Effect of feed-, nitrogen-, fibres- and water-intakes on emissions of NH_3, N_2O, CH_4, CO_2 and water vapour of grouped gestating sows kept on straw-based deep litter

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Introduction

The main pollutant gasses in pig production are ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2). Besides, water vapour (H_2O) flow is an important criterion in specifying ventilation rates, especially in bedded systems that release more moisture. Bedded systems are associated with improved animal welfare (Tuyttens, 2005), reduced odour nuisance and better brand image of livestock production. Therefore, since few decades, they get a renewed interest, particularly for gestating sows. The aims of this study were to measure NH_3-, N_2O-, CH_4-, CO_2- and H_2O-emissions of grouped gestating sows kept on straw based deep litter and to relate emissions to intakes of feed, nitrogen (N), neutral-detergent fibres (NDF) and water.

Material and methods

Gestating sows were allocated in sixteen groups of 5 or 8 animals, according to parity, body weight and backfat thickness. On average, the parity was 4.6 ± 2.2, the initial weight was 206.8 ± 27.2 kg and the backfat thickness was 14.9 ± 4.2 mm (mean ± sd between groups). Four groups of five sows and two of eight sows (36 sows) were fed *ad libitum* with a high-fibre diet based on sugar-beet pulp and wheat bran (12.9% crude protein, CP; 33% neutral-detergent fibres, NDF). Ten groups of sows (50 sows) were fed in stalls with restricted conventional gestating diet based on wheat, barley and maize (13.2%, CP; 18% NDF). For these sows, the amount of daily feed was determined by group as function of parity and backfat thickness. The meal was supplied once a day at 8.30 AM. Sows were blocked in stalls during the meal and liberated after one hour. The access to the stalls was forbidden between meals. In each pen, water was provided *ad libitum*.

Each group had its own experimental room. According to the group, the available space was 2.5 or 3 m² per sow. Before the arrival of animals in the pens, whole wheat straw was supplied to constitute the initial deep litter of about 30 cm depth. Extra straw was supplied regularly throughout the experiment. The average amount of straw was about 1.5 kg per sows and per day. Ventilation was provided using an exhaust fan in each room and the ventilation rate was automatically adapted on order to maintain a constant ambient temperature. The air inlet was an opening of 0.34m² connected to a service corridor of the building.

The gas concentrations in the air of the experimental rooms and of the corridor providing fresh air were measured by photoacoustic detection with a Multi-gas Monitor 1312 (Innova Air Tech Instruments) equipped to measure NH_3, N_2O, CH_4, CO_2 and H_2O. The lower levels of detection were 0.2 p.p.m. for NH_3, 0.03 p.p.m. for N_2O,0.1 p.p.m. for CH_4 and 3.4 p.p.m. for CO_2, with an accuracy rate of 95%. Measurements were conducted during 6 consecutive days at the 6th, 9th and 12th week of gestation. The sampling of the air in the rooms was performed above the exhaust fan, and the sampling of the air of the corridor at about 1m from the air inlets. The air was analysed every hour. The ventilation rates were continuously measured using an electronic device (Exavent, Fancom®) and the hourly means were recorded. Emissions (E), expressed as mg/h, were calculated according to the following formula:

$$E = D \cdot (C_i - C_e),$$

with D being the hourly mass flow (kg air per h); C_i and C_e being, respectively, the concentrations of gas in the air of the room and corridor (mg/kg dry air).

Differences between feed intakes (feed, nitrogen, NDF, water) and gaseous emissions (NH_3, N_2O, CH_4, CO_2 and H_2O) of restrictedly- or *ad libitum*-fed sows were analysed with a student test (Excel®, test.student). To explain the variability of emissions, simple linear regressions were established between pooled data of emissions and the feed intakes (Excel®, droitereg). Mean values per group were used for these analyses.

Results

The average ambient temperature in the experimental rooms was 19.1 ± 1.8 °C and the hourly average ventilation rate was 232.0 ± 62.3 m³/sow (mean ± sd between groups). The feed intakes and gaseous emissions are presented on table 1. Determination coefficients between emissions and feed intakes are shown on table 2. Figure 1 presents some relations between these two parameters.

