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Research Paper

Carbon dioxide production from a fattening pig building with partial pit ventilation system

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Carbon dioxide (CO_2) is useful for determining ventilation rates in livestock buildings and its release from manure plays an important role in ammonia emission. CO_2 production in a fattening pig house with a partial pit ventilation system was investigated under working conditions. The influences of animal mass, animal activity, and ventilation rate on CO_2 concentrations and emissions were assessed. Results showed that the CO_2 production rate increased with growing pig body mass. A mathematical model of CO_2 production was developed based on the measured data. The measured CO_2 productions ranged from 30.3 to 99.0 g h^{-1} pig^{-1} for pigs from 30.1 to 111.5 kg. Comparing the last days of the fattening period with and without pigs, it was found that 2.3–3.4% of the total CO_2 production was released from manure. Higher pit ventilation rates resulted in higher CO_2 concentration in pit air and higher emission rates *via* pit exhaust, but had limited influence on the total emission rate (*via* room + pit exhaust). However, higher room ventilation rates resulted in lower CO_2 concentrations in room air but higher room and total emission rates. Diurnal variations in CO_2 productions were mainly influenced by animal activities. Four models of CO_2 production in literature were reviewed and compared with the model developed in this study. The CO_2 production model developed in this study had similar values with the CIGR model for a pig under 80 kg and the TCER model for a pig above 60 kg.

1. Introduction

Carbon dioxide (CO_2) is one of the most important gaseous contaminants in confinement pig buildings since it is an important parameter for determining indoor quality and a useful tool for calculation of ventilation rate (Estellés, Rodríguez-Latorre, Calvet, Villagrá, & Torres, 2010; Feddes & DeShazer, 1988; Ouwerkerk & Pedersen, 1994; Van't Klooster & Heitlager, 1994). Also, CO_2 release influences ammonia release from manure by affecting its pH change (Blanes-Vidal, Guàrdia, Dai, & Nadimi, 2012; Blanes-Vidal & Nadimi, 2011; Ni, Hendriks, Vinckier, & Coenegrachts, 2000).

Normally, there are two primary sources of CO_2 production in a pig house without combustible heating: animal respiration and manure release. Carbon dioxide produced by animal respiration is a function of energy metabolism rate, which is

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Nomenclature

system C	room with diffusion ceiling/ceiling jet inlets
system W	room with wall jet inlets
PB	proportional band
LYD	Danish Landrace × Yorkshire × Duroc
Q	emission/production rate, g h^{-1}
V	ventilation rate, m^3 h^{-1}
C	carbon dioxide concentration, g m^{-3}
M	pig body mass, kg
F_c	feed consumption, kg d^{-1}
E	metabolisable energy content of feed, J kg^{-1}
Φ_{tot}	total heat production, W
LU	livestock unit, 500 kg animal mass per LU
hpu	heat production unit, 1 hpu = 1000 W of total animal heat production at 20 °C.
TCER	tranquil CO_2 exhalation rate, g h^{-1}

Subscripts

p	total production
r	respiration
m	manure release
rm	room
pt	pit
tot	total
re	room exhaust
pe	pit exhaust
in	inlet

related to body mass, feeding level and diet nutrient composition, and animal activity (CIGR, 2002; Pedersen et al., 2008). The CO_2 from manure is the gaseous CO_2 released from animal faeces, which are either in the manure pit or on the floor (Ni, Vinckier, Hendriks, & Coenegrachts, 1999). Some studies claimed that the quantity of CO_2 released from manure was very small compared with that produced by animal respiration (Anderson, Smith, Bundy, & Hammond, 1987; CIGR, 1992; Feddes & DeShazer, 1988; Ouwerkerk & Aarnink, 1992, 1995; Ouwerkerk & Pedersen, 1994; Van't Klooster & Heitlager, 1994). However, other studies found that the quantity of CO_2 from manure release had considerable contribution to the total CO_2 production in fattening pig houses (Ni, Hendriks, Coenegrachts, & Vinckier, 1999; Ni, Vinckier, Hendriks, Coenegrachts, 1999; Pedersen et al., 2008). Pedersen et al. (2008) concluded that the CO_2 produced from manure release varied between houses with different control and management systems. The quantities of CO_2 production in pig houses is mainly affected by the volume, temperature, and age of manure stored in the houses. Biogas produced from stored manure under anaerobic condition consists of about 35%–60% of CO_2 (Deublein & Steinhauser, 2011). To date, only a few studies have determined CO_2 production in pig house using experimental measurements.

Ventilation system and control strategy can significantly influence the airflow characteristics inside a livestock room, which can further influence the emission of gaseous contaminants from animal buildings. A partial pit ventilation system in pig building has recently been developed. It extracts air with the most concentrated gaseous contaminants from the pit headspace directly *via* pit exhausts and can reduce the gaseous emissions efficiently from the building if the extracted air is treated with an air purification system (Saha, Zhang, Kai, & Bjerg, 2010; Wu, Kai, & Zhang, 2012; Zong, Feng, Zhang, & Hansen, 2014). Nevertheless, no study on CO_2 concentrations in and emissions from the pig building applying such a system has been reported. It is therefore interesting to experimentally investigate the CO_2 production and emission associated with animals and animal manure from the pig building with a partial pit ventilation system.

The objectives of this study are to: (1) investigate the influence of animal mass, ventilation rates and animal activities on CO_2 productions in the building that was equipped with partial pit ventilation system; (2) quantify the CO_2 produced by pig respiration and CO_2 released from manure in the building; (3) develop a mathematical CO_2 production model based on measurement data.

2. Materials and methods

2.1. *Pig house and ventilation system*

The investigation was carried out in two rooms in an experimental fattening pig house (Fig. 1) between 6th August and 23rd October 2012. The dimensions and layout of the house followed the design of typical commercial Danish pig production units. The only difference between the two rooms was its ventilation. One room was equipped with a diffusion ceiling and ceiling jet air inlets (denoted as system C), while another room had wall jet air inlet (denoted as system W) (Fig. 1a). The indoor air temperature was controlled at 22 °C at the beginning of fattening period for both systems. After 1 week the set-point temperature was decreased linearly until it reached 18 °C at the end of the fattening period. To prevent the ventilation control flap from being open and close too frequently, the proportional bands (P-band or PB) of 2.4 and 3.3 °C were applied for system C and system W, respectively. There were two pens (4.8 m long and 2.45 m wide) equally divided by a 1-m high partition wall in each room (Fig. 1b). The floor areas of all pens were designed with two thirds of slatted floor and one third of drain floor (Fig. 1b). The opening ratio of the slatted floor and drain floor was 17.2% and 8.6%, respectively. Each pen had a 0.7-m deep manure pit underneath the floor. Manure was pumped out through the valves in the pit bottom when the depth of stored manure was close to or more than 300 mm to avoid manure entering into the pit air exhausts. The manure in the two pits was emptied twice during the experiment.

The experimental building was ventilated by negative pressure ventilation. Systems C and W each had a ceiling-top room exhaust (Fig. 1a) and four partial pit exhausts (Fig. 2). The capacity of the total ventilation rate of each system was pre-adjusted to 100 m^3 h^{-1} pig^{-1}. The room ventilation rate was automatically controlled by a climate control system (VengSystem, Denmark) based on the indoor air temperature. The pit ventilation rate was fixed at approximately 10 m^3 h^{-1} pig^{-1} throughout the fattening period (10% of the