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Pig housing system versus greenhouse gas emissions

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Abstract: *Pig housing system versus greenhouse gas emissions.* Animals emit greenhouse gases (GHG): carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) through respiration and digestion, and also in feces. The emission rate depends on the way animals are fed and housed. The objective of the study was to determine the emission rates of carbon dioxide, methane and nitrous oxide in two pig fattening farms with deep litter or slatted floor systems. The study was carried out on farm I, which raises 7,617 pigs on slatted floor per year, and on farm II, which keeps 1,594 pigs on deep litter. Carbon dioxide equivalents of 25 for CH_4 and 298 for N_2O were used in the calculations. The study estimated GHG emissions from livestock production only. Greenhouse gas emissions in CO_2 equivalent was 374.52 t on farm I and 68.91 t on farm II, corresponding to 49.17 kg (farm I) and 43.23 kg per pig (farm II). The present study showed lower GHG emissions in the deep litter system compared to the slatted floor system.

Key words: fatteners, greenhouse gases, emission, deep litter, slatted floor system

INTRODUCTION

The intensity of the greenhouse effect is controlled by the accumulation of greenhouse gases (GHG), the emissions of which are caused mainly by the burning of fossil fuels, changes in land use, deforestation, and livestock production. Animals emit greenhouse gases such as carbon dioxide (CO_2), which is produced from respiration, as well as methane (CH_4) and nitrous oxide (N_2O), which come from digestion and animal waste (Nalborczyk et al. 1997, IPCC 2006). The emission potential of CH_4 and N_2O is respectively about 25 and 300 times higher than that of CO_2. The consumption of electricity and liquid fuels, which is associated with animal production, is an additional source of CO_2 emissions. If a farm cultivates plants for animal feed, the GHG balance accounts also for energy used to produce fertilizers and pesticides. Greenhouse gas balance in livestock production is estimated using IPCC Tier 1 and Tier 2 (2006), ASABE (USDA 2014) and Nalborczyk et al. (1999) methods, with allowance made for the data on animal production systems and production results. The methane and nitrous oxide emission rates show high amplitudes for both pigs kept on slatted floor and those raised on deep litter (Philippe and Nicks 2014).

The agricultural sector is a significant contributor to greenhouse gas emissions, in particular methane and nitrous oxide, which account for 35 and 73% of total GHG emissions, respectively

(KOBiZE 2012). In looking for ways of reducing GHG emissions, much attention is being paid to animal feeding and housing systems (Cabaraux et al. 2009, Philippe and Nicks 2014). Management of animal manure in various pig housing systems affect the level of GHG emissions. The objective of the study was to determine the emission rates of carbon dioxide, methane and nitrous oxide (in carbon dioxide equivalent) in two pig fattening farms with deep litter or slatted floor systems.

MATERIAL AND METHODS

Data for the balance of emissions were collected in two individual open-cycle pig farms located in Central Poland. Between 1 October 2013 and 30 September 2014, detailed information was gathered concerning the course of different pig production cycles (Table 1) and the consumption of energy sources used in livestock production (Table 2). The fatteners were kept on slatted floor in the first farm (farm I) and on deep litter in the second farm (farm II). The study estimated GHG emissions from livestock production only.

Open-cycle fattening based on purchased feeds was conducted in both farms. Fattening started at a body weight of ca 35 kg and ended at a body weight of ca 122 kg. Four-phase fattening was conducted in farm I and three-phase fattening in farm II. During the analysed period, 7,617 and 1,594 pigs were kept in farms I and II, respectively.

TABLE 1. Production results of pigs raised in the farms under study

Data on pig fattening	Unit	Farm	
		I slatted floor	II deep litter
Number of pigs per production cycle	head	2 539	797
Duration of one production cycle	day	115	110
Number of fattening cycles during the study	–	3	2
Average weight of pig on the first day of fattening	kg	34	35
Average weight of pig on the last day of fattening	kg	122	121
Average feed conversion (kg feed/kg gain)	kg	2.71	2.79
Average dressing percentage	%	79.2	79.5
Average meatiness of pigs sold	%	58.4	59.1

TABLE 2. Amount of energy sources used in the farms under study

Source of emission	Unit	Farm	
		I slatted floor	II deep litter
Electric energy	kWh	48 390	10 800
Diesel fuel	dm^3	6 460	1 870

Emission of CO_2 was estimated according to Nalborczyk et al. (1999) using KOBiZE (2014) coefficients of electric energy and fuel oil consumption (Matin et al. 2004, Ludwicka 2009) as follows: 1 kWh of electric energy – 0.8315 kg CO_2; 1 dm^3 of diesel oil – 2.7631 kg CO_2 equivalent.

