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LIMITING ODOUR EMISSION FROM PIGGERY TROUGH APPLICATION OF HEAT RECOVERY SYSTEM

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ABSTRACT

The aim of the study was to determine the effect of manure cooling by the use of the heat recovery system on odour emission from a deep litter piggery. Annual comparative research was carried out in a twin-room deep litter piggery located in Wielkopolska Voivodeship. The recovered heat was transferred to central heating and domestic hot water systems of a residential building. The study showed that the average odour emission rate from the room, where heat was recovered (0.192 ± 0.083 $ou_E\cdot s^{-1}\cdot kg$ m.c.$^{-1}$) was lower than in the room without heat recovering (0.273 ± 0.138 $ou_E\cdot s^{-1}\cdot kg$ m.c.$^{-1}$) ($p<0.05$). The difference was 27%. It was also found that there was statistically significant strong correlation ($r = 0.86$) between the amount of the recovered heat and the percentage odour emission reduction ($p < 0.05$). This relationship was described by the logarithmic regression line $y=12.5\ln(x)-21.5$ ($r^2=0.74$)

Introduction

The recent twenty years have marked an increase in the number of complaints concerning the odour nuisance related to agriculture (Both, 2001; Rappert and Müller, 2005). It results mainly from the progressing intensification and concentration of animal production and development of residential buildings in the vicinity of traditionally agricultural areas (Nimmermark, 2011). Emission of odour from livestock buildings depends on many factors, e.g. temperature and relative humidity of air, animals' activity, air exchange and the animals' housing system (Romain et al., 2013).

Since the 50's of the 20th century in Western Europe and since the 70's in Poland non-litter systems have gained more popularity in the pigs' breeding. They replaced traditional litter piggeries, which resulted from the reduction of production costs (Philippe et al., 2007). However, presently, one may notice a new interest in litter systems caused by the increase in the consumer's awareness. Keeping pigs in litter systems favourably influences the level of animals' welfare (Tuyttens, 2005). Using pens with deep litter allows reduction of workload on bedding and the size of outdoor storages of natural fertilizers. Manure is collected in pens till the production cycle ends.

Fermentation processes in exothermic grounds, e.g. in deep litter cause the increase of temperature to 50ºC (Myczko, 1994). Such thermal conditions are maintained during the entire production cycle (Nawrocki, 2000). In deep litter housing systems, heat generated in litter may be recovered and used for example for heating farms and residential buildings (Domagalski et al., 2011). The use of heat recovery from deep litter systems is favourable not only due to economic reasons but also environmental because cooling litter reduces emission of harmful gases (Rzeźnik, 2013). Additionally, high temperature of manure intensifies odorants, which influences the increase of odour emission from inventory buildings (Ndegwa et al., 2003; Le et al., 2005; Wang et al., 2011), thus the heat recovery from litter should limit this process.

The objective of the study was to determine the impact of cooling manure on the emission of odours from deep litter piggery through the use of heat recovery installation.

Methodology

Research was carried out in a deep litter piggery in Charcice (Wielkopolska Voivodeship). A research object is a double-room building with a nominal livestock of 480 pigs. Each room was separated with a tight barrier and had four pens for pigs (fig. 1,2).

Figure 1. Piggery in Charcice

Figure 2. Pen in the investigated piggery

The fermenting litter is a source of energy for a heat pump. There is a spiral, liquid heat exchanger under the floor of the resting area of each pen (in total 357.6 m^2). It enables recovery of heat generated in deep litter. The piggery is equipped with a water flow controller which separates the liquid flow in heat exchangers in each pen and controls heat recovery from deep litter (fig. 3). Energy recovered from litter is transmitted to the heat pump with the power of 16.8 kW, which moves thermal energy opposite to the direction of spontaneous heat flow by absorbing heat from a cold space (deep litter) and releasing it to a warmer one (central heating and domestic hot water systems) (fig. 4).

