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EFFECTS OF WOOD SHAVINGS ADDITION AND DIFFERENT CLIMATIC CONDITIONS ON AMMONIA AND ODOUR EMISSIONS FROM FRESH ANIMAL MANURE

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ABSTRACT The addition of wood shavings and changing the climatic conditions as methods of mitigating ammonia and odour emissions were investigated using fresh pig and cow manure samples. The manure from each animal type was separated into two portions and wood shavings were mixed with one portion. Emissions from identical quantities of manure with and without wood shavings were measured in a flux chamber. The manure temperature was varied between 15 and 30 °C. Fresh air at temperatures between 15 and 25 °C was passed at a fixed rate over the manure in the chamber. Gas and odour concentrations were measured using a photoacoustic multi-gas analyser 1412 (Lumasense Technologies A/S) and an olfactometer respectively. The addition of wood shavings decreased the total-N and NH_4^+-N but increased the ratio between carbon and nitrogen (C/N) as well as the pH. Ammonia emissions increased with manure temperature for both manure types. Odour emissions increased with the cow manure temperature. Odour emissions had a positive tendency with the pig manure temperature for samples without wood shavings. The water vapour pressure was positively correlated to the emissions from the cow manure but not from the pig manure. A clear relationship between ammonia and odour emissions could not be established. The addition of wood shavings lowered the ammonia emissions from the cow manure but not from the pig manure.

Keywords: Dry matter, C/N ratio, temperature

INTRODUCTION Animal production has to be taken into consideration when planning emission mitigation strategies with the main focus on housing, manure handling, feed composition and management systems (Hartung 1992). Animal manure is the main odour source and the focus of mitigation has directly been towards manure handling and treatment (Kai et al. 2008; Le et al. 2005).

Gaseous emissions are affected by environmental factors, manure characteristics, and factors related to management (Andersson 1995; Gustafsson 1996). The air humidity (water vapour pressure) is an important parameter for ammonia and odour release (Nimmermark and Gustafsson 2005). Ammonia production from urea hydrolysis to the subsequent processes of dissociation and volatilisation is faster at higher temperatures (Groot Koerkamp 1994; Monteny and Erisman 1998). Odour emissions from pig manure have also been reported to increase with temperature (Le et al. 2005). The cumulative effect of these factors might be difficult to investigate in practice.

The nature and quantity of the materials like straw, wood shavings, and peat that are used as bedding for animals affect gaseous emissions. The materials increase the dry matter content (DM) and the C/N ratio of the manure thereby providing energy for microbes to immobilise excess ammonium leading to reduced ammonia emissions (Groenestein and Van Faassen 1996; Poincelot 1974). Ammonia emissions seems to he greater from solid compared to slurry manure just during the initial phase due to a higher self-heating temperature increase resulting from microbial activities in solid manure (Dewes 1999).

Experiments were conducted with fresh animal manure under different climatic, physical and chemical conditions in order improve the knowledge on ways to mitigate emissions in animal buildings. Ammonia, methane, nitrous oxide and odour emissions from fresh manure with and without the addition of wood shavings were compared in a laboratory experiment using a climate controlled chamber. The temperatures of the air and the manure were the input parameters. An attempt was made to establish a relationship between odour and ammonia emissions.

2 MATERIAL AND METHODS

2.1 Experimental set-up Fresh manure was collected from the pit underneath the slated floor in a building with fattening pigs and from an open shallow slurry channel in a tie-stall dairy cow barn. It was collected three times (samples 1 to 3) from each animal building (Table 1). Each manure sample was divided into two portions and wood shavings were mixed with one portion.

Each manure portion was placed in a container (surface area 0.25 m^2) which was lowered into a water-bath. The height of the manure layer was 4–5 cm. Manure temperatures (~15, 20 or 25ºC) were attained by heating the water. A closed chamber was achieved by placing an insulated hood on top of the manure container. The hood was equipped with an inlet duct, an exhaust fan, and a circulation fan for mixing the air. The diameter of the inlet and outlet ducts were 6.5 cm. Fresh air outside the building was pulled through the chamber by the exhaust fan. The outside air was heated (~15, 20 or 25ºC) before entering the chamber. The air flow through the chamber was 113 ± 2 m^3 m^{-2} h^{-1} for the pig manure and 80 ± 2 m^3 m^{-2} h^{-1} for the cow manure.

Each manure sample had 18 treatments, (9 without and 9 with wood shavings) giving a total of 54 treatments per animal manure type (Table 1). The samples were analysed within a couple of days after collection. Plastic papers were placed over the containers with the manure samples at the end of each day experiments were conducted. The samples were stored at room conditions in the building where the experiments carried out.