Daily amount of CH_4 from digestion was estimated according to IPCC Tier 1 methodology (IPCC 2006):

$$CH_4 = population \cdot 0.00411$$

where:
CH_4 – daily methane emissions (kg);
population – number of swine (head);
0.00411 – daily CH_4 emissions from each animal (kg).

Methane emission from animal manure was estimated according to IPCC Tier 2 methodology (IPCC 2006). Coefficients recommended by IPCC were used based on the data concerning the number of pigs raised and the housing system.

$$E_{CH_4} = VS \cdot B_0 \cdot 0.67 \cdot \frac{MCF}{100}$$

where:
E_{CH_4} – daily CH_4 emissions per animal (kg);
VS – volatile solids (kg VS/kg dry manure), $VS = 0.3$;
B_0 – maximum CH_4 producing capacity for manure (m^3/kg VS), $B_0 = 0.45$;
MCF – CH_4 conversion factor for the manure management system (%), slatted floor – 10%, deep litter – 2%;
0.67 – conversion factor of m^3 CH_4 to kg CH_4.

Emission of N_2O was estimated according to ASABE methodology (USDA 2014), using data on feed composition, duration of production cycle, pig fattening and slaughter results, and housing system:

$$E_{N_2O} = [n \cdot N_{ex} \cdot (1 - \%NH_3loss/100) \times \times EF_{N_2O} \cdot \frac{44}{28} \cdot d \cdot c] \cdot \frac{1}{1{,}000}$$

where:
E_{N_2O} – daily nitrous oxide emissions (kg);
n – number of head of livestock species (animal);
N_{ex} – total daily nitrogen excretion per animal (g);
$\%NH_3loss$ – percent of N_{ex} lost as NH_3 in animal housing (USDA 2014, Tables 5–12);
EF_{N_2O} – N_2O emission factor for manure in housing (kg N_2O-N/kg N) (USDA 2014) – deep bedding – 0.01; pit storage – 0.002 kg;
$\frac{44}{28}$ – conversion of N_2O-N emissions to N_2O emissions;
d – days on feed to finish animals (grow-finish phase) (day);
c – number of phases per year;
$\frac{1}{1{,}000}$ – conversion of g to kg.

$$N_{ex} = N_{\mathrm{intake}} - N_{\mathrm{retention}}$$

where:
N_{ex} – total nitrogen excretion per animal (g);
N_{intake} – nitrogen intake per finished animal (g);
$N_{\mathrm{retention}}$ – nitrogen retained per finished animal (g).

$$N_{\mathrm{intake}} = ADFI_G \cdot C_{CP} \cdot \frac{DOF_G}{625}$$

$$N_{\text{retention}} = \frac{BW_F \cdot DP_F \cdot FFLP_F}{159.4} - BW_I \cdot [DP_F - 0.05 \cdot (BW_F - BW_I)] \cdot \frac{FFLP_F + 0.07 \cdot (BW_F - BW_I)}{159.4}$$

where:

$ADFI_G$ – average daily feed intake over finishing period (g/day);

C_{CP} – concentration of crude protein of total (wet) ration (%);

DOF_G – days on feed to finish animals (grow-finish phase) (day);

BW_F – final (market) body weight (kg);

DP_F – average dressing percent (yield) at final weight (%);

BW_I – initial body weight (kg);

$FFLP_F$ – average fat-free lean percentage at final weight (%).

Carbon dioxide equivalents of 25 for CH_4 and 298 for N_2O were used in the calculations (IPCC 2007).

RESULTS AND DISCUSSION

The carbon dioxide emission was calculated to be 58.09 t in farm I and 14.15 t in farm II (Table 3). The emission due to consumption of electric energy, used for ventilation of livestock buildings, accounted for 69% in the slatted floor system and for 63% in the deep litter system. The remainder of the emission came from diesel oil burned by agricultural machines for the purpose of organic fertilizer management. Carbon dioxide exhaled by animals is not concentrated in the atmosphere (Walczak 2013) and was not included in the calculations (IPCC 2006).

TABLE 3. Volume of greenhouse gas emissions from different sources as tons of CO_2 equivalent

Emitted gas	Source of emission	Farm	
		I slatted floor	II deep litter
Carbon dioxide	electric energy	40.24	8.98
	liquid fuels	17.85	5.17
Methane	enteric fermentation	89.77	17.98
	animal manure	198.08	7.93
Nitrous oxide	animal manure	28.59	28.86

The methane emission as CO_2 equivalent totaled 287.85 t in farm I and 25.91 t in farm II (Table 3). Share of 69 and 31% of total methane emission came from animal manure in farm I and II, respectively. As reported by Zaliwski and Purchała (2007), the primary source of methane emissions from animal production systems is enteric fermentation in ruminants and manure from pigs. Emission of CH_4 from manure results from microbial processes occurring in the manure. Factors that favour methane production are lack of oxygen, high temperature, a high level of degradable organic matter, high moisture content, a neutral pH, and a C/N of between 15 and 30 (Philippe and Nicks 2014). When estimating methane emissions from manure, it is necessary to account for region of the world, climate, technological group of animals, and the manure management method (IPCC 2006, KOBiZE 2012).

