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COMPARISON OF GREENHOUSE GAS EMISSIONS DURING SUMMER FROM DEEP LITTER AND FULLY-SLATTED PIGGERY

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ABSTRACT

The aim of the study was to determine greenhouse gases emission factors from fattening pigs kept on deep litter and on fully slatted floor in order to compare them. The emissions were measured from July to September 2013. The buildings were located in the farms in the neighbourhood, in the Wielkopolskie Voivodeship. Gas concentrations were measured by photo – acoustic spectrometer Multi Gas Monitor INNOVA 1312. The average value of CO_2 emission factor was 105 $g \cdot day^{-1} \cdot kg^{-1}$ (V_{CO2}=29%) for the deep litter and 62 $g \cdot day^{-1} \cdot kg^{-1}$ (V_{CO2}=31%) for a system with a fully slatted floor. For N_2O value was respectively 0.047 $g \cdot day^{-1} \cdot kg^{-1}$ (V_{N2O}=31%) and 0,027 $g \cdot day^{-1} \cdot kg^{-1}$ (V_{N2O}=34%). The CH_4 emission factor value was respectively 0.809 $g \cdot day^{-1} \cdot kg^{-1}$ (V_{CH4}=63%) and 0.715 $g \cdot day^{-1} \cdot kg^{-1}$ (V_{CH4}=30%). The emission factors of researched gases were higher in deep litter fattening house, for CO_2 by 69%, for N_2O by 74% and for CH_4 by 13% than in the building with a fully slatted floor. According to the warming potentials of greenhouse gases, rearing pigs on deep litter would emit 59% more of CO_2–equivalents.

Introduction

Agriculture, and in particular animal production, is one of the main reasons for environmental problems worldwide (Monteny et al., 2006; Steinfeld and Wassenaar, 2007). It is the main source of gas pollution (Kolasa-Więcek, 2012). Greenhouse gases such as: carbon dioxide, methane and nitrous oxide influence global warming and cause climatic changes. Additionaly, methane and nitrous oxide affect decrease of ozone layer in the stratosphere (IPCC, 2007; Jugowar, 2001; 2013).

In the FAO report (2006) „*Livestock Long Shadow: Environmental Issues and Options*" it was stated that agriculture causes 18% of global emission of anthropogenic greenhouse gases, including: 9% CO_2 emission, 37% CH_4 emission and 65% N_2O emission. These values differ in relation to the world part. According to KOBIZE (State Centre for Emission

Balancing and Management) participation of agriculture in the national emission of greenhouse gases in 2011 was 9.4% (not including CO_2). It is estimated that this sector causes up to 34.1% of total methane emission in Poland and 83.7% of the national nitrous oxide emission (KOBIZE, 2013). Emission of gas pollutions is calculated based on theoretical emission factors, values of which differ from factors obtained during research carried out in livestock buildings (Mielcarek, 2012).

Review of national and international papers shows that there are considerable differences in values of greenhouse gases emission factors. They depend on many factors, inter alia: measurement period, various micro and macro-climate parameters and also measurement devices (Jungbluth et al., 2001; Rigolot et al., 2010). Research concern mainly non-litter housing systems, whereas not many of them is carried out in buildings with the litter housing system. It is caused by a relatively low popularity of these systems in the industrial pigs rearing in the Western Europe. There are not many papers, where research of gas emissions from two different pigs housing systems were carried out at the same time.

The aim of the study was determination of greenhouse gases in the summer season, from deep litter and fully-slatted piggery for fattening pigs and their comparison. It allowed determination of emission factors of the researched pollutions and indication of the housing systems of the less negative impact on the environment.

Methodology

Research facilities

The research was carried out from July to September 2013 in two piggety for fattening pigs with various housing systems. They were located in the farms in the neighbourhood, in the Wielkopolskie Voivodeship. It allowed prevention of the impact of meteorological conditions on the obtained results. In the piggeries pigs were fattened in the open system. In the A building pigs were kept on the deep litter and fed dry fodder ad libitum. It has 10 chambers in which is kept 100 pigs in two pens (nominal livestock of a piggery was 1000 items).