Except for a heat pump, a thermal center consists of a coal furnace and a double-jacket heat exchanger with a mixing valve, which allows control of temperature of the central heating system. A coal furnace constitutes an energy reserve in case of an insufficient amount of heat (fig. 5)

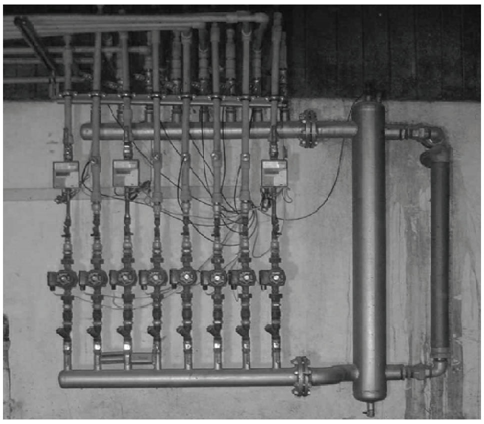
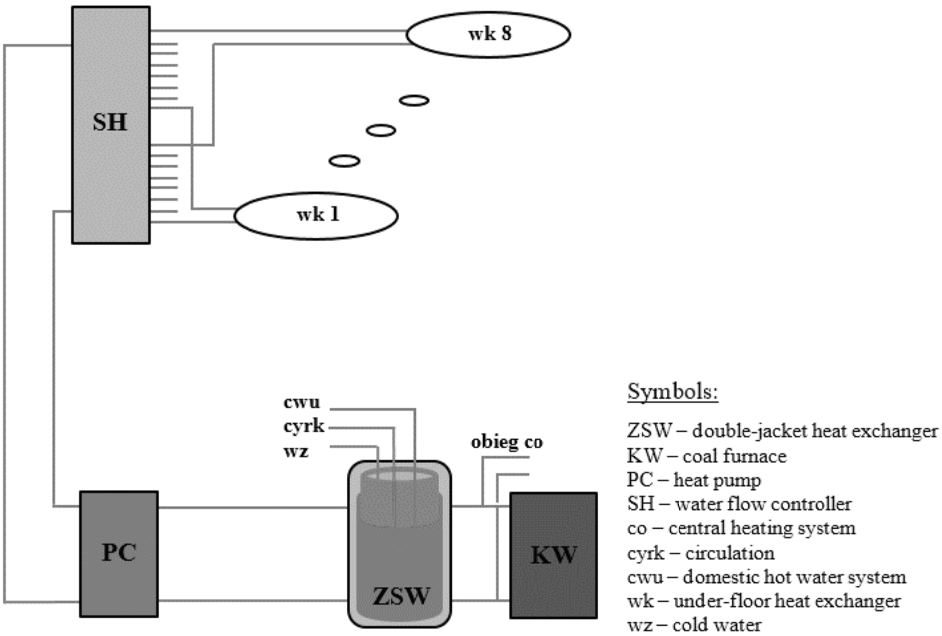


Figure 3. Water flow controller

Figure 4. Installation with heat meters



Source: Adamczyk et al., 2014

Figure 5. Schematic representation of the heat recovery installation from deep litter

In order to determine the impact of cooling the manure in a deep litter pen on the odour emission, annual comparative research in each room of a piggery was carried out. Within the period of research, heat from deep litter was recovered only from one room and the other constituted the reference point. During each of 15 measurements, the air samples were collected to determine the odour concentration. The total time of sampling during single research was 20 minutes for each room. On each day of research, air samples were collected between 11 and 12 a.m. at the inlet to ventilation channels removing air from the piggery. CSD30 sampler by ECOMA company and 8-litre single bags made of Nalophan plastic (PET) were used for this purpose. It allowed reduction of pollution diffusion from bags to atmospheric air and therefore reduction of the chemical composition change of the sample from the moment of collecting to testing.

Evaluation of odour concentration was carried out up to 24 hours from sampling by an accredited olfactometry laboratory located in the Institute of Technology and Life Sciences in Poznań. Odour concentration of the collected samples was determined with the dynamic olfactometry method according to the Polish standard PN-EN 13725:2007, used ECOMA TO 8 olfactometer (PN-EN, 2007). The same team assessed all air samples.

Each room of piggery had an under-pressure mechanical ventilation, controlled by temperature. It was equipped with one fan with the nominal efficiency of 24000 $m^3 \cdot h^{-1}$. A momentary ventilation rate was determined based on the current-voltage characteristic provided by the producer of the ventilation system.

