Wiadomości Zootechniczne, R. LVI (2018), 2: 16-22

Effect of Sow Manure Storage Conditions on Manure Decomposition and Ammonia Emission

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For several years animal production has been the subject of analyses carried out with respect to the environmental onerousness. Under the latter term, we mean the natural environment in the form of soil and water ecosystems or the atmosphere, as well as the immediate vicinity of farms and residential buildings. Determining the threats to the natural environment required a number of long-term research (Williams, 2008). Nitrogen and phosphorus - two biogenic elements released in excess to the environment from commercial livestock production - cause eutrophication of ecosystems, extinction of some and excessive growth of other species of flora and fauna. Harmful gas admixtures emitted to the atmosphere from farm breeding of animals and biogenic compounds used as soil fertilisers may, locally and globally, adversely affect the formation of acid rain and ozone depletion, eutrophication of water and its hygienic quality (Philippe & Nicks, 2015; Riaño and Garcia-Gonzalez, 2015). The employees servicing animals are exposed to a number of diseases resulting from excessive ammonia, hydrogen sulphide and dust concentrations. However, the odours such as: ammonia, hydrogen sulphide and methane are the earliest possible nuisance resulting from the large scale and concentration of animal production. The first attempts to solve the problem were activities improving the purity of the animals and the places they were kept. A number of bedding materials characterised by a partial sorption of gas particles was also used. With the development of non-litter systems, further concentration of animals and reduction of labour inputs, the odour problem became less prominent. The use of mechanical ventilation shifted the burden of the problem to the outside of the livestock buildings (Kurc and Sisman, 2017). At that time, research work addressed the issues of air circulation in premises, the volume of air exchange, the speed of air movement and the construction and dimensions of ventilation ducts. Another problem was the agricultural management of animal waste. Today, this issue returns in the form of environmental restrictions imposed on farms. Detailed requirements for plates and tanks, the attempts to obtain methane or the introduction of composting are good examples of the importance of this aspect of animal production (Liqiang et al., 2016).

The elimination or the reduction of emissions of damaging gaseous admixtures as well as odours associated with animal production, is not simple as they constitute a mixture of over one hundred compounds of different origins. The following groups can be mentioned: cyclic hydrocarbons, aldehydes, alcohols, ketones, free fatty acids, mercaptans, phenols, cyclic amines and esters (Yue et al., 2017) and less numerous inorganic compounds. Ammonia, hydrogen sulphide and methane are characterised by high concentrations of these gas admixtures, which can be relatively easily reduced. The issue of limiting the emission of harmful gas admixtures and odours is also a priority from the legal point of view. The new European Union legislation introduces the obligation to use sealed tanks (Article 18 paragraph 1 of the Act of 10 July 2007 on fertilisers and fertilisation, Journal of Laws 2015, item 625). Among the other provisions, already at the level of individual member states, some are admissible distances of farm buildings from residential areas, public places, water reservoirs or food plants (the Ordinance of the Minister of Agriculture and Food Economy of 7 October 1997 on technical conditions to be met by agricultural buildings and their location). Farms that do not meet these conditions are often forced to use expensive ventilation systems, equipped with washer filters. Another option is the use of bio-filters (Tymczyn et al., 2009, 2010). Biochemical methods in the reduction of the formation of harmful gas admixtures refer to the use of preparations that are mixtures of enzyme compounds, anaerobic microflora and mineral compounds changing pH or showing significant gas sorption. Existing first commercial preparations, however, do not show the desired effect. The reason may be only the theoretical combination of biochemical components reacting with organic compounds, and not the actual combination of potential processes. What can be called a technical direction in research into the reduction of the above-mentioned impact, leads to the elaboration and implementation of various solutions, constructions and even technologies (Eunsun et al., 2015).

Pig farms are characterised by a high concentration of livestock and not only a significant production of meat, but also manure, which is a huge environmental threat. The rational management of manure, especially due to the existing norms regulating the burden of the environment, becomes a priority problem. The uncontrolled use of manure for fertilising purposes has serious environmental consequences. They are related to the problem of soil fertilisation, washing up of elements and the resultant groundwater and eutrophication of surface water (Azam et al., 2002). The significant biogenic potential of manure makes their improper agrotechnical development the cause of degradation of the soil environment. Gas compounds formed during manure storage, including ammonia, also have an adverse effect on the natural environment (Azam et al., 2002; Bicudo et al., 2002; Xiao-Kang et al., 2013). The purpose of the study was to determine the possibility of biogenic potential reduction and ammonia emission from stored manure from pregnant and nursing sows. This issue is of particular importance in the context of environmental protection and the quality of life in rural areas.