Whereas, in the B building pigs were housed without litter, on the fullty-slatted floor and fed 4 times a day liquid fodder. Ten pens for fattening pigs are located on each of two storeys of the piggery (nominal animal number was 600 pigs). For comparative research one chamber from the A building and the ground floor of B piggery were selected, where, during the measurement period fattening pigs of a comparative mass were kept (initial 30 kg, final 80 kg). The area per one pigs in both buildings was 0.77 $m^2 \cdot pig^{-1}$.

Both piggeries were equipped with temperature controlled mechanical ventilation. In the investigated A piggery, there were installed 2 fans of a nominal efficiency 6,250 $m^3 \cdot h^{-1}$ each (nominal efficiency per pigs 125 $m^3 \cdot h^{-1} \cdot pig^{-1}$). Whereas, on the ground floor of the B facility there were installed 3 fans of a nominal efficiency 7.850 $m^3 \cdot h^{-1}$ each (nominal efficiency per pig 125 $m^3 \cdot h^{-1} \cdot pig^{-1}$). In both buildings, the regulated inlets of fresh air were placed in side walls of buildings.

Figure 1. Piggery A

Figure 2. Chamber in the A piggery

Figure 3. Piggery B

Figure 4. Lower storey of B piggery

Measurement of air exchange and concentration of gas pollution

The real efficiency of fans in the investigated piggery was determined according to the standard PN-EN 12599:2013 "Ventilation of buildings – Procedures of research and measurement methods used during the reception of ventilation installation and air conditioning" for two flap positions in air inlets (fully-opened and half-opened). Based on the prepared temperature characteristics of the ventilation systems and data from daily temperature monitoring inside the buildings a daily air exchange rate were calculated.

In order to determine greenhouse gases emission, 4 daily measurements of concentration of gas pollution were carried out for each. Photo-acoustic spectrometer Multi Gas Monitor 1312 was used thereto. Air samples were collected at the inlet to the ventilation channel and the concentration value of gas pollutions were registered every hour.

Temperature and relative humidity of air inside buildings were measured in one hour intervals used TESTO recorder 175-H2.

Gas pollutions emission

Daily emission of the investigated gases (E_g) was calculated as a product of the concentration value in the investigated piggery and a daily air exchange rate in buildings (1). Daily greenhouse gases emission factor (WE_g) was determined as a quotient of daily gas emission and total mass of animals from the equation (2):

$$E_g = c_g \cdot V_d \cdot 10^{-6} \tag{1}$$

where:
E_g – emission of gasses ($kg \cdot day^{-1}$),
c_g – average daily concentration of gases in air removed from a building ($mg \cdot m^{-3}$),
V_d – daily air exchange ($m^3 \cdot day^{-1}$),

$$WE_g = E_g \cdot m^{-1} \cdot 10^3 \tag{2}$$

where:
WE_g – daily gases emission factor ($g \cdot day^{-1} \cdot kg^{-1}$),
m – total mass of animals in the building (kg).

Calculated values of factors were described with basic descriptive statistics: arithmetic mean, standard deviation and coefficient of variance.

Total emission factor of the investigated greenhouse gases in the equivalent of CO_2 (WE_{qCO2}) calculated from the relation (3):

$$WE_{qCO_2} = WE_{CO_2} + 23\, WE_{CH_4} + 296\, WE_{N_2O} \tag{3}$$

where:
WE_{CO2} – daily carbon dioxide emission factor ($g \cdot day^{-1} \cdot kg^{-1}$),
WE_{CH4} – daily methane emission factor ($g \cdot day^{-1} \cdot kg^{-1}$),
WE_{N2O} – daily nitrous oxide emission factor ($g \cdot day^{-1} \cdot kg^{-1}$).

Thermal potential GWP (*Global Warming Potential*) for methane and nitrous oxide was accepted after IPCC (2001).

