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Effects of space allowance on gas emissions from group-housed gestating sows

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1. INTRODUCTION

Nowadays, in addition to economic factors, livestock production has to combine several aspects, like animal welfare and environmental aspect. According to European legislation (Directive 2001/88/CE), by 2013, pregnant sows will have to be kept in groups at least from 4 weeks after insemination till 1 week before parturition. Besides, the minimal legal space allowance is 2.25 m^2 sow^{-1}, +10% for groups containing less than 6 sows.
Behavioural impact of an increased space allowance has been quite largely studied with gestating sows, concluding in improved welfare with lower animal density (Salak-Johnson et al., 2007; Remience et al., 2008). However, effects of space allowance on environmental parameters have been few studied.
Therefore, the aim of this study is to evaluate the impact of space allowance on ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) emissions from group-housed gestating sows kept on straw-based deep litter and allowed 2.5 m² or 3.0 m².

2. MATERIAL AND METHODS

2.1. Housing conditions

Two experimental rooms, similar in volume (103 m³) and surface (30 m²), were arranged for this essay. Rooms consisted of a service area and a pen to house a group of five gestating sows. Pens were divided in a straw-bedded area and five individual feeding stalls. The surface of bedded area was 12.6 m² (2.5 m² sow^{-1}) and 15 m² (3 m² sow^{-1}) in the two rooms respectively. In each pen, before the arrival of the animals, 150 kg of whole wheat straw were used to constitute the initial deep litter of about 25-30 cm depth. Thereafter, supplementary amounts of straw were provided regularly depending on the cleanliness of the sows. The feeding stalls were raised the height of 30 cm. They were equipped with front troughs and rear gates preventing the access to the stalls between meals. At the end of each batch, pens were cleaned and manures were removed, weighted, sampled and analysed for determination of dry matter, organic matter and N -contents.
Each room was ventilated with an exhaust fan and the ventilation rate was adapted automatically to maintain a constant ambient temperature. Fresh air entered through an opening of 0.34 m^2 which was connected to the service corridor of the building; the outside air was thereby preheated before entering the experimental rooms. The air temperatures of the experimental rooms, the corridor and the outside were measured automatically every hour. The ventilation rates were measured continuously and the hourly means were recorded with an Exavent apparatus (Fancom®) with accuracy of 35 m^3 h^{-1}, i.e. 1% of the maximum ventilation rate of the fan.

2.2. Animals and feed

Four replicates were carried out for this experiment with a batch of ten Belgian Landrace gestating sows per replicate. One month after service, batches were homogeneously divided in two groups of five animals, according to parity, body weight and backfat thickness. Groups were randomly allocated to a treatment function of space allowance, 2.5 m² or 3 m² per sow. Each replicate lasted about 10 weeks and 15 days prior to giving birth, sows were transferred to farrowing pens.

Sows were fed in stalls with restricted conventional gestating diet based on wheat, barley and maize (13.2% of crude protein; 18% of neutral-detergent fibres). 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*.

2.3. Gas emissions measurement

The concentrations of gases in the experimental rooms and in the corridor supplying fresh air were measured by infrared photoacoustic detection with a Multi-gas Monitor equipped for simultaneous measurement of NH_3, N_2O, CH_4 and CO_2. The lower levels of detection were 0.2 ppm for NH_3, 0.03 ppm for N_2O, 0.1 ppm for CH_4 and 3.4 ppm for CO_2, with an accuracy rate of 95%. The air in the experimental rooms was sampled upstream of the exhaust fan and that one of the corridor, at 1 m from the air inlet. For each batch, the hourly concentrations were measured durin 3 period of 6 consecutive days(weeks 6, 9 and 12 of gestation).

The emissions (E_{gas}) were calculated on an hourly basis and expressed in mg h^{-1} using the following formula: $\mathbf{E_{gas} = D \times (Ci - Ce)}$

with D, the hourly mass flow (kg air h^{-1}); Ci and Ce, the concentrations of gas in the air of the room and corridor respectively (mg kg^{-1} air).

