,b]

[a] INRA, UMR1069 Sol Agro et hydrosystème Spatialisation, F-35000 Rennes, France
[b] Agrocampus Ouest, UMR1069, F-35000 Rennes, France
[c] INRA, UR83 Recherches Avicoles, F-37380 Nouzilly, France
[d] INRA, UE1206 Élevage alternatif et santé des monogastriques, Domaine du Magneraud, F-17700 Saint-Pierre-d'Amilly, France
[e] INRA, UMR1348 PEGASE, F-35590 Saint-Gilles, France
[f] Agrocampus Ouest, UMR1348 PEGASE, F-35000 Rennes, France

ARTICLE INFO

Article history:
Received 24 January 2015
Received in revised form 26 July 2015
Accepted 3 August 2015
Published online 22 August 2015

Keywords:
Ammonia
Greenhouse gas
Poultry
Organic
Outdoor run
Excretion

Two organic broilers rearing systems, each associated with a broiler house of 75 m^2 and an outdoor run of 2500 m^2, were studied. In the first system, the outdoor run consisted of grassland (GRASS) but in the second, the outdoor run was planted with oaks (TREE). Two batches of broilers were studied from winter to spring (WS) and from summer to autumn (SA). Indoor and outdoor airborne concentrations of NH_3, N_2O, CH_4, CO_2 and H_2O were measured using a photoacoustic infrared analyser. Air flow rate through the broiler house was estimated using SF_6 tracer gas. The final amount and composition of the manure was determined. A mass balance was determined for N, P and water. Results showed that in SA, more nutrients were excreted in the outdoor run (41%) compared with WS (11%). During the WS season, outdoor excretion was greater in the TREE system but this was not observed during SA. Ammonia indoor emissions were higher during WS (200–283 mg [NH_3] d^{-1} $bird^{-1}$) than during SA (99–116 mg [NH_3] d^{-1} $bird^{-1}$). Total emissions from the systems (indoor + outdoor) were assessed using our values and data from the literature for outdoor emissions. This confirmed that total NH_3 emissions were in the same range as emissions of broilers reared in closed houses. N_2O emissions were higher during WS but represented less than 0.5% of indoor N excretion. Total CH_4 emissions were very low (40–60 mg [CH_4] d^{-1} $bird^{-1}$), particularly in comparison with emissions in other species.

Abbreviations: GRASS, broiler system in which the outdoor run consisted of grassland; TREE, broiler system in which the outdoor run was planted with trees; WS, winter–spring; SA, summer–autumn; DM, dry-matter; LM, live mass.

* Corresponding author. INRA, UR83 Recherches Avicoles, F-37380 Nouzilly, France. Tel.: +33 2 42 47 78 47; fax: +33 2 47 42 77 78.
E-mail address: bertrand.meda@tours.inra.fr (B. Méda).

http://dx.doi.org/10.1016/j.biosystemseng.2015.08.001

Nomenclature

X	nitrogen or phosphorus or water
$X_{Ingestion}$	total ingestion of X (kg)
X_{Body}	total body deposition of X in slaughtered and dead birds (kg)
$X_{Total\_excretion}$	total excretion of X (kg)
$P_{Indoor\_excretion}$	total indoor excretion of phosphorus (kg)
P_{Manure}	total amount of phosphorus in manure (kg)
P_{Straw}	total amount of phosphorus in straw (kg)
$P_{Outdoor\_excretion}$	outdoor excretion of phosphorus (kg)
$P_{Total\_excretion}$	total excretion of phosphorus (kg)
$100 * R_{Out/Tot}$	total:outdoor excretion ratio (%)
V	nitrogen or water
$V_{Outdoor\_excretion}$	outdoor excretion of V (kg)
$V_{Total\_excretion}$	total excretion of V (kg)
$V_{Indoor\_excretion}$	indoor excretion of V (kg)
N_{Indoor_losses}	total indoor nitrogen losses (kg)
$N_{Indoor\_excretion}$	total indoor nitrogen excretion (kg)
N_{Manure}	total amount of nitrogen in manure (kg)
N_{Straw}	total amount of nitrogen in straw (kg)
E	hourly emissions of water, CO_2, NH_3, N_2O or CH_4 (mg h^{-1})
C_{int}	indoor air concentration of water, CO_2, NH_3, N_2O or CH_4 (mg m^{-3})
C_{out}	outdoor air concentration of water, CO_2, NH_3, N_2O or CH_4 (mg m^{-3})
Q	housing ventilation rate (m^3 h^{-1})

1. Introduction

Societal concerns about animal production have been increasing throughout the world. Confined and intensive livestock farming systems are frequently associated with negative environmental impacts, poor animal welfare and low product quality (Siegford, Powers and Grimes-Casey, 2008; Verbeke & Viaene, 2000). Conversely, alternative systems such as organic farming systems have a positive image in terms of product quality, animal welfare and environment respect (Hughner, McDonagh, Prothero, Shultz, & Stanton, 2007).