Results and a discussion

Results of daily measurements of concentrations of the investigated gases were presented in table 1. It also presents average daily values of temperature and relative humidity of air inside researched buildings and total mass of animals kept in the piggeries during the research.

Average daily values of carbon dioxide and nitrous oxide concentrations in both buildings were comparable, they characterized with low diversity and had values from 2,004 to 2,865 $mg \cdot m^{-3}$ for CO_2 and from 0.88 to 1.17 $mg \cdot m^{-3}$ for N_2O. Considerable changes occurred in concentration of methane between the investigated buildings as well as between particular measurement data. Is was lower in the deep litter piggery and was from 6.3 to 60.7 $mg \cdot m^{-3}$, whereas in a non-litter piggery, it was on the level from 17.7 to 44.4 $mg \cdot m^{-3}$. The last day of measurement was an exception. Difference favorable for the building B resulted from bedding down in a piggery on deep litter which was not on time.

Table 1
Average daily concentration of greenhouse gases in a piggery

Measurement date		Average daily temperature (°C)	Average daily relative humidity (%)	Total mass of pigs (kg)	Average daily concentration (mg·m^{-3}) CO_2	N_2O	CH_4
Building A	08.07.2013	25.4	65.8	3570	2223	1.00	6.3
	22.07.2013	25.6	60.5	4798	2102	0.97	7.5
	12.08.2013	24.8	63.7	5693	2269	1.02	22.5
	05.09.2013	23.8	61.1	7920	2865	1.17	60.7
Building B	09.07.2013	25.5	61.7	8730	2004	0.88	17.7
	23.07.2013	25.3	51.6	13095	2212	0.95	22.3
	13.08.2013	23.7	62.4	17460	2660	0.96	44.4
	04.09.2013	23.9	61.4	23280	2049	0.90	26.7

Table 2 presents values of daily emission of gas pollutions from a piggery, calculated based on the equation (1).

Table 2
Daily emission of gas pollutions

Measurement date		Average air exchange (m^3·h^{-1})	Average daily emission (kg·day^{-1}) CO_2	N_2O	CH_4
Building A	08.07.2013	10082	530	0.239	1.51
	22.07.2013	9983	494	0.227	1.73
	12.08.2013	9972	537	0.240	5.26
	05.09.2013	8714	584	0.241	12.12
Building B	09.07.2013	16264	747	0.334	6.74
	23.07.2013	15467	778	0.346	7.93
	13.08.2013	11321	719	0.259	11.96
	04.09.2013	11137	539	0.238	6.95

Average emissions of nitrous oxide in the investigated facilities were on a comparable level despite almost three times higher stock in the building with a slatted floor. Relation between the stock and the level of emission was noticeable in case of carbon dioxide and methane. In deep litter piggery average daily emission of CO_2 was lower and in case of CH_4 it was even few times lower than in building B.

From the relation (2) daily emission factors of the above mentioned air pollutions were calculated in each investigated day and presented in table 3.

Table 3
Daily factors of gas pollution emission related to 1 kg of body mass

	Measurement date	Daily emission factor ($g \cdot day^{-1} \cdot kg^{-1}$)		
		CO_2	N_2O	CH_4
Building A	08.07.2013	148	0.07	0.42
	22.07.2013	103	0.05	0.36
	12.08.2013	94	0.04	0.92
	05.09.2013	74	0.03	1.53
Building B	09.07.2013	86	0.04	0.77
	23.07.2013	59	0.03	0.61
	13.08.2013	41	0.01	0.69
	04.09.2013	23	0.01	0.30

Calculated values of gas emission factors were described with arithmetic means, standard deviation and coefficient of variance and were presented in table 4. It allowed comparison of the investigated piggery between themselves and with results presented in other papers

Table 4
Average gas pollutions emission factors in the investigated period

	CO_2		N_2O		CH_4	
	Building A	Building B	Building A	Building B	Building A	Building B
$\bar{y}$ ($g \cdot day^{-1} \cdot kg^{-1}$)	105	62	0.047	0.027	0.809	0.715
SD ($g \cdot day^{-1} \cdot kg^{-1}$)	30	19	0.014	0.009	0.511	0.218
V_y (%)	29	31	31	34	63	30

