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Research Paper

Characterisation of pig manure for methane emission modelling in Sub-Saharan Africa

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There is limited information in the literature regarding models or direct measurements of CH_4 emissions from the rapidly growing pig industry in Sub-Saharan Africa. Measurements were conducted in pig fattening barns with slated and concreted floors in Cameroon to measure manure parameters and to subsequently model CH_4 emissions. Each barn was partitioned into pens containing pigs of a similar body mass range. Manure, collected over 24 h from each pen was weighed to calculate the average daily production per pig. Manure collected from each pen was mixed homogenously, subsampled into 60 ml vials for subsequent analyses of its moisture, dry matter (DM), ash and volatile solid (VS) contents. The daily VS excretion rate was used to model CH_4 production. On average, a 50 kg pig produced about 3 kg of manure day^{-1}, of which 2.09 kg (~70%) was the moisture content and 0.91 kg (~30%) was the DM. The ash content of the manure was 17% DM (0.14 kg pig^{-1} day^{-1}) while the VS was 83% DM (0.77 kg pig^{-1} day^{-1}). A 28 kg pig produced about 0.21 kg VS pig^{-1} day^{-1}, which is lower than the 0.30 kg VS pig^{-1} day^{-1} value recommended by IPCC, 2006 for Africa. The average CH_4 production rate was estimated as 1.68 ± 1.14 kg pig^{-1} day^{-1}. Exponential equations with coefficients of determinations (R^2) > 88% were used to describe the relationships between manure, DM and VS excretion rates, as well as CH_4 production rates as a function of the mass of the pigs.

1. Introduction

Agriculture and livestock production contributes significantly to the anthropogenic emissions of greenhouse gases (GHGs) into the atmosphere, especially methane (CH_4) (Massé, Masse, Claveau, Benchaar, & Thomas, 2008; Riaño & García-González, 2015). As such, reducing emissions from livestock production and animal houses is vital since large quantities of GHGs originate from animals and manure (FAO, 2006). Pig production in Sub-Saharan Africa is growing rapidly (Thornton, 2010), and since CH_4 emissions from pig production are significant, this study focuses on quantifying its emissions from the manure of fattening pigs. Emission models have been used to estimate CH_4 production from livestock manure (Li et al., 2012; Petersen, Olsen, Elsgaard, Triolo, & Sommer, 2016), with the standard methodology described in the IPPC guidelines for GHG inventories (IPCC, 2006). The Tier 2 approach shown in Eq. (1) has been used to estimate country-specific CH_4 emissions from manure management (ANIR, 2012; Du Toit, Niekerk, & Meissner, 2013; Environment-Canada, 2012).

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Nomenclature

Bo	Maximum CH_4 producing capacity (m^3 CH_4 kg^{-1} of VS excreted)
DM	Dry matter content of manure (kg or %)
EF	CH_4 production rate (kg CH_4 pig^{-1} day^{-1})
IPCC	Intergovernmental Panel on Climate Change
k	Climate region
M_{pig}	Daily wet mass of manure produced by a pig (kg)
M_w	Wet mass of manure subsampled from the daily wet mass of manure produced (kg)
M_d	Oven dried mass of the wet manure (kg)
M_c	Mass of crucible
M_1	Mass of crucible and subsample of oven dried manure
M_2	Mass of crucible and ash
MCF	CH_4 conversion factor
MS	Fraction of livestock category T's manure handled using manure management system S in climate region k
S	Manure management system
T	Livestock category
VS	Daily volatile solid excreted (kg VS pig^{-1} day^{-1})
W_{pig}	Mass of a pig (kg)
Y	Daily manure, DM, VS or CH_4 production rate (kg pig^{-1} day^{-1})

$$EF_{(T)} = VS_T \times 365 \times B_{0(T)} \times 0.67 \times \sum MCF_{S,K} \times MS_{T,S,K} \quad (1)$$