The estimated emission of nitrous oxide did not differ to a significant degree in the analysed farms (Table 3), but in terms of 1 animal it was more than four-fold lower in the slatted floor system compared to the deep litter system (Table 4). In livestock buildings N_2O comes exclusively from animal manure (Philippe and Nicks 2014) and is a by product of nitrification and denitrification. Nitrous oxide emission is estimated based on the animal's N (protein) intake during fattening, N retention, and the manure management method. In manure this process is mainly performed by heterotrophic aerobic bacteria. N_2O accumulation in natural fertilizers is favoured by the presence of oxygen and the low availability of degradable carbohydrates. Nitrous oxide may also be produced in other microbial reactions such as anaerobic or aerobic ammonium oxidation, in the processes known as nitrifier denitrification and anammox (anaerobic ammonia oxidation by bacteria). Most nitrification and denitrification organisms aremesophilic bacteria, as a result of which N_2O is generally not produced at temperatures exceeding 40–50°C. Nitrous oxide production from manure has a stochastic nature, especially due to its numerous sources of emission and environmental controls (Philippe and Nicks 2014).

TABLE 4. Greenhouse gas emissions in the analysed farms in terms of 1 pig and 1 kg of live pigs

Emitted gas	Farm			
	I – slatted floor		II – deep litter	
	pure component	CO_2 equivalent	pure component	CO_2 equivalent
In terms of 1 pig (kg)				
CO_2	7.63	7.63	8.88	8.88
CH_4	1.51	37.79	0.65	16.25
N_2O	0.01	3.75	0.06	18.10
Total	–	49.17	–	43.23
In terms of 1 kg of live pigs (g)				
CO_2	62.51	62.51	73.35	73.35
CH_4	12.39	309.76	5.37	134.32
N_2O	0.10	30.76	0.50	149.62
Total	–	403.03	–	357.29

Greenhouse gas emission as CO_2 equivalent per pig and per kg of live pigs was 49.17 and 43.23 kg in farm I and 0.40 and 0.36 kg in farm II, respectively (Table 4). The present research showed that compared to the slatted floor system, the deep litter system, in terms of unit of production (1 pig, 1 kg of live pigs) is characterized by lower CH_4 emission, considerably higher N_2O emission, and the consequently lower GHG emission as CO_2 equivalent. Since the following parameters the pig housing system, feed conversion rate, duration of production cycle, dressing percentage and meatiness were involved in the formulas for CH_4 and N_2O emission, there is a possibility to elaborate the efficient way of substantial reduction of GHG emission on pig farm.

The carbon dioxide emission, estimated in the analyzed farms, constituted ca 16–21% of total emission (Figs 1 and 2), but in farm II the proportion of emissions from diesel oil combustion was 36%, which is 5% higher than in farm I.

From the calculated GHG emission, originating from animal production only

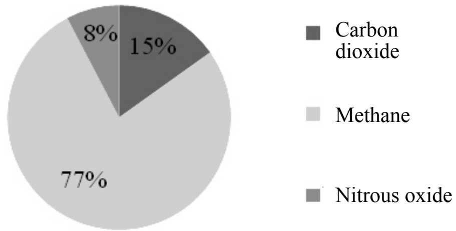

FIGURE 1. Proportion of different greenhouse gases in total emission on farm I

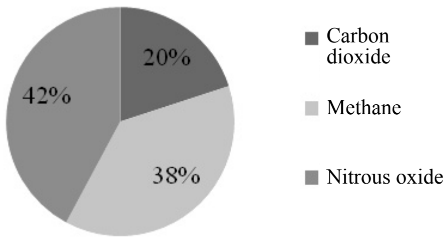

FIGURE 2. Proportion of different greenhouse gases in total emission on farm II

(without consumption of energy and liquid fuels during feed production), it follows that in the slatted floor system 77% of total emissions came from methane, 8% from nitrous oxide, and the remainder from carbon dioxide due to consumption of electric energy and liquid fuels. In farm II, as much as 42% of total emission came from nitrous oxide, a gas with the highest emission potential (IPCC 2007).

CONCLUSIONS

Slatted floor housing of the pigs caused five times lower N_2O and twice higher CH_4 emissions, compared to the deep litter system, which translated into higher total GHG emission as CO_2 equivalent. GHG emission per pig was ca 12% higher in the farm keeping animals on slatted floor compared to deep litter. Comparison of GHG emission from two pig farms belonged to different housing systems speaks for the prevalence of deep litter system over slatted floor one.