$\bar{y}$ – average, SD – standard deviation, V_y – coefficient of variance

Comparing the researched buildings, it has been found that differences between the emission factors of CO_2 and N_2O are statistically very significant ($p<0.001$). Their values in deep litter piggery were higher than in a fully-slatted piggery, for carbon dioxide by 69% and nitrous oxide by 74%. In case of methane, differences in values of emission factor were also statistically significant ($p<0.05$). Its value was by 13% higher in deep litter building.

Factor of carbon dioxide emission from deep litter piggery (105 $g \cdot day^{-1} \cdot kg^{-1}$) was almost two times higher than for non-litter system (62 $g \cdot day^{-1} \cdot kg^{-1}$). Philippe et al. (2007) compared emission of greenhouse gases for those two systems of housing pigs for CO_2 obtained values 29 g·day^{-1}·kg^{-1} in the deep litter system and 26 g·day^{-1}·kg^{-1} for the fully-slatted floor. Comparing calculated in the paper values of factors with the research results, concerning non-litter systems carried out by Gallmann et al. (2003), Dong et al. (2007) and Costa and Guarino (2009), which are within 26 to 40 g·day^{-1}·kg^{-1}, they are higher, which is caused by a summer period of measurements and parameters of ventilation system operation.

Higher emission of N_2O was reported from the deep litter piggery. Similar relation was reported by Philippe et al. (2007) emission of this gas was also higher in a litter system piggery (0.02 g·day^{-1}·kg^{-1}) than in a non-litter system (0.001 g·day^{-1}·kg^{-1}). Available in literature values of factors of emission of N_2O for systems with a slatted floor are considerably lower than the obtained in this paper and they are within 0.001 to 0.007 g·day^{-1}·kg^{-1} (Sneath et al., 1997; Guarrino et al., 2003; Amon et al., 2007; Dong et al., 2007; Blanes-Vidal et al., 2008; Costa and Guarrino, 2009). Rzeźnik (2013) determined an average daily factors of nitrous oxide emission when he carried out research in deep litter piggery. Its value was higher than the results of this paper and it was 0.074 g·day^{-1}·kg^{-1}. Philippe et al. (2007) state that a literature data show higher diversity in values of N_2O emission factors for deep litter systems and slatted floor systems, respectively from 0.03 to 8 g·day^{-1}·pig^{-1} and 0.17 to 2.26 g·day^{-1}·pig^{-1}. The obtained results in the paper were within these scopes (2.36 g·day^{-1}·pig^{-1} – deep litter system and 1.01 g·day^{-1}·item^{-1} – a fully-slatted floor system).

Methane emission factor was also higher in the deep litter building and was 0.81 g·day^{-1}·kg^{-1}, and in fully-slatted piggery was equal to 0.72 g·day^{-1}·kg^{-1}. Philippe et al. (2007) obtained results over three times lower than the results of this paper. Values of CH_4 emission factors for the researched housing systems by them were comparable and were 0.24 g·day^{-1}·kg^{-1}. The literature presents high diversity in the values of methane emission factors for the fully slatted housing system from 0.06 to 0.38 g·day^{-1}·kg^{-1} (Sneath et al., 1997; Gallmann et al., 2003; Guarino et al., 2003; Amon et al., 2007; Dong et al., 2007; Blanes-Vidal et al., 2008; Costa and Guarino, 2009). Only few papers concerned the deep litter housing system. Rzeźnik (2013) determined average methane emission factor equal to 1.71 g·day^{-1}·kg^{-1}. Whereas Philippe et al. (2007) after Stout et al. (2003) and after Nicks et al. (2004) state that average emission of CH_4 is equal to respectively 2.77 g·day^{-1}·pig^{-1} and 7.39 g·day^{-1}·pig^{-1}. These values are few times lower than those obtained in this paper (51.88 g·day^{-1}·pig^{-1}).

