PRODUCTION OF POLLUTANTS FROM ORGANIC LITTER FOR DAIRY COW

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Abstract

The aim of the experiment was to analyse the production of ammonia and greenhouse gases in dairy farms depending on the type of litter used. Two stables A and B – with the same structure situated next to each other - were used for the analysis. Straw litter was utilized in the deepened cubicles in building A; the bedding based on recycled manure solids (RMS) was used in building B. A significant difference in concentration of all gases were observed in stable A and B (P <0.01). Production of ammonia and methane was significantly lower in stable A ($NH_{3,(straw,AVG)}$ = 0.86 mg.m^{-3}±0.53 and $CH_{4,(straw,AVG)}$ = 8.36±2.93 mg.m^{-3}) than in stable B ($NH_{3,(RMS,AVG)}$ =2.35 mg.m^{-3}±0.69 and $CH_{4,(RMS,AVG)}$ = 20.61±12.26 mg.m^{-3}), while other microclimatic conditions in both were not statistically different. However, the average and maximum values of ammonia and other monitored gases in stable A, as well as in stable B with RMS, did not exceed permitted limit values.

Key words: *dairy cattle; organic bedding; harmful gases concentration.*

INTRODUCTION

Global atmospheric concentrations of the most important gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3), have increased significantly in the last 150 years (*Monteny et al., 2006*). Livestock farming systems are a major source of trace gases contributing to atmospheric pollution locally and globally. Emissions from dairy cow production systems need to be reduced to limit the environmental problems associated with livestock (*Saha et al., 2014*). The membership of the Slovak Republic in the EU imposes obligations to implement EU directives into Slovak laws amending the responsibility of production enterprises for the environment. Increasing demands on the quality of animal products make it necessary to deal with the improving of the animal housing conditions (*Balková and Pogran, 2009*); however, monitoring and reduction of emissions of greenhouse gases must be also ensured (*Pogran et al., 2011*). Currently, great attention is paid to usage of livestock manure so that it can be re-evaluated in the further agricultural activity. Dairy farms are under gradual pressure to improve their management of manure. Bedding is a very costly component of dairy farming that has significant implications for animal health, as well as environment. The cost and availability of bedding fluctuates, and good bedding materials can be expensive and difficult to obtain. Farmers using RMS report greater cow comfort than with other bedding materials they have used (*Harrison, et al., 2008*). Recent technological advancements in the dairy sector have enabled the dairy farms with liquid manure to use mechanical solid-liquid separation systems equipped with active composting of the separated solids. Farmers consider this desirable, because liquid manure storage requirements are reduced, and composted solids are used as bedding material, avoiding thus an increase in cost of purchased bedding (*Husfeldt et al., 2012*). Appropriate manure separators allow separation of the solid part from the liquid component up to 40% of dry matter and its subsequent usage as a plastic litter that improves animal welfare (*Jelinek et al., 2006*). Selection of bedding materials by farms is related to the manure system used, availability and cost of materials. Increased promotion of high-performance slurry separation machinery that can produce separated manure solids with dry matter (DM) exceeding 30% has provoked interest in this practice in European farms, in which there are very different climatic conditions. Scientists also try to address the issue of bacteriology and hygiene risks of organic litter. With increasing temperature, the production of specific harmful gases also increases (*Zhang et al., 2005, Rong et al., 2014*). The aim of this work was to compare the concentrations of harmful gases in two dairy housing units, using the straw bedding and bedding from the recycled manure solids during summer.