REFERENCES

CABARAUX J., PHILIPPE F., LAITAT M., CANART B., VANDENHEEDE M., NICKS B. 2009: Gaseous emission from weaned pigs raised on different floor systems. Agric. Ecosyst. Environ. 130: 86–92.

IPCC, 2006: IPCC Guidelines for National Greenhouse Gas Inventories. Institute for Global Environmental Strategies. Hayama, Japan.

IPCC, 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. USA.

KOBiZE, 2012: Krajowy raport inwentaryzacyjny. Inwentaryzacja Gazów Cieplarnianych w Polsce dla lat 1988–2010. Krajowy Ośrodek Bilansowania i Zarządzania Emisjami. IOŚ-PIB Warszawa.

KOBiZE, 2014: Komunikat dotyczący emisji dwutlenku węgla przypadającej na 1 MWh energii elektrycznej. IOŚ-PIB, Warszawa. Retrieved from http://www.kobize.pl/pl/article/2014/id/569/komunikat-dotyczacy-emisji-dwutlenku-wegla-przypadajacej-na-1-mwh-energii-elektrycznej.

LUDWICKA A., 2009: Wpływ upraw energetycznych na emisję gazów cieplarnianych. Probl. Inż. Rol. 2: 127–133.

MATIN A., COLLAS P., BLAIN D., HA C., LIANG C., MacDONALD L., McKIBBON S., PALMER C., RHOADES K., 2004: Canada's Greenhouse Gas Inventory 1990–2002. Environment Canada Ottawa. Ontario.

NALBORCZYK E., ŁOBODA T., PIETKIEWICZ S., SIUDEK T., MACHNACKI M., SIECZKO L., 1997: Emisja gazów cieplarnianych w polskim rolnictwie i możliwości jej redukcji. Part III. Bilans gazów cieplarnianych w różnych typach gospodarstw specjalizujących się w produkcji zwierzęcej. Ekspertyza SGGW, Warszawa.

NALBORCZYK E., PIETKIEWICZ S., ŁOBODA T., SIECZKO L., 1999: The emission, absorption and retention of greenhouse gases (GHG) in Polish agriculture. Geographia Polonica 72: 89–98.
PHILIPPE F.X., NICKS B., 2014: Review on greenhouse gas emissions from pig houses: Production of carbon dioxide, methane and nitrous oxide by animals and manure. Agric. Ecosyst. Environ. 199: 10–25.
USDA, 2014: Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity – Scale Inventory. USDA Technical Bulletin.
WALCZAK J., 2013: Oddziaływanie chowu świń na środowisko naturalne. Instytut Zootechniki – PIB, Kraków.
ZALIWSKI A.S., PURCHAŁA L., 2007: Oszacowanie emisji podtlenku azotu i metanu z rolnictwa w przekroju województw za 2005 rok. Acta Agrophysica 4: 76–82.

Streszczenie: *System utrzymania tuczników a wielkość emisji gazów cieplarnianych.* Zwierzęta emitują gazy cieplarniane (GHG): dwutlenek węgla (CO_2), metan (CH_4) i podtlenek azotu (N_2O) w procesach oddychania i trawienia oraz w odchodach. Wielkość emisji zależy m.in. od sposobu żywienia i utrzymania zwierząt. Celem pracy było określenie wielkości emisji dwutlenku węgla, metanu i podtlenku azotu w dwóch gospodarstwach prowadzących tucz świń na głębokiej ściółce lub na rusztach. Badania przeprowadzono w gospodarstwie I – utrzymującym rocznie 7617 tuczników w systemie rusztowym i w gospodarstwie II – utrzymującym 1594 tuczniki w systemie głębokiej ściółki. W obliczeniach przyjęto równoważniki na CO_2 dla CH_4 i N_2O wynoszące odpowiednio 25 oraz 298. W pracy oszacowano emisję GHG pochodzącą wyłącznie z produkcji zwierzęcej. Emisja gazów cieplarnianych wyrażona w ekwiwalencie CO_2 w gospodarstwie I wyniosła 374,52 t, w gospodarstwie II 68,91 t, co w przeliczeniu na 1 tucznika stanowiło odpowiednio: 49,17 kg (gospodarstwo I) i 43,23 kg (gospodarstwo II). Na podstawie badań stwierdzono, że w ściołowym systemie utrzymania zwierząt w porównaniu z systemem rusztowym jest mniejsza emisja GHG.

Słowa kluczowe: tuczniki, gazy cieplarniane, emisja, głęboka ściółka, system rusztowy

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