The global warming potential (GWP) of the greenhouse gases, N_2O and CH_4 together, was expressed in CO_2 equivalents (CO_2-Eq) using the following equation:

$$\mathbf{CO_2\text{-}Eq\ (kg\ d^{-1}\ sow^{-1}) = 21\ E_{CH4} + 310\ (E_{N2O})}$$

with E_{CH4} and E_{N2O} being the emissions of CH_4 and N_2O (kg d^{-1} sow^{-1}), and taking into account that the warming potentials of CH_4 and N_2O over a 100-year period are, respectively, 21 and 310 times that of CO_2 (IPCC, 2006). For E_{N2O}, indirect emissions from atmospheric deposition of N from NH_3 on soils and water surfaces have been added to the direct emissions. The indirect emissions were calculated considering an emission of 0.01 kg N_2O-N kg^{-1} emitted NH_3-N (IPCC, 2006). Emissions of CO_2 were excluded from this estimation because one can estimate that CO_2 production by livestock is compensated by CO_2 consumption by photosynthesis of plants used as feed (IPCC, 2006).

2.4 Statistical analyses

For performance data recorded per sow, the differences between groups were tested using analysis of variance with 2 criteria (proc GLM, SAS): space allowance (1 df), replicates (3 df) and interaction between space allowance and replicates. For intakes data and manure characteristics, recorded per pen, the differences were tested using t-test for paired data (TEST.STUDENT, Microsoft Office Excel 2003).

For ventilation rates, room temperatures, and gas emissions, the differences with regards to the space allowance (2.5 m² *versus* 3.0 m²) were tested in the form of a mixed model for repeated measurements with 2 criteria (proc MIXED, SAS): space allowance (1 df), week of measurement (2 df) and interaction between space allowance and week of measurement with

144 (24h × 6d) successive measurements per week. Residuals were assumed normally distributed, with a null expectation. Correlation between successive measurements was modelled using a type 1-autoregressive structure.

RESULTS

3.1. Climatic characteristics of the rooms

The average temperatures of the air were 18.5°C in both experimental rooms (*P*>0.05), 16.6 °C in the corridor and 11.6°C outside. The mean ventilation rates were 263 m³ h^{-1} per sow allowed 2.5 m² and 232 m³ h^{-1} per sow allowed 3.0 m² (*P*>0.05).

3.2. Zootechnical characteristics

About animal performance, none of the differences between groups were statistically significant regarding space allowance (*P*>0.05). The parity was on average 4.5 for both groups. At the beginning and at the end of experiments, the mean body weights (BW) were 204.6 and 259.3 kg, respectively, and the mean backfat thickness were 14.9 and 21.1 mm, respectively. On average, the daily feed-, N- and water-intakes per sow were 2.99 kg, 63.2 g and 7.3 L, respectively. Total numbers of piglets born and live born were 11.9 and 10.5 per sows.

Characteristics of manure did not significantly differ between groups (*P*>0.05). The amounts of supplied straw and collected manure were about 1.3 kg and 3.9 kg d^{-1} sow^{-1}. The dry matter and organic matter contents were respectively 291 g and 246 g per kg of fresh manure. Nitrogen and ammonium content were respectively 8.27 g N and 1.65 g N-NH_4^+ per kg of fresh manure. The mean pH value was about 8.27 for both groups.

3.3. Gas emissions

Table 1 presents the mean gas emissions observed for each group of sows. Increasing space allowance from 2.5 to 3.0 m² raises NH_3-emissions by 17% but decreases N_2O-, CH_4-, CO_2-Eq- and CO_2-emissions by 29%, 33%, 29% and 12%, respectively.

Table 1 - Gas emissions (least square means per sow and per day) of ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4), CO_2-equivalent (CO_2-Eq) and carbon dioxide (CO_2) per gestating sows allowed 2.5 m² or 3.0 m².

	2.5 m² sow^{-1}	3.0 m² sow^{-1}	s.e.	Significance
NH_3 (g)	6.45	7.53	0.23	**
N_2O (g)	3.84	2.74	0.22	**
CH_4 (g)	15.18	10.15	0.44	***
CO_2-Eq (kg)	1.54	1.10	0.05	***
CO_2 (kg)	2.40	2.12	0.03	***