MATERIALS AND METHODS

INNOVA Air Tech Instruments Photoacoustic Multi-Gas Monitor with a 1309 multichannel sampling system was used to measure NH_3, CO_2, CH_4, N_2O concentrations. This equipment was installed in two buildings A and B with the same ground plan dimensions and roof height. Dairy cows are housed in comfortable lying cubicles with a length of 2.5 m and a width of 1.2 m, which are located at the external walls in two rows. Manure corridor is between them. The feeding passes are in the middle of the stall. During the experiment, 170 dairy cows were housed in each stable, the Holstein-Friesian breed with an average weight of 580 kg. The experiment was conducted in the summer months of June, July and August on selected days when the indoor air temperature ranged from 14 to 34 °C. Temperature and relative air humidity were recorded using a Comet datalogger. Straw is used as bedding in cow cubicles in the stable A; and the identical cubicles with the same location are filled with litter of separated slurry (RMS) in the stable B. The produced liquid manure and urine are continuously removed by a hydraulic blade scraper into the cross-channel and from there to the two-chamber pumping sump and then to a slurry separator where the liquid is separated from the solid part. The liquid part – slurry is pumped into above-ground storage tanks and the solid part is sprinkled from the separator into the transport mechanism and is used as litter for the cubicle lying in the cowshed. Both stables have longitudinally opened walls protected by a net with hexagonal openings that can be covered with a controllable flow system from a height of 600 mm above ground. Natural ventilation is ensured by roof ridge that is 56 m long. The measuring points of livestock gases production were at eight locations in both buildings (Fig. 1).

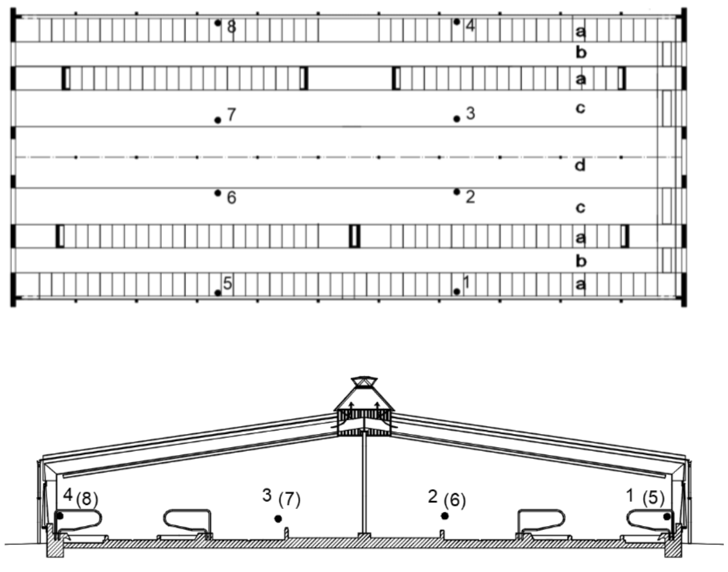

Fig. 1 Ground plan and cross-section of the stable (A and B) with air sampling locations
Legend: a - cubicles; b - manure corridor; c – feeding area; d - feeding passage; 1, 4, 5, 8 - measuring points in the cubicles; 2, 3, 6, 7 - measuring point in the feeding area (with liquid manure)

RESULTS AND DISCUSSION

Indoor and outdoor temperatures, relative humidity of air and gas concentrations recorded during the measurement periods are presented in Tab. 1. The Statistica 10 software, one-factor ANOVA, the Tukey HSD test at the significance level $\alpha = 0.05$ was used to evaluate and compare the gas production in the monitored stables in terms of used litter material in the lying cubicles. Test results show that the average values of the gas concentrations observed in measurements at stables A and B were significantly different (Tab. 2). Ammonia production was statistically significantly lower in building A (0.86 $mg.m^{-3}$±0.53), in which the straw was used for litter than in building B (2.35 $mg.m^{-3}$±0.69), in which the separated slurry was used. However, microclimatic conditions in both housings were not statistically different. The average and maximum values of ammonia and other monitored gases in stable A, as well as in stable B with litter of separated slurry did not exceeded permitted limit values.