Table 1. Experimental design for each animal manure type

	Manure without wood shavings					Manure with wood shavings				
			MT, ºC					MT, ºC		
			15	20	25			15	20	25
Sample 1, 2 or 3	AT, ºC	15	- Gases - Odour	"	"	AT, ºC	15	- Gases - Odour	"	"
		20	"	- Gases - Odour	"		20	"	- Gases - Odour	"
		25	"	"	-Gases - Odour		25	"	"	- Gases - Odour

AT: Air temperature, MT: Manure temperature, ": Gases and odour emissions were measured

2.2 Measurements of gaseous and odour emissions The concentrations of CO_2, N_2O, NH_3, CH_4 and water vapour in the air were measured with a photoacoustic multi-gas analyser. Background concentrations at the air inlet of the climate chamber were measured for about an hour for each day experiments were carried out. The concentration of a gas at the exhaust for each temperature combination in Table 1 was measured for about 30 minutes during which time it changed steadily before stabilising. The emission rate was calculated using the measured air flow rate and the relative concentration of the gas as given in Eq. (1).

$$ER = VR(C_{exhaust} - C_{inlet}) \qquad (1)$$

where ER is the emission rate in mg m^{-2} s^{-1}, VR is the ventilation rate in m^{3} m^{-2} s^{-1}, $C_{exhaust}$ is the gas concentration in mg m^{-3} at the exhaust of the chamber. This was the mean for about 5 minutes of measurements after the exhaust air concentrations had stabilised, C_{inlet} is the gas concentration in mg m^{-3} at the inlet to the chamber. This was the mean for about 5 minutes of measurements after stabilisation.

Samples for odour analysis were collected in nalophan bags at the exhaust of the climate chamber using a vacuum sampling device manufactured by ECOMA (Honigsee, Germany). Samples were taken at the end of each experiment when the temperatures and gas concentrations were stable. The samples were analysed following procedures described in European guidelines (CEN 2003). A standardised panel and an ECOMA (Honigsee, Germany) TO7 olfactometer were used for measurements of odour concentrations (OUE). Odour emissions were calculated from measured odour concentrations and measured air flow rates.

2.3 Measuring the temperature and the manure chemical content Thermocouples (Cu/CuNi) and a logger (INTAB Interface-Teknik AB, Stenkullen, Sweden) were used to measure temperatures in the air inlet, manure chamber, air outlet and the water bath. Temperatures for a specific experiment were calculated as the mean for about 5 minutes of measurements after the exhaust air concentrations had stabilised.

A small quantity of manure from each portion was sent to a laboratory (Eurofins) where the dry matter content, total-N, NH_4^+-N, C/N ratio and pH, were measured.

RESULTS

3.1 Influence of wood shavings on the manure composition The addition of wood shavings to both manure types led to increased DM, C/N ratio and the pH levels (Table 2). It decreased the total-N and NH_4^+-N levels in both animal manure types. A slight discrepancy was observed in the third cow manure sample with an increased total-N after wood shavings were added.

Table 2. Percentage change in the manure parameters after adding wood shavings

Manure content	Pig manure			Cow manure		
	Sample1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
DM	18	26	53	48	37	83
C/N ratio	38	33	65	78	56	67
pH	8	8	8	3	0	5
Total-N	-14	-5	-16	-11	-13	9
NH4+-N	-18	-13	-31	-17	-30	-22

DM: dry matter

3.2 Relationships between emissions and climate parameters The correlation coefficients between ammonia and odour emissions and some climate parameters are presented in Table 3. No significant amounts of methane or nitrous oxide emissions were found in the study.

Table 3. Pearson's product-moment correlation coefficients between emissions and climate parameters

Pig manure	No wood shavings		Wood shavings	
	Ammonia	Odour	Ammonia	Odour
Manure temperature	0.70***	0.40 (NS)	0.72***	-0.70**
Air temperature	0.18 (NS)	0.15 (NS)	0.11 (NS)	-0.16 (NS)
Relative humidity	-0.20 (NS)	-0.24 (NS)	-0.15 (NS)	0.06 (NS)
Water vapour pressure	0.06 (NS)	-0.23 (NS)	-0.06 (NS)	-0.23 (NS)
Ammonia/Odour correlation	0.40 (NS)		-0.51*	
Cow manure				
Manure temperature	0.48*	0.75***	0.69***	0.47*
Air temperature	0.20 (NS)	-0.09 (NS)	0.13 (NS)	0.05 (NS)
Relative humidity	0.24 (NS)	0.44 (NS)	0.36 (NS)	0.13 (NS)
Water vapour pressure	0.57**	0.66**	0.67***	0.39 (NS)
Ammonia/Odour correlation	0.47*		0.43 (NS)	

Level of significance *: $p \leq 0.05$, **: $p \leq 0.01$, ***: $p \leq 0.001$, NS: Not significant

A positive correlation existed between the ammonia emissions and the manure temperature for all the manure types. Odour emissions were positively correlated with the cow manure temperature although a negative relationship was observed for the pig manure with wood shavings. The air temperature and relative humidity did not significantly affect the ammonia or the odour emissions. Although the water vapour pressure positively correlated with the emissions from the cow manure, this was not the case for the pig manure.