Based on the odour concentration values and the momentary ventilation rates a momentary odour emission was calculated according to the equation (1). Odour emission rate (We_{od}) was determined as a ratio of the momentary odour emission and the mass of pigs which are kept in the room, from the equation (2) (Kołodziejczyk et al., 2011):

$$E_{od} = c_{od} \cdot V \tag{1}$$

$$We_{od} = E_{od} \cdot m^{-1} \tag{2}$$

where:

E_{od} – momentary odour emission, ($ou_E \cdot s^{-1}$)
We_{od} – odour emission rate, ($ou_E \cdot s^{-1} \cdot kg^{-1}$)
c_{od} – odour concentration, ($ou_E \cdot m^{-3}$)
V – momentary ventilation rate, ($m^3 \cdot s^{-1}$)
m – total mass of animals kept in the room, (kg)

During measurements the mass of animals was determined based on the results of random weighting of the selected 5 pigs from each room. The average mass of a pig in a room is an arithmetic mean of the weighted pigs.

Moreover, the amount of heat recovered from the deep litter was measured and recorded with the use of a thermal energy electronic meter DanfossMultical 3.

The calculated data were analysed statistically. For concentration values and values of odour emission rates the differences between their means were tested (independent groups) at the significance level of α=0.05. To determine the relation between the amount of heat recovered from deep litter within one day and the percentage reduction of odour emission, the Spearman coefficient was calculated and tested by the t-Student significance test (α=0.05).

Research results

Results of measurements of indoor microclimate parameters of a piggery (momentary temperature and relative humidity of air and ventilation rate, mass of the animals, geometric means and standard deviations of odour concentration in the room of the investigated piggery were presented in table 1 and 2. Standard deviation was calculated from algorithmic values of odour concentration and then recalculated into odour units (McGinley and McGinley, 2006).

Table 1.
Concentration of odours and parameters of microclimate in the room without heat recovery

Date	Air temperature (ºC)	Relative humidity of air (%)	Momentary ventilation rate ($m^3 \cdot s^{-1}$)	Total mass of pigs (kg)	Concentration of odours ($ou_E \cdot m^{-3}$)	Standard deviation ($ou_E \cdot m^{-3}$)	
						+	−
10 March	18.3	61.2	5.9	6023	343	65	44
24 March	16.5	58.3	5.9	6695	414	120	86
12 April	17.2	68.2	5.9	4756	227	44	41
15 June	24.6	72.3	6.1	7285	410	72	64
19 July	24.2	59.8	6.0	5625	146	22	12
28 July	22.3	64.7	6.1	4956	217	51	33
12 August	23.4	58.2	6.1	5934	192	48	32
5 September	25.1	54.2	6.1	7045	283	97	79
28 September	19.8	52.6	5.9	4927	551	56	65
2 November	16.2	63.9	5.2	6580	549	99	90
15 November	15.3	53.8	1.3	7726	648	64	63
21 November	16.2	58.3	1.3	7628	1204	166	178
29 November	17.1	53.5	1.3	6256	646	71	68
13 December	17.3	52.3	1.3	4465	477	17	52
28 December	16.6	55.2	1.3	6366	1056	254	112
Average					413	67	58

Table 2.
Odour concentration and parameters of microclimate in the room with heat recovery

Date	Air temperature (ºC)	Relative humidity of air (%)	Momentary ventilation rate ($m^3 \cdot s^{-1}$)	Total mass of pigs (kg)	Odour concentration ($ou_E \cdot m^{-3}$)	Standard deviation ($ou_E \cdot m^{-3}$)	
						+	−
10 March	18.5	63.2	5.9	7258	264	42	36
24 March	17.5	58.8	5.9	8925	322	31	28
12 April	17.1	67.9	5.9	5542	186	23	20
15 June	24.3	70.3	6.1	6852	296	67	55
19 July	25.1	62.8	6.0	7354	165	10	9
28 July	22.3	60.7	6.1	6846	235	34	30
12 August	23.4	58.2	6.1	7652	198	23	21
5 September	24.8	53.4	6.1	5964	211	24	22
28 September	18.4	52.3	5.9	7458	537	49	45
2 November	17.6	65.5	5.2	8254	410	60	52
15 November	15.3	53.8	1.3	7656	443	28	26
21 November	15.1	56.3	1.3	5879	746	53	50
29 November	17.3	55.5	1.3	7642	620	37	35
13 December	16.8	53.3	1.3	6886	521	44	41
28 December	16.2	54.1	1.3	7658	825	100	89
Average					350	36	33