DISCUSSION

Ammonia emissions factors obtained in this experiment meet lower values presented in the literature ranging from 7 g to 31 g NH_3 day^{-1} for grouped sow kept on litter (Groot Koerkamp et al., 1998; Misselbrook et al., 2000; Bos et al., 2003; Dore et al., 2004). On slatted floor, cited values ranges from 6 g to 18 g NH_3 sow^{-1} day^{-1} (Groot Koerkamp et al., 1998; van der Peet-Schwering et al., 2001; Groenestein et al., 2003). Whatever the floor type, numerous factors can influence NH_3-emissions, like feeding management, interior climate, season and waste treatment (van der Peet-Schwering et al., 1999; Andersson, 1996; Groot Koerkamp et al., 1998; Hassouna et al., 2005; Philippe et al., 2006 and 2009). Furthermore, for litter systems, properties of bedding materials (C/N ratio, carbon availability, pH value and physical structure, among others) affect volatilization (Jeppsson, 1998). In the current essay, the raise of emissions (+17%) is explained by increase of space allowance (+20%) and therefore increase of emitting surface area. Few studies evaluate this parameter on emissions. Partial results obtained with fattening pigs (Hassouna et al., 2005) seem to show a reduction of NH3-emissions with extra space allowance. Besides, they observed a reduction of N2O-emissions with the lower animal density, as measured in this experiment.

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). N_2O-synthesis needs close combination of aerobic and anaerobic area. These heterogeneous conditions are met within the litter (Veeken et al., 2002) and this explains higher emissions usually observed with bedded systems in comparison with slurry systems (Philippe et al., 2007a). Few data are available for gestating sows. For fattening pigs kept on deep litter, values from literature reach 8 g pig^{-1} day^{-1} compared with about 2 g day^{-1} for pigs on slatted floor (Robin et al., 1999; European Commission, 2003; Nicks et al., 2004; Hassouna et al., 2005). However, in bedded systems, N_2O-formation may be reduced in case of too aerobic litter (Kermarrec and Robin, 2002). In the current study, by increasing space allowance, strictly aerated part of manure is also increased and, consequently, N_2O-formation are impaired .

In this experiment, increasing available floor space from 2.5 m² to 3.0 m² reduce CH_4 emissions from 15 g to 10 g CH_4 sow^{-1} day^{-1}, respectively. In literature, large variations were observed between authors with values ranging from 5 g to 60 g sow^{-1} day^{-1} (Groot Koerkamp et Uenk, 1997 ; Godbout et al., 2003 ; Dong et al., 2007 ; Gac et al., 2007). Methane originates from anaerobic degradation of organic matter in the digestive tract of animal and in the manure. Methanogenesis is mainly performed by mesophilic bacteria (25-40°C) with an optimal pH of 7.0-7.2 (Hellmann et al., 1997). Enteric fermentations are enhanced by fibres intake (Ramonet et al., 2000b; Le Goff et al., 2002a; Philippe et al., 2008). In manure, CH_4-releasse are promoted by high temperature and elevated dry matter content (Amon et al., 2006 ; Haeussermann, 2006). Straw supply may enhance emissions by increasing manure contents in dry matter and degradable carbohydrates. It constitutes also a potential source of dietary fibres. On the other hand, it may inhibit production because of too great aeration (Amon et al., 2006 ; Yamulki et al., 2006). As observed for N_2O, reduction in CH_4 emissions is explained by more aerobic conditions associated to extra space allowance.

GWP is reduced by about one third with the higher available space floor. This is due to the lowering of N_2O and CH_4 emissions, representing 78% and 20% of total CO_2-Eq emitted, respectively. In contrast, our results indicate that indirect emissions of N_2O from NH_3 deposition are negligible, with low impact on GWP.

Carbon dioxide emissions during this experiment are lower that former results obtained with sows kept on slatted floor, ranging from 3 kg to 6 kg sow^{-1} day^{-1} (Godbout et al., 2003; Dong et al., 2007). In piggeries, the main source of CO_2 come from animal respiration. CO_2-exhalation is function of metabolism and therefore, function of BW, feed-intakes and activity. However, releases from manure are not negligible as observed by several authors with solid or liquid manures (Philippe et al., 2007a, Ni et al., 1999; Jeppsson, 2000). Production in manure have two origins: hydrolysis of urea leading to ammonia and carbon dioxide, but principally anaerobic degradation of organic components (Aarnink et al., 1995; Ni et al., 1999). Its synthesis is promoted by high temperature but reduced by aerobic environment. Aeration of litter linked to space allowance explains reduction of emissions measured for the groups with lower animal density. In this way, our results show that, although diet characteristics, feed intakes, animal performances and climate conditions are similar for both groups, CO_2-emissions may differ because of housing conditions. Therefore, ignoring CO_2 in evaluation of GWP may be debatable.

In conclusion, increasing space allowance for gestating sow kept on straw-based deep litter is environmentally conflicting because it favours NH_3-emissions by increasing emitting surface, but it impair emissions of greenhouse gases (N_2O, CH_4 and CO_2) by reducing anaerobic conditions required for their synthesis.

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