Tab. 1 Evaluated gas concentrations, indoor and outdoor temperature and relative humidity during measurement in housing stable A (straw litter) and stable B (litter from RMS), P<0.01

	unit of measur.	stable	N valid	average	min.	max.	stand. dev.	var. coefic.
NH_3	mg.m^{-3}	A	3328	0.9	0.1	6.6	0.5	61.4
		B	3328	2.4	0.2	3.3	0.7	29.2
CO_2	mg.m^{-3}	A	3328	1032.2	787.0	1692.3	120.9	11.7
		B	3328	1370.7	821.5	2573.5	384.8	28.1
CH_4	mg.m^{-3}	A	3328	8.4	0.3	29.0	2.9	35.0
		B	3328	20.6	4.6	61.5	12.3	59.5
N_2O	mg.m^{-3}	A	3328	1.0	0.7	1.3	0.1	8.2
		B	3328	1.2	0.8	1.6	0.2	16.2
indoor air temperature	°C	A	3328	24.6	14.5	33.4	4.2	17.2
		B	3328	24.3	14.9	32.7	4.1	16.9
relative humidity of indoor air	%	A	3328	60.2	30.6	83.4	13.7	22.7
		B	3328	61.1	30.9	87.5	14.0	22.8
outdoor air temperature,	°C		3328	23.8	12.7	34.3	5.0	21.1
relative humidity of outdoor air	%		3328	58.6	23.0	97.2	18.7	31.8

Tab. 2 Statistical analysis of gas concentrations, indoor temperature and relative humidity during measurement in stable A (litter from straw) and stable B (litter from RMS), Tukey´s HSD, P<0.05

		unit of meas.	stable	average value	p-value
1	NH_3	mg.m^{-3}	A	0.9	0.000009
2			B	2.4	
1	CO_2	mg.m^{-3}	A	1032.2	0.000008
2			B	1370.7	
1	CH_4	mg.m^{-3}	A	8.4	0.000009
2			B	20.6	
1	N_2O	mg.m^{-3}	A	1.0	0.000007
2			B	1.2	

Similar results in terms of ammonia concentrations in free dairy housing utilizing deep straw litter were reported by *Herbut and Angrecka (2014)*, who recorded average values of ammonia as follows: 0.98 mg.m^{-3} in June; 0.79 mg.m^{-3} in July; and 0.86 mg.m^{-3} in August. Straw is frequently used bedding material, and it is characteristic with an ability to absorb the water and gases, as well as with high content of dry mass (approx. 85%). For many years, these two factors determined the popularity of its application (*Adamski et al., 2011*). One kilogram of straw absorbs approx. 2-5 g of ammonia. In absorption is increased in modified straw, (treated by i. e. cutting or gridding). This experiment also included investigation of the physical properties of materials used in the cubicles, namely the dry matter content under operating conditions. Results are reported in *Lendelova et al. (2016)*, who found an average dry matter content value of 27.18 ± 0.96% by measuring the dry matter content of the RMS prior to its supplying to the cubicle without significant differences at each sampling site (P <0.01). After four days, the average RMS dry matter content in the selected samples taken from the cubicle was 51.61% and 65% after another 4 days. The average dry matter content of straw was 90.88 ± 0.79% prior to its spreading to the cubicles, dropping to 88.12% after supplying with litter, and continued to drop to 68.38% before being removed from the storage. Results showed that after spreading the separated sludge slurry into cubicles in the stable with free stalls filled with separated raw manure solids, there was a significant increase in dry matter during 2–8 days from starting dry matter content of 27% to 65%, which is positive in terms of hygiene and comfort. Situation is quite the opposite in wet and cold environments, where RMS farmers are sceptical (*Leach et al., 2015*) and the research was subsequently devoted to the chemical and bacteriological characteristics of RMS and their impact on milk quality and welfare (*Gooch et al., 2005, Bradley et al., 2018*). Efficiency of DM removal is greatly variable depending on the type of used separators: 16-78% for screw pressers, 14-40% for roller presses, and 25-77% for decanter centrifuges (*Godbout et al., 2002, Gooch et al., 2005*). According to *Rumburg et al. (2004*) and *Rogge et al. (2006)*, the quality of beddings and their moisture influence the emissions of organic compounds, and odour and dust into the air and are assessed on the basis of animal behaviour standards that are an important determinant of welfare in addition to other things (*Adamski et al., 2011*). *Fillingham et al. (2017)* reported that solid-separation and composting are potential greenhouse gas mitigation practices for dairy farms. Separation reduces carbon in the liquid fraction entering the manure storage, hence reducing the potential methane emissions, with a high global warming potential. Carbon dioxide is emitted only as a part of the short (biogenic) carbon cycle and does not contribute to the net atmospheric concentration (*Vergé et al., 2013*). Nitrous oxide is a potent greenhouse gas with climate-carbon feedback emitted from solid manure and compost. Manure emits ammonia, which is an indirect greenhouse gas and has adverse health effects (*Harrison and Yin, 2000*). According to *Misselbrook and Powell (2005)*, there is a number of ways, influencing the emissions from different bedding materials. These include physical structure, chemical composition of bedding and different capacity to absorb deposited urine. Absorption may reduce emissions by increasing the resistance to gaseous transport. For example, mixture of peat and chopped straw reduced emissions from young cattle in bedded pens by approximately 50% compared to long straw, chopped straw, or wood shavings; this reduction was attributed to high ammonia absorbing capacity of this bedding (*Jeppsson, 1999*). Considering the recycled manure solids with the much greater absorbance capacity presented by *Misselbrook and Powell (2005)*, it was suggested that the majority of the urine was retained in the upper layers of bedding with a lower resistance to transport, resulting in higher emissions in comparison to sand bedding. Generally, the presence of bedding material can reduce NH_3 emissions from cattle housing. *Chambers et al. (2003)* reported emissions lower from a deep straw litter in cattle housing system to be lower by 30% in contrast to a slurry-based system. Our possibilities at experimental farm did not allow us to compare the absorption capacity of RMS with sand or non-bedded system. However, a partial analysis of concentration of ammonia and other gasses over the cow beds in stable A and stable B did not show any significant difference in stable utilizing the RMS in contrast stable using the straw litter. Nevertheless, this claim will be subject to detailed analysis of litter exposed to different litter cycles and with a different rate of excrement removal from the manure corridors, both of which may have a significant impact on the overall result for cubicles filled with straw and cubicles filled with bedding from recycle manure solids.