Calculated according to the equation (3) values of total greenhouse gases emission in the CO_2 equivalent prove 59% higher potential of creating a greenhouse effect of deep litter piggery (WE_{qCO2}=137 g·day^{-1}·kg^{-1}) than a building with fully-slatted floor (WE_{qCO2}=86 g·day^{-1}·kg^{-1}).

Conclusions

Based on the research which was carried out, the following conclusions have been made:

- Average values of the investigated gases emission factors from deep litter piggery were: CO_2 –105 g·day^{-1}·kg^{-1}, N_2O – 0.047 g·day^{-1}·kg^{-1}, CH_4 – 0.809 g·day^{-1}·kg^{-1}.
- Factors of the investigated gases emission from a fully-slatted took the following values: CO_2 – 62 g ·day^{-1}·kg^{-1}, N_2O – 0.027 g·day^{-1}·kg^{-1}, CH_4 – 0.715 g·day^{-1}·kg^{-1}.

- Values of the investigated gases emission factors were higher in deep litter piggery CO_2 by 69%, N_2O by 74% and for CH_4 by 13% than in building with fully-slatted floor.
- Average factor of greenhouse gases emission of expressed in the CO_2equivalent was 137 $g_{ekwCO2}{\cdot}day^{-1}{\cdot}kg^{-1}$ for deep litter housing system and (WE_{qCO2}=86 $g{\cdot}day^{-1}{\cdot}kg^{-1}$) for building with fully-slatted floor. It proves 59% higher potential of creating a greenhouse effect of the facility on deep litter.

Summarizing, it should be noted that deep litter piggeries guarantee a higher level of pigs welfare. However, they emit more gas pollutions to the environment than fully-slatted piggeries. Due to a small number of papers on greenhouse gases emission from production of pigs kept in the litter systems and high diversity of values of greenhouse gases emission factors,one should continue research on this subject. This allow for precise determination the range of their values and comparison of various housing systems of pigs with regard to the greenhouse gases emission and explicit indication of technology which is more environmentally friendly.

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PORÓWNANIE EMISJI GAZÓW CIEPLARNIANYCH Z RÓŻNYCH SYSTEMÓW UTRZYMANIA TUCZNIKÓW W SEZONIE LETNIM

Streszczenie. Celem pracy było określenie i porównanie emisji gazów cieplarnianych z tuczarni na głębokiej ściółce i z budynku dla tuczników z podłogą szczelinową (system bezściołowy). Badania przeprowadzono, w sezonie letnim, od lipca do września 2013 roku. Budynki były zlokalizowane w województwie wielkopolskim, na terenie gospodarstw, będących w bezpośrednim sąsiedztwie. Stężenie gazów mierzono foto-akustycznym spektrometrem Multi Gas Monitor 1312. Średnie wartości wskaźników emisji z budynku z podłogą szczelinową wynosiły: CO_2 – 62 $g \cdot doba^{-1} \cdot kg^{-1}$, N_2O – 0,027 $g \cdot doba^{-1} \cdot kg^{-1}$ i CH_4 – 0,715 $g \cdot doba^{-1} \cdot kg^{-1}$. W tuczarni z systemem utrzymania na głębokiej ściółce przyjmowały wartości: CO_2 – 105 $g \cdot doba^{-1} \cdot kg^{-1}$, N_2O – 0,047 $g \cdot doba^{-1} \cdot kg^{-1}$ i CH_4 – 0,809 $g \cdot doba^{-1} \cdot kg^{-1}$ i były one większe odpowiednio o 69%, 74% oraz 13%. Po przeliczeniu wartości wskaźników na ekwiwalent CO_2 system utrzymania na głębokiej ściółce charakteryzuje się o 59% większym potencjałem tworzenia efektu cieplarnianego.

Słowa kluczowe: emisja gazów cieplarnianych, głęboka ściółka, system utrzymania, trzoda chlewna