Table 1. Intakes of feed, nitrogen (N), fibres (NDF) and water and gaseous emissions of ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4) and water vapour (H_2O) per sow and per day according to gestation feeding regimen (mean ± sd between groups)

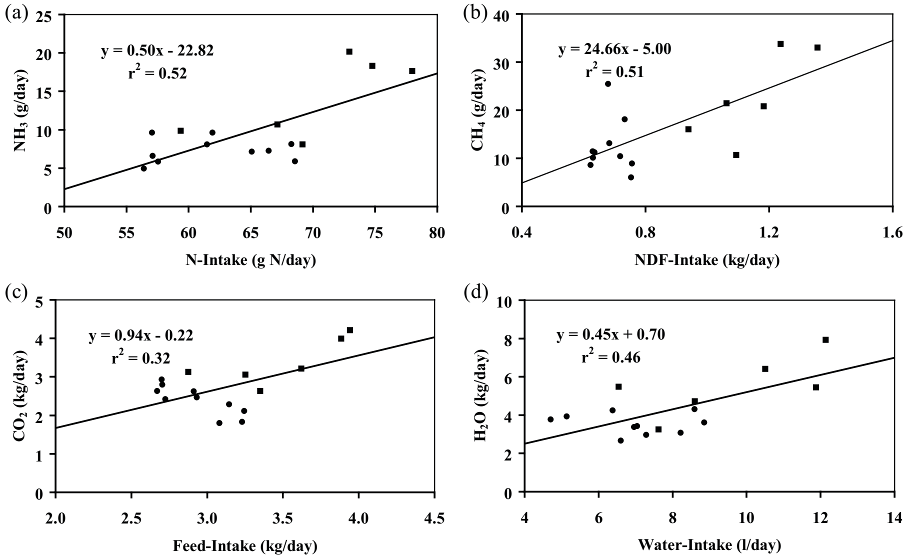
Item	Restricted (n=10)	Ad libitum (n=6)	P-value
Intakes			
Feed (kg)	2.94 ± 0.23	3.49 ± 0.41	0.003
N (g)	62.0 ± 4.8	70.2 ± 6.6	0.012
NDF (kg)	0.68 ± 0.05	1.15 ± 0.15	<0.001
Water (l)	6.98 ± 1.37	9.55 ± 2.31	0.014
Gaseous emissions			
NH_3 (g)	7.29 ± 1.58	14.09 ± 5.15	0.001
N_2O (g)	3.46 ± 1.89	1.53 ± 0.27	0.028
CH_4 (g)	12.29 ± 5.59	22.58 ± 9.19	0.014
CO_2 (kg)	2.38 ± 0.38	3.37 ± 0.60	0.001
H_2O (kg)	3.53 ± 0.54	5.53 ± 1.57	0.002

Table 2. Coefficients of determination between gaseous emissions and feed intakes

	FEED	N	NDF	WATER
NH_3	0.68***	0.52**	0.71***	0.67***
N_2O	0.08	0.05	0.22^T	0.03
CH_4	0.48**	0.33*	0.51**	0.64***
CO_2	0.32*	0.16	0.55***	0.33*
H_2O	0.39*	0.20	0.54**	0.46**

SIGNIFICANCE : ^{T} : P=0.07, * : P<0.05, ** : P<0.01, *** : P<0.001

Figure 1. Relation between emissions of ammonia (a), methane (b), carbon dioxide (c) and water vapour (d) and feed intakes of restrictedly-fed (●) and *ad libitum*-fed (■) sows



Discussion

Ammonia emissions factors obtained in this experiment, 7.3 g and 14.1 g NH_3/day per sow fed restrictedly or *ad libitum* respectively, meet values of the literature ranging from 7 g to 31 g NH_3/day for grouped sow kept on litter (Groot Koerkamp et al., 1998; Bos et al., 2003, Dore et al., 2004). Studies of Groenestein et al. (2007) seem to show that straw bedding for sows reduces NH_3 emissions of about 65% in comparison with concrete floor or slatted floor. It is contrary to the results of Philippe et al. (2007) who observed two-fold emissions for fattening pigs on straw compared with slatted floor. On slatted floor, most of cited values for sows are around 14 g NH_3/day (Groot Koerkamp et al., 1998; Groenestein et al., 2003). Values near 6 g NH_3/day.sow were obtained with specific accommodations for lower emissions (metal slat, sloped walls in the manure pit, frequent manure removal) (van der Peet-Schwering et al., 2001). Whatever the floor type, numerous factors can influence NH_3-emissions from piggeries, like animal density, weight of animals, waste treatment, removal/storage system, cleaning system, interior climate and the season (Groot Koerkamp et al., 1998). Feeding management is also an important mean to modulate emissions. For example, there is a positive correlation between N-intake and NH_3 emissions (Canh et al., 1998a; Hayes et al., 2004; Philippe et al., 2006; Lynch et al., 2008). Some authors have also observed a reduction of emissions with high levels of fibres in the diet of fattening pigs kept on slatted floor (Canh et al., 1998b; Lynch et al., 2008). Nevertheless, in the current experiment, both N-intakes and NDF-intakes were positively correlated to NH_3 emissions. According to Ramonet et al. (2000) and Noblet and Le Goff (2000), ingestion of large amount of feed, and particularly of fibres, decreases N digestibility with possible impact on NH_3 emissions.