Momentary values of temperature and relative humidity inside the investigated rooms and of the ventilation rate were comparable. The statistical analysis did not confirm statistically significant differences ($p<0.05$). Average odour concentration in a room in which heat was recovered from deep litter was 350 $ou_E \cdot m^{-3}$ and in the second room it was 413 $ou_E \cdot m^{-3}$. Results were highly variable. Coefficient of variability was respectively 53% and 63%. However, in case of sensory analyses this value is correct (van Langenhove and De Bruyn, 2001). The statistical analysis did not prove differences between average odour concentration in the investigated rooms ($p<0.05$) which would have resulted from varied mass of animals kept there.

The odour concentration values obtained in the paper were higher than those published by Wang et al., (2011) – 67 $ou_E \cdot m^3$, and lower than the results of research presented by Kołodziejczyk et al., (2009) – 653 $ou_E \cdot m^{-3}$.

Based on the data from table 1 and 2 the odour emission rate was calculated with the use of the equation (2) and a percentage reduction of odour emission. Results of calculations were set with the amount of the energy recovered from deep litter, during a day and presented in table 3.

Table 3.
Odor emission rates and percentage reduction of odour emission and thermal energy recovered from the deep litter in the investigated piggery

Date	Odour emission rate ($ou_E \cdot s^{-1} \cdot kg$ m.c.$^{-1}$)		Reduction of odour emission (%)	Heat recovered from deep litter (kWh)
	without heat recovery	with heat recovery		
10 March	0.336	0.215	36.1	129.4
24 March	0.365	0.213	41.7	92.6
12 April	0.282	0.198	29.8	87.8
15 June	0.344	0.264	23.2	23.7
19 July	0.156	0.134	13.8	19.4
28 July	0.268	0.210	21.6	21.8
12 August	0.197	0.158	19.9	29.6
5 September	0.245	0.216	11.6	22.6
28 September	0.660	0.425	35.6	82.5
2 November	0.434	0.259	40.4	119.3
15 November	0.109	0.075	31.1	72.8
21 November	0.205	0.165	19.6	43.6
29 November	0.134	0.105	21.5	58.2
13 December	0.139	0.098	29.2	52.8
28 December	0.216	0.140	35.0	49.8
Average	0.273	0.192	27.3	60.4

Average rate of odour emission from the room where deep litter was cooled was 0.192±0.083 $ou_E \cdot s^{-1} \cdot kg$ m.c.$^{-1}$, and in a room, where heat was not recovered it was 0.273±0.138 $ou_E \cdot s^{-1} \cdot kg$ m.c.$^{-1}$. The statistical analysis showed that the average odour emission rate from the experimental room (with heat recovery) was lower than from the control room (without heat recovery) ($p<0.05$). Difference between odor emission rates was 27%.

The correlation analysis between heat recovered from deep litter and the percentage reduction of odour emission proved a strong positive relation between the investigated values (coefficient of Spearman's correlation – $r=0.86$). T-Student test proved statistical significance of the calculated coefficient of correlation ($\alpha=0.05$). This relation was described with a logarithmic regression line with the equation $y=12.5\ln(x) - 21.5$ (fig. 6).

Relation between the percentage reduction of odour emission and the amount of the recovered heat described with the equation $y=12.5\ln(x) - 21.5$ is fits well (74%) to the empirical data.