In the European Union, poultry reared under organic certification must have access to an outdoor run so that birds can express natural behaviours such as exploration, foraging and dust bathing (European Commission, 2008). However, the levels of nitrogen (N) and phosphorus (P) excreted in the outdoor run of these systems are not well known although risks of nitrate leaching or phosphorus run-off may exist. The amount of N and P excreted by organic laying hens in outdoor runs has been evaluated in a limited number of studies (Aarnink, Hol, & Beurskens, 2006; Dekker, Aarnink, De Boer, & Koerkamp, 2012) which indicated that local N and P loads in outdoor runs (*i.e.* close to the poultry house) can exceed the European thresholds for these nutrients (170 kg [N] ha^{-1} yr^{-1} and 100 kg [P_2O_5] ha^{-1} yr^{-1} respectively). Furthermore, these excretion rates might be extremely variable since poultry behaviour (*e.g.* percentage of time spent outdoors) is known to be influenced by many factors such as climatic conditions and the characteristics of the outdoor run (*e.g.* presence of trees) (Cornetto & Estevez, 2001; Germain et al., 2011; Haneklaus, Schnug, & Berk, 2000; Hegelund, Sørensen, Kjær, & Kristensen, 2005; Lubac et al., 2003; Zeltner & Hirt, 2003, 2008).

A logical consequence of higher outdoor excretion rates could be a decrease in indoor excretion and thus a decrease in the emission of volatile compounds such as ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4), known for their negative effects on the environment (Bouwman, Van Vuuren, Derwent, & Posch, 2002; IPCC, 2007). However, as reported by Méda, Hassouna, Aubert, Robin, and Dourmad (2011), gaseous emissions from organic poultry houses have been rarely investigated and, to our knowledge, only organic laying hens have been studied so far (Dekker, Aarnink, de Boer, & Koerkamp, 2011).

Within this context, the aim of this study was, firstly to evaluate nutrient balances and housing gas emissions from organic broiler production, and secondly to estimate the influence of climatic conditions (season) and outdoor run characteristics (presence or absence of trees) on these flows.

2. Material and methods

2.1. *Description of rearing systems and animal management*

Two batches of slow-growing strain broilers (Hubbard JA657) were studied between December 2009 and November 2010 in the INRA French experimental facility "Le Magneraud" (Long. 00°41′25″ W, Lat. 46°09′04″ N). The first batch was reared under Winter–early Spring (WS) conditions and the second one in Summer–Autumn conditions (SA). For each batch, 758 and 788 birds per house, for WS and SA batches respectively, were equally allocated to two rearing systems composed of a non-insulated, naturally-ventilated broiler house of 75 m^2 provided with straw bedding (10.5 birds m^{-2}). Both broiler houses had side curtains (height: ≈700 mm; Fig. 1) along the full length of both the South-East and North-West sides. These curtains were manually opened or closed by the technical staff in charge of animal care in order to regulate indoor climatic conditions (temperature, air moisture). In each house, two pop-holes of 2 m long allowed broilers to access an outdoor run after 37 or 30 d for WS and SA batches, respectively. In the first system, a seeded grassland (grass + clover mixture) was used (GRASS system) whereas in the second one, a natural herbaceous cover planted with trees, mainly oaks, was used (TREE system). Both outdoor runs had the same area of 2500 m^2 (0.3 broilers m^{-2}). The location of the two rearing systems on the experimental site is given in Fig. 1. Dates of arrival, age at first access to the outdoor run and age at slaughter are given in Table 1. In each house, supplemental heat before first outdoor access was provided when necessary with propane radiant heating devices, to reach a minimum ambient temperature decreasing from 28 °C at chick arrival down to 23 °C at first outdoor access.

Broilers had *ad libitum* access to water and feed. Feed was distributed in tube feeders and water was provided with cup waterers. During the rearing period, broilers were fed with