where $EF_{(T)}$ is the annual CH_4 emission factor for livestock category T, kg CH_4 $animal^{-1}$ yr^{-1}. $VS_{(T)}$ is the daily volatile solid (VS) excreted for livestock category T, kg dry matter $animal^{-1}$ day^{-1}. 365 is the basis for calculating annual VS production, days yr^{-1}. $B_{0(T)}$ is the maximum CH_4 producing capacity for manure produced by livestock category T, m^3 CH_4 kg^{-1} of VS excreted. 0.67 is the conversion factor from m^3 CH_4 to kg CH_4. $MCF_{(S,k)}$ is the CH_4 conversion factors for each manure management system S by climate region k, %. $MS_{(T,S,k)}$ is the fraction of livestock category T's manure handled using manure management system S in climate region k, dimensionless.

An important parameter in Eq. (1) is the $VS_{(T)}$, which is often modelled according to estimates of gross energy intake, feed digestibility, urinary energy and the ash content of manure (IPCC, 2006; Møller, Sommer, & Ahring, 2004). Direct measurements of the VS content from manure will provide better estimates of CH_4 production using Eq. (1). However, there is limited information in the literature and more especially for conditions in Sub-Saharan Africa, regarding direct measurements of VS or the ash content of manure. Furthermore, whilst CH_4 emission factors elsewhere have been revised, values for Africa have hardly changed due to the limited availability of accurate information (Wolf, Asrar, & West, 2017).

As such this research is aimed at quantifying daily manure production rates from fattening pig barns under conditions typical of Cameroon. Furthermore, the manure was characterised for its moisture, DM, ash and VS daily excretion rates. These parameters were then used to model CH_4 production rate. Finally, relationships between daily manure, DM and VS excretion rates, as well as the modelled CH_4 production rates were established as a function of the mass of the pigs.

2. Material and methods

2.1. *Barns and manure management systems*

The study was carried out in the savanna highlands of Bamenda, the regional capital of the North West Region, Cameroon. Manure production rate and its characterisation were measured in two big barns operating with different management systems.

The first barn had a slated floor, with side walls made of plywood. The barn was completely roofed and made up of several pens in one large building. The slated floor was raised to a height of about 0.7 m above the ground. Solid manure underneath the slated floor was removed periodically for storage in a sheltered structure and subsequently sold to farmers. The pigs were 2–9 months old, with body mass in the range of 26–75 kg. They consumed wet feed, with additional water supplied separately in a drinking trough. Pigs above 30 kg were fed once a day at 9 A.M. with feed composed of 20 kg kernel cake, 40 kg wheat bran, 15 kg seashell and 15 kg fowl droppings. Pigs below 30 kg were fed once a day at 7 A.M. with feed composed of 40 kg of wheat bran, 10 kg sea shell and 10 kg of corn.

The second barn was completely roofed, and had a concreted floor that was slightly inclined to a circular outlet hole at the back. The barn was made up of several pens separated by short concrete walls. Manure on the floor was cleaned daily and dumped in a sheltered structure for drying and subsequently sold to farmers. After cleaning, the floor was washed and the water channelled through the outlet hole into the surrounding fields. The pigs were 2–9 months old, with body mass in the range of 26–71 kg. They consumed dry feed at 7:30 A.M., with water supplied in a separate drinking trough. The feed was composed of 40 kg kernel cake and 50 kg of wheat bran.

2.2. *Environmental data*

Air temperature and relative humidity around the barns were measured using a Tinytag data logger (Gemini Data loggers, Chichester, UK) at 5 min intervals. During days when manure production was measured, the instantaneous manure temperature at the storage was also measured with a compost thermometer (TFA Dostmann, Wertheim, Germany).

2.3. *Measurements of animal mass, feed intake and manure production rate*

Pigs of similar sizes (and hence ages) were kept in the same pen to ease management. As such, it could be expected that feed consumption and manure production rates were similar for pigs within each pen. Therefore, the pens were categorised