Materials and methods

The experimental material consisted of manure from pregnant and nursing sows in the amount of 1 t/heap. The manure - next to the dung - consisted of uncut wheat straw used as litter in livestock premises. The animals were fed according to the standards

resulting from current feeding standards (Grela and Skomiał, 2014) according to the scheme applicable at the farm, where the daily dose was for pregnant sows - BO 14.39% and EM 19.22 MJ/kg while for nursing sows - BO 15.94% and EM 19.03 MJ/kg.

The manure was stored for 6 months in the period of increasing and decreasing temperatures, i.e. from March to August and from September to February, on manure plates in 2 heaps (corresponding to individual technological groups of pigs) with the dimensions of 3.0 x 5.0 x 2.5 m. The experiment was carried out in 2 repetitions. The experiment consisted in determining the concentration of biogenic compounds and ammonia emissions from manure storage under repetition conditions. The experimental design is illustrated in the diagram below.

Experimental design

Specification	*Repetition*	*Manure*	
		nursing sows	*pregnant sows*
Determination of concentration of biogenic compounds and ammonia emission values in the conditions of increasing and decreasing temperatures	1.	1 t	1 t
	2.	1 t	1 t

Multibar electronic gas meter by Dräger. In addition, the emission of ammonia per unit of time per ton was determined, which was calculated from the volume of air flow and the concentration of gas present in it, divided by the amount of manure tons.

All the tests were performed using aerodynamic tunnels, so-called "Tunnel system". Through the tunnel, a fixed volume of air was injected mechanically through the ventilation inlet and also removed mechanically by the exhaust fan. The composition of both inlet and outlet air was monitored. The volume of flowing air was calculated from the measured velocity of its flow, its duration and the known cross-section of the measuring (exhaust) channel, using the physics quation to account for the "flow right" (Q and P in the feed rations of animals from which the manure originated). The obtained results were evaluated statistically using the Lotus, Excel, Statgraphics Standard Edition computer software.

The results and their discussion

The study, conducted as a part of the experiment, aimed at determining the concentration of biogenic compounds and the ammonia emission values in the period of increasing temperatures (March-August) and decreasing temperatures (September-February), characterised the diverse initial composition of manure of the nursing and pregnant sows. (Tab. 1 and 3). An important role was played by the C: N ratio. Its value determined the effectiveness of microbiological transformations occurring in the manure and ammonia emissions. In the manure stored in the spring and summer period, its value was 13.98 kg/t of fresh matter for both pregnant and nursing sows. After a 6-month spring-summer storage period, this ratio decreased to 11.26 and 10.76 kg/ton of fresh matter, respectively. In the autumn-winter period, the C: N ratio was similar for nursing sows (13.94 kg/t), but lower for the pregnant sows (12.21 kg/t) and after 6 months during the summer and winter storage period increased accordingly to the value of: 13.49 and 14.81, which resulted, among others, from reducing the rate of microbiological changes taking place inside the heap and lower carbon dioxide emissions.

The share of total nitrogen in the composition of $Q = V/T = A_1v_1 A_2v_2 = A_3v_{32}$ v = const; where: Q – the initial sow manure during the spring – summer season was similar: 11.03 and 10.17 kg/t of the fresh matter and it did not differ significantly in the statistic terms (Tab. 1). In the season of decreasing temperatures the highest content of total nitrogen was found in the manure of pregnant sows volume flow [m^3/s], v – volume [m^3], t = time [s], A1, A2, A3cross-sectional area of the pipeline in subsequent locations [m2], v1, v2, v3) – flow speed in these points [m/s]).