A significantly positive correlation existed between the odour and ammonia emissions from the cow manure without wood shavings whereas a negative relationship was observed for the pig manure with wood shavings (Figure 1). A positive tendency existed in the relationship between ammonia and odour in 3 out of the 4 cases.

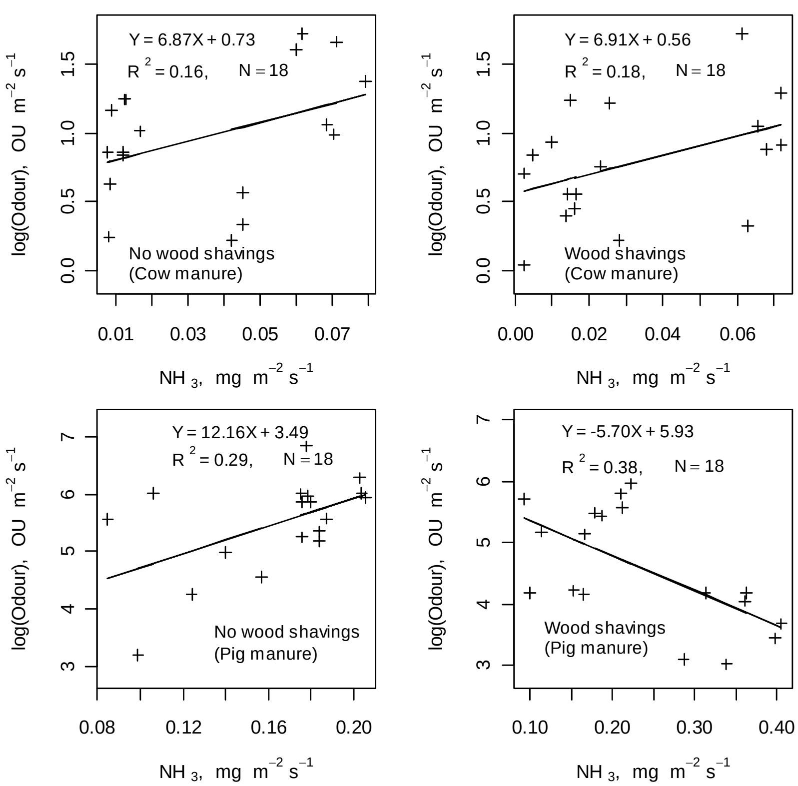

Figure 1. Relationship between odour and ammonia emissions from specific pig and cow manure compositions

3.3 Comparison of emissions from manure with and without wood shavings The effect of adding wood shavings to the manure on the emissions were analysed for each manure sample in a two-way ANOVA model shown in Eq. (2). Multiple comparison testing was carried out using Fisher's LSD test to determine which manure treatment had higher emissions.

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \lambda_k + \varepsilon_{ijk} \qquad (2)$$

where Y is the emission, μ is the overall mean emission, α is the treatment effect (with or without wood shavings), β is the effect of the manure temperature, λ is the effect of time (days) of manure storage before analysis, ε is the error, i, j and k are levels in the factors.

Ammonia emissions were higher ($p < 0.05$) from all the three pig manure samples with wood shavings compared to the control (Figure 2). They were lower from the cow manure with wood shavings in samples 2 and 3. There was no significant difference in the ammonia emissions from the cow manure in sample 1.

There was no significant difference in the odour emissions from the pig manure with and without wood shavings in sample 2, whereas in sample 3 the manure with wood shavings had a lower odour emission. No significant difference was observed in the odour emissions from all the cow manure samples.