Few data are available about nitrous oxide emissions by sows. The European Pollution Emission Register (EPER, 2003) presents emissions factors of 1 g and 5.1 g N_2O/sow. day for Ireland and Germany, respectively. For fattening pigs, data from literature range from 0.03 g to 8 g per day for pigs on deep litter and from 0.17 g to about 2.26 g per day for pigs on slatted floor (Robin et al., 1999; European Commission, 2003; Nicks et al., 2004; Hassouna et al., 2005). The formation of N_2O occurs during incomplete nitrification/

denitrification processes that normally convert NH_3 into dinitrogen (N_2) (Groenestein and Van Faassen, 1996). Nitrification needs aerobic conditions while denitrification needs anaerobic conditions. N_2O is mainly synthesised during denitrification, in case of presence of oxygen and/or low availability of degradable carbohydrates (Poth and Focht, 1985). During nitrification, N_2O can also be synthesised where there is a lack of oxygen and/or nitrite accumulation (Groenestein and Van Faassen, 1996; Veeken et al., 2002). Therefore, deep litters, with both aerobic and anaerobic sites, enhance N_2O production (Veeken et al., 2002). However, these heterogeneous conditions make its formation variable and explain variations observed by several authors (Hassouna et al., 2005; Philippe et al., 2007a, 2007b). In this study, feed intakes do not explain significantly variations observed between groups. This shows that N_2O emissions are mainly functions of particular conditions in the manure rather than feed management. However, a trend was obtained (P=0.07) between emissions and NDF-intakes, with lower emissions related to higher NDF-intakes. The availability of degradable carbohydrates can be used as source of energy for micro-organisms that achieve complete nitrification/denitrification processes with lower N_2O by-product.

Methane originates both from digestive tract of animal and from manure. Enteric fermentations are function of fibres intake, as measured in metabolic cages by several authors (Ramonet et al., 2000; Le Goff et al., 2002). Le Goff et al. (2002) observed increasing enteric CH_4 from 4 to 8 g per day by increasing NDF-intake from 210 g to 435 g per day. Production from manure comes from anaerobic degradation of organic matter (Hellmann et al., 1997). Methanogenesis is mainly performed by mesophilic bacteria (25-40°C) with an optimal pH of 7.0-7.2. By increasing organic matter content of manure and by lowering the pH of manure towards optimum (Canh et al., 1998b; Massé et al., 2003; Lynch et al., 2008), dietary fibres could enhance methane emission from manure (Aarnink and Verstegen 2007). Therefore, fibres could have an influence on both sources of methane, resulting in higher emissions for sows fed *ad libitum* with high fibre diet. Besides, water intake is linearly related to emissions (r^2=0.68, P<0.001). This result can be explained by assuming that litter of more drinking sows is wetter, contains more anaerobic area and promotes CH_4 emissions. However, regulation of synthesis inside the manure is relatively complex because of interactions between several processes (Hobbs et al., 1999).

Carbon dioxide from piggeries has two main origins: animal respiration and manure. CO_2 exhalation is estimated to about 2.8 kg per day per sow, according to CIGR equations based on body weight (CIGR, 2002). This production is also function of metabolism. Thus, it is consistent to obtain linear relation between emissions and feed-intake. Releases from manure have also two sources: on the one hand, hydrolysis of urea leading to ammonia and carbon dioxide, on the other hand, anaerobic degradation of organic components (Aarnink et al., 1995; Ni et al., 1999). With restrictedly-fed sows, production from manure seems to be neglected while with *ad libitum*-fed sows, production could be estimated to about 0.6 kg. Some studies have already showed negligible releases from manure (Anderson et al., 1987; van 't Klooster and Heitlager, 1994). Other studies with fattening pigs estimated emissions from slurry or litter between 0.2 to 0.5 kg CO_2/pig.day (Philippe et al., 2007a, Ni et al., 1999; Jeppsson, 2000). Availability of degradable organic matter, temperature and oxygenation level in the litter may enhance releases from manure (Aarnink et al., 1995; Ni et al., 1999). Thus, these factors explained significant relations obtained between CO_2 emissions and NDF- and water-intakes.

Like methane and carbon dioxide, water vapour has two origins: animals and manure. Evaporation by animals is function of body weight, heat production and ambient temperature (CIGR, 2002). With bedded systems, H_2O emissions are enhanced by the high temperature met in litter due to fermentation (Nicks et al., 1994; Philippe et al., 2007a, 2007b). By contrast, emissions from slatted floor systems are negligible

(Philippe et al., 2007a). Thus, litter systems need higher ventilation rates in “winter conditions” when air relative humidity is the key factor determining the ventilation rate. In the current experiment, emissions are positively correlated with water intakes. Likewise, higher fibres intakes may partly explain higher emissions by increasing organic substrates for fermentation, with higher temperature in litter as consequence.

Therefore, it can be conclude that the level of feed intake is a key factor to modulate emissions of NH_3, N_2O, CH_4, CO_2 and H_2O from grouped gestating sows on straw based deep litter.

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