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Level and distribution of odorous compounds in pig exhaust air from combined room and pit ventilation

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ABSTRACT

Combined room and pit ventilation in pig houses (*Sus domesticus*) is evaluated for its potential to concentrate odorous compounds in the pit ventilation air, which would have advantages for both the indoor air quality and ventilation air treatment. In an experimental fattening pig house, levels of odorous volatile compounds were continuously measured by proton transfer reaction–mass spectrometry for three weeks in order to study the odorant production in a partial pit ventilation system. Three ventilation set-ups were applied: room ventilation, and combined room and pit ventilation with pit air extraction either under the dunging area of the piggery room, or under the resting area. Based on these on-line measurements and on fresh faeces headspace analysis, volatile organic acids are recognised as the main odorants arising from the surfaces in the pig house, while sulphur compounds, phenols and amines are more likely to originate from the slurry pit. When pit ventilation air is extracted under the dunging area instead of under the resting area, the pit to room concentration ratio increases for ammonia, amines and phenol.

1. Introduction

During intensive livestock production, animals and their waste give rise to high amounts of volatile organic compounds and gases, including odorous compounds such as reduced sulphur compounds, organic acids, phenols and indoles, ammonia and amines (Le et al., 2005). These odorants are mainly produced by microbial conversions in the gastrointestinal tract of the animals, in the manure pit and on the fouled floor of the animal house (Hamon et al., 2012).

By applying mechanical ventilation, indoor conditions like gas concentrations, humidity and temperature can be controlled to ensure the well-being of workers and animals (Saha et al., 2010) and the production performance (Schauberger et al., 2000). Temperature is often the driving variable to determine the ventilation flow rate. However, when ventilation air from animal houses is emitted to the atmosphere, the air pollutants are introduced into the environment and can induce odour nuisance, next to other environmental problems like contribution to the greenhouse effect and acidification (Mackie et al., 1998). Environmental odours have been associated with psychosocial effects such as annoyance, health risk perception and behavioural interference and several health problems have been reported among neighbours of industrial or agricultural activities (Blanes-Vidal et al., 2014).

Biological air cleaning techniques such as biofiltration proved to be a cost-effective way for odour abatement (Estrada et al., 2012) and are capable of treating odour nuisance problems around livestock facilities. Biofilters can reduce the emission of a wide range of livestock air pollutants including ammonia, hydrogen sulphide and odorous volatile organic compounds (Chen and Hoff, 2009; Hansen et al., 2012c), both acidic and basic compounds (Hamon et al., 2012), and even particulate matter (Lim et al., 2012). The recommended maximum ventilation rate of $100\,m^3\,h^{-1}$ per fattening pig of 100 kg (Seedorf et al., 1998), will require a large capacity for air cleaning to treat all the exhaust air (Saha et al., 2010). Consequently, researchers investigate how to treat only part

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of the ventilation air, while preventing odour nuisance in the neighbourhood around the emission source. In the USA, the widespread practice of hybrid ventilation (fans combined with natural ventilation by curtain opening at high ventilation requirements), can be equipped with partial biofiltration (Hoff et al., 2009). Odour nuisance is most likely when there is little air mixing due to a stable atmosphere, like in morning and evening hours. Since outside temperature is lower in this situation, sufficient ventilation can be provided without curtain opening, while applying air treatment to the remaining mechanical ventilated air. Air cleaning can therefore be organised more economically by dimensioning it on a critical minimum ventilation rate, characteristic for these stable atmospheres (Hoff et al., 2009). In Northern and Western Europe, the majority of fattening pigs is raised in 100% mechanical ventilated buildings, in Denmark often equipped with partial pit ventilation. By extracting part of the ventilation air under the slatted floor, from the headspace of the slurry surface, the indoor air quality is improved, while this limited amount of pit ventilation air contains a large concentration of pollutants. Treating only this pit exhaust air might reduce environmental impact of pig production without excessive investment and operational costs (Hansen et al., 2012a). A few studies have been performed on the effect of pit ventilation. Saha et al. (2010) experienced that a pit ventilation flow of around 1/6 of the total ventilation flow contained 43% of the total ammonia emission (pit and room) and significantly reduced the ammonia concentration in

Table