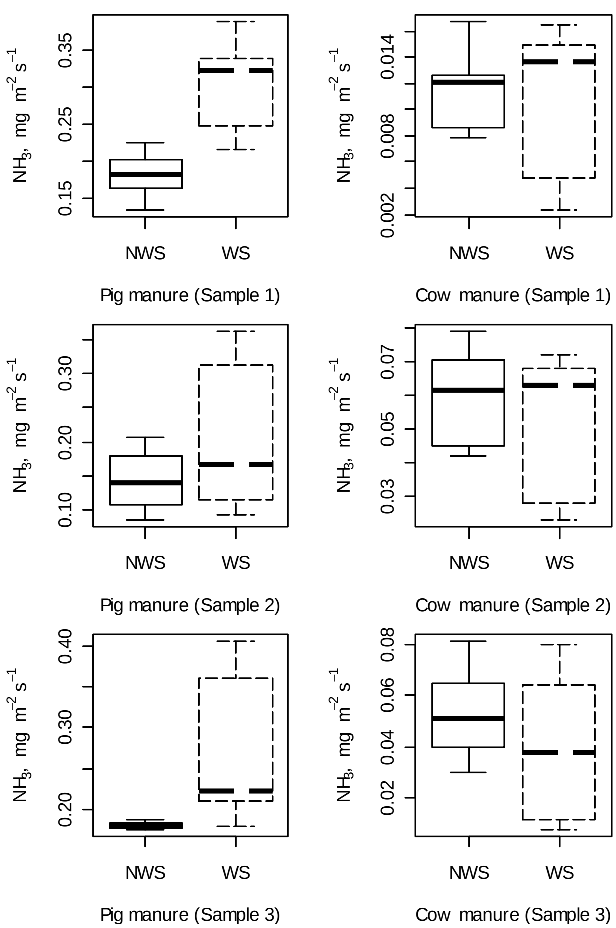

Figure 2. Comparison of ammonia emissions between manure with wood shavings (WS) and without wood shavings (NWS)

4 DISCUSSION The ammonia emissions were about 2 times lower at manure temperatures of about 15 ºC compared to emissions at about 25 ºC. Lowering the manure temperature can be an effective mitigation strategy. Ammonia emissions in a cow barn were reduced by 11–23% when incoming drinking water was passed through pipes in the manure gutter to cool the manure (Gustafsson et al. 2005).

The increase in odour emissions with increasing cow manure temperature has been supported in a laboratory experiment for pig manure (Le et al. 2005) and in a floor housing system for hens (Nimmermark and Gustafsson 2005). The non-significant or negative relationship between the odour emissions and the pig manure temperature could not be fully explained. These samples had very low odour emissions at manure temperatures of 25 ºC, but measured values at 20 ºC were higher than values at 15 ºC.

The air temperature did not significantly influence the ammonia and odour emissions in the present measurements. Another factor like the manure temperature might have masked the effect of the air temperature. It was noted that when the manure temperature was about 25 ºC, it was difficult to set the air temperature to about 15 ºC due to heat transfer. Positive correlations between air temperature and emissions have been reported (Jeppsson 2002; Le et al. 2005).

Positive correlations between odour emissions with water vapour pressure and ammonia emissions with water vapour pressure have also been reported (Nimmermark and Gustafsson 2005). Positive correlations were observed between ammonia emissions and water vapour pressure deficit (Gordon et al. 2001; Mkhabela et al. 2009).

Reductions in ammonia emissions have been reported after adding wood shavings to animal manure (Luo et al. 2004; Tasistro et al. 2008). The increase in the ammonia emissions from the pig manure when wood shavings were added could be due to the increase in the pH after adding wood shavings. In addition, it was observed that the temperature of the manure with wood shavings increased faster than that without wood shavings. Microbial activity resulting to self-heating might explain this faster rise in temperature. This was also evident in higher CO_2 emissions for the manure samples with wood shavings relative to samples without wood shavings. These can explain the high ammonia emissions from the pig manure with wood shavings in conformity with another report (Dewes 1999). However, manure with a higher DM emits less ammonia over a longer period of time (Dewes 1999).

The inconsistent relation between ammonia and odour in the present measurement has been observed elsewhere. A non significant correlation between ammonia and odour concentrations has been measured (Fakhoury et al. 2000). A study suggests that ammonia contribution to odour concentration is only significant in the absence of hydrogen sulphide (Blanes-Vidal and Hansen 2008). Positive correlations between ammonia and odour emission rates have been reported and utilised to calculate volatile organic compound emission rates (Ngwabie et al. 2008; Wood et al. 2001).

5 CONCLUSIONS

- The manure temperature was positively correlated to the ammonia emissions. Emissions were about 2 times lower at manure temperatures of about 15 ºC compared to emissions at about 25 ºC.
- The cow manure temperature was positively correlated to the odour emissions. The temperature of the pig manure without wood shavings had a positive

tendency with the odour emissions, while a negative correlation was observed between pig manure temperature with wood shavings and the odour emissions.

- The addition of wood shavings decreased the total-N and NH_4^+-N but increased the ratio between carbon and nitrogen as well as the pH.
- Water vapour pressure was positively correlated with the ammonia and odour emissions from the cow manure although no influence of the relative humidity on the emissions was observed.
- The addition of wood shavings to animal manure lowered the ammonia emissions from the cow manure but rather increased the emissions from the pig manure.
- No clear relationship between the ammonia and odour emissions was established although a positive tendency was favoured.

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