The following measurements were also made: temperature of manure (daily in the morning, afternoon and evening hours in the central, upper and side planes of manure at a depth of about 10 cm), manure composition (NPK, dry matter, samples collected and analysed at the beginning and end of the 6-month storage period), volume and composition of liquid manure carried out during storage (volumetric analysis was carried out once a week, chemical at the beginning and end of the 6-month storage period, and analysis of N content that (7.31 kg/ton of fresh matter), and in the manure of the nursing sows it was 6.55 kg/t of fresh matter (Tab. 3). The content of total nitrogen in the manure of pregnant and nursing sows resulted from the fixed ratio of C: N and the addition of straw. The six-month period of spring-summer storage of pregnant and nursing sows manure led to similar losses of this element in the examined heaps. In the manure of pregnant sows there was 1.03 kg/t of fresh matter and in the nursing sows manure - 1.12 kg/t of fresh matter of the total nitrogen (Tab. 2). Fall and winter storage of the manure reduced total nitrogen loss to respectively: 0.21 and 0.26 kg/t of fresh matter of this form of element (Tab. 4). Likewise, in the case of organic nitrogen and the overall amount of loss of the both nitrogen forms in the manure of pregnant and nursing sows reached the value of nearly 80% higher after the storage in the period of rising temperatures as compared to the storage in winter season. The highest losses of organic nitrogen were found in the manure of pregnant sows after the storage in the summer period (1.31 kg/ton of fresh matter), and the manure of nursing sows in the winter period (0.37 kg/ton of fresh matter). In the case of total nitrogen, the loss of this form of element for pregnant sow manure kept in the summer reached the value of 1.76 kg/ton of fresh matter, and in winter 0.34 kg/ton of fresh matter (Tab. 2 and 4). The share of dry matter in the initial composition of pig manure in the spring and summer months was the highest in the case of pregnant sows and amounted to 30.47%

(Tab. 1), and in autumn and winter months in the manure of nursing sows (25.12%) (Tab.3). After the summer and winter storage periods, the share of dry matter decreased to the following values: 5.87 and 3.18% (Tab. 2 and 4). The phosphorus content in the manure reached the maximum amount of 9.18 kg/ton of fresh matter in the case of nursing sows during spring and summer months (Tab. 1) and 5.70 kg/t of fresh matter in autumn and winter months (Tab. 3). The losses of this element in the manure of nursing sows after its storage in the period of increasing temperatures amounted to 0.28 kg/t and 0.19 kg/t of fresh matter in the period of decreasing temperatures and were close to its losses in the manure of pregnant sows during these storage periods (0.31 and 0.15 kg/ton of fresh matter) (Tab. 2 and 4). The amount of potassium in the manure of pregnant and nursing sows during the increasing temperatures was 6.43 and 6.25 kg/t of fresh matter of its composition (Tab. 1) while in the period of decreasing temperatures, respectively: 3.09 and 3.89 kg/fresh matter (Tab. 3). The highest potassium losses during the increasing and decreasing temperatures were determined in the manure of nursing sows (0.18 and 0.12 kg/ton of fresh matter) (Tab. 2 and 4). The emission of ammonia in the spring and summer period did not differ significantly in terms of statistics and was slightly higher than manure of pregnant sows (1.14 kg/ton of fresh matter) than for nursing sows (0.98 kg/ton of fresh matter) (Tab. 5). A similar dependence was related to the emission of this gas in autumn and winter (0.28 and 0.16 kg/ton of fresh matter) (Tab. 6). The ammonia emission from manure of both technological groups, higher by over 75%, measured in the period of increasing temperatures as compared to those observed during low temperatures, was associated with a much faster rate of biochemical changes occurring in manure in the spring and summer season and a thermophilic phase accompanying these transformations that activates the appropriate bacterial microorganism. In the period of decreasing temperatures (September-February) affecting the manure heaps from nursing and pregnant sows (Tab. 8), the average outside temperature was 10.4°C. In the period of increasing temperatures (March-August) (Tab. 7) the average outside temperature was 23.37°C. The remaining selected external microclimate parameters affecting the manure of sows in the period of decreasing temperatures were in the case of relative humidity at the level of 64.42% (Tab. 8). The air movement in the period of decreasing temperatures reached the average value of 2.99 m/s. In the period of increasing temperatures, the average outdoor humidity around the sow manure heaps was 49.3%, and the air movement was 2.97 m/s (Tab. 7).

Table 1. Initial content of biogenic compounds in pig manure during increasing temperatures (kg/t fresh matter)

Item	*d.m. (%)*	*N-total*	*N-organic*	*TKN*	P	K	C:N
Manure – pregnant sows	30,47 a	11,03 a	7,92 a	9,81 a	7,31 a	6,43 a	13,98 a
Manure – nursing sows	30,21 b	10,17 a	6,50 b	0,97 a	9,18 a	6,25 a	13,98 a

ab – lowly significant differences.

Table 2. Loss of biogenic compounds in pig manure during increasing temperatures (kg/t fresh matter)

Item	*d.m. (%)*	*N-total*	*N-organic*	*TKN*	P	K	C:N
Manure – pregnant sows	5,87 a	1,03 a	1,31 a	0,76 a	0,31 a	0,12 a	11,26 a
Manure – nursing sows	8,06 b	1,12 a	0,90 a	0,98 a	0,28 a	0,18 a	10,76 a

ab – lowly significant differences.

Table 3. Initial content of biogenic compounds in pig manure during decreasing temperatures (kg/t fresh matter)

Item	*d.m. (%)*	*N-total*	*N-organic*	*TKN*	P	K	C:N
Manure – pregnant sows	20,74 a	7,31 a	4,55 a	7,11 a	3,39 a	3,09 a	12,21 a
Manure – nursing sows	25,12 a	6,55 a	3,68 b	6,41 a	5,70 b	3,89 a	13,94 b

ab – lowly significant differences.

Table 4. Loss of biogenic compounds in pig manure during decreasing temperatures (kg/t fresh matter)

Item	*d.m. (%)*	*N-total*	*N-organic*	*TKN*	P	K	C:N
Manure – pregnant sows	2,08 a	0,21 a	0,33 a	0,34 a	0,15 a	0,11 a	13,49 a
Manure – nursing sows	3,18 a	0,26 a	0,37 a	0,31 a	0,19 a	0,12 a	14,81 a

ab – lowly significant differences.

Table 5. Ammonia emission from pig manure stored during increasing temperatures (kg/t fresh matter)

Item	*Manure – pregnant sows*	*Manure – nursing sows*
NH_3	1,14 a	0,98 a

ab – lowly significant differences.

Table 6. Ammonia emission from pig manure stored during decreasing temperatures (kg/t fresh matter)

Item	*Manure – pregnant sows*	*Manure – nursing sows*
NH_3	0,28 a	0,16 a

ab – lowly significant differences.

Table 7. Mean microclimate values for different sow manure heaps during increasing temperatures

Outdoor temperature	*Rate of air movement*	*Outdoor humidity*
23,37 (± °C)	2,97 m/s	49,33%

Table 8. Mean microclimate values for different sow manure heaps during decreasing temperatures

Outdoor temperature	*Rate of air movement*	*Outdoor humidity*
10,40 (± °C)	2,99 m/s	64,42%

Summary and Results

The results obtained during the research and their analysis allow the identification of certain regularities that are important from the point of view of the assumed goals, which can be formulated in the form of the following generalisations. During the storage of manure from pregnant and nursing sows, there are losses and changes in the active forms of biogenic elements contained in the manure. The losses of the biogenic compounds of manure take place through the emission of gaseous compounds, mainly in the form of ammonia, but also as carbon dioxide. The level of the reduction of the content of biogenic compounds in the manure of pregnant and nursing sows is strictly related to weather conditions, especially the thermal conditions. The ammonia emission from the manure of both technological groups, higher by over 75%, measured in the period of increasing temperatures as compared to those observed during low temperatures, was associated with a much faster rate of biochemical changes occurring in manure in the spring and summer season and a thermophilic phase accompanying these transformations that activates the appropriate bacterial microorganism. Erecting the sow manure heaps and storing it at low temperatures results in a reduction in the loss of biogenic compounds caused by the absence of a thermophile phase.

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EFFECT OF SOW MANURE STORAGE CONDITIONS ON MANURE DECOMPOSITION AND AMMONIA EMISSION

Summary

The aim of the study was to determine the possibility of reducing the biogenic potential and emission of ammonia from stored manure originating from pregnant and nursing sows. This issue is of particular importance in the context of environmental protection and quality of life in rural areas.

The experiment determined absolute ammonia emission volume as well as changes in manure composition during its storage under increasing temperatures (spring-summer period) and decreasing temperatures (autumn-winter period). The experiment was conducted in field conditions. Manure was stored for 6 months using the tunnel method. Also the microclimate conditions and the manure composition were monitored. Ammonia emission from the manure from both technological groups, measured during the period of increasing temperatures, was higher by more than 75% compared to that measured during low temperatures. This was associated with a much more rapid rate of biochemical changes taking place in the manure in the spring-summer period and the accompanying thermophilic phase, which activates appropriate bacterial microflora.

Key words: manure, storage, ammonia emissions