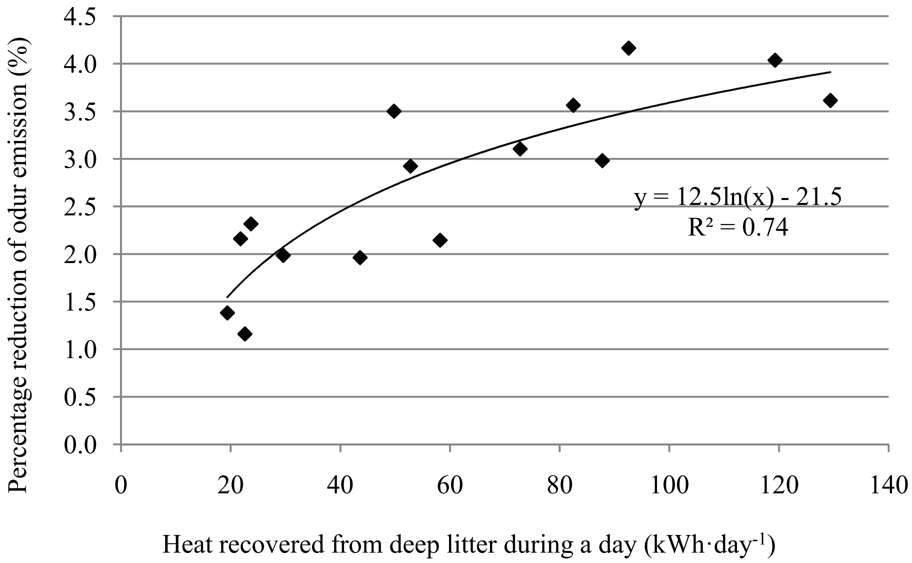


Figure 6. Relation of the reduction of odour emission and heat collected from deep litter

Due to a small number of papers concerning cooling deep litter and assessment of the impact of this process on odour emission from production of pigs, research should be continued in order to based there on precisely determined environmental advantages resulting from the applied solution. It will allow improvement of technology which minimizes negative effect of odours emitted from livestock buildings on environment.

Conclusions

Based on the research the following conclusions have been formulated:

1. Average odour concentration in the experimental room (with heat recovery) was 350 $ou_E \cdot m^{-3}$ (V_x=53%) and in the control room (without heat recovery) 413 $ou_E \cdot m^{-3}$ (V_x=63%). Differences between the values were not statistically significant ($p<0.05$).
2. Cooling deep litter in a piggery reduced odour emission. Odour emission rates referred to 1 kg of the animal body mass in the experimental room (average odour emission rate 0.192±0.083 $ou_E \cdot s^{-1} \cdot kg$ m.c.$^{-1}$) were lower than in the control room (average odour emission rate 0.273±0.138 $ou_E \cdot s^{-1} \cdot kg$ m.c.$^{-1}$) ($p<0.05$). Difference between odour emission rates was 27%.
3. Between the amount of the recovered heat and the percentage reduction of odour emission there was a statistically significant relation ($p<0.05$) which was described with a logarithmic equation $y=12.5\ln(x) - 21.5$.

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OGRANICZANIE EMISJI ODORÓW Z TUCZARNI POPRZEZ ZASTOSOWANIE INSTALACJI DO ODZYSKU CIEPŁA

Streszczenie. Celem pracy było określenie wpływu schładzania obornika, w kojcu z głęboką ściółką na emisję odorów z tuczarni, poprzez zastosowanie instalacji do odzysku ciepła. Roczne badania porównawcze przeprowadzono w dwukomorowej tuczarni na głębokiej ściółce znajdującej się w województwie wielkopolskim. Budynek wyposażony był w instalację do odzysku ciepła z głębokiej ściółki. Dolnym źródłem był obornik znajdujący się w kojcu, natomiast górnym były instalacje centralnego ogrzewania i ciepłej wody użytkowej budynku mieszkalnego. W pracy wykazano, że średni wskaźnik emisji odorów z komory, gdzie odzyskiwano ciepło ($0,192 \pm 0,083$ $ou_E \cdot s^{-1} \cdot kgm.c.^{-1}$) był mniejszy, niż w komorze bez odzysku ciepła ($0,273 \pm 0,138$ $ou_E \cdot s^{-1} \cdot kgm.c.^{-1}$) ($p<0,05$). Różnica ta wynosiła 27%. Stwierdzono również, że między ilością pobranego ciepła, a procentową redukcją emisji odorów istnieje statystycznie istotna silna zależność, $r=0,86$ ($p<0,05$). Opisano ją dobrze dopasowaną do danych empirycznych ($r^2=0,74$) logarytmiczną linią regresji o równaniu $y=12,5\ln(x) - 21,5$.

Słowa kluczowe: odory, głęboka ściółka, pompa ciepła, schładzanie obornika