CONCLUSIONS

The classic organic litter is well formable, flexible and usually thermally insulated, but problem lies in its availability, labour demands and cost. The issue of their influence on the internal and subsequently external environment, which is dependent on changes in physical properties in relation to changes in air chemistry, is also essential. The recycled sludge bedding gives the impression of non-hygiene, unpleasant odour and undesirable production of emissions. The work is based on the assumption that ammonia and methane productions increase with increasing ambient temperature. Therefore, the first experiments were focused on monitoring of production of pollutants in the building with litter made of separated sludge slurry in the summer and opportunity of simultaneous measurements in the same neighbouring building utilizing straw as litter had allowed us to compare the obtained data. The experiment was conducted in two phases, the first phase included observation of litter physical properties, the second phase included measurement of differences in the concentrations of produced gases. On the basis of the results of our measurements, we have determined the following conclusions. Considering the two neighbouring buildings (each with 170 cow cubicles), the average concentrations of NH_3, CO_2, CH_4, resp. N_2O were significantly higher in the building with recycled sludge slurry bedding (2.35 $mg.m^{-3}$, 1370 $mg.m^{-3}$, 20.61 $mg.m^{-3}$, 1.19 $mg.m^{-3}$, respectively) than in building with the straw bedding (0.86 $mg.m^{-3}$, 1032.24 $mg.m^{-3}$, 36 $mg.m^{-3}$, 0.98 $mg.m^{-3}$ respectively). Increased concentrations of NH_3, CO_2, CH_4 and N_2O did not show that RMS litter absorbs produced pollutants, however, observed concentrations did not exceed permitted limits for dairy farming.

ACKNOWLEDGEMENTS

This research was supported by project NFP 26220220014 and knowledges gained from LivAGE (project COST): Ammonia and Greenhouse Gases Emissions from Animal Production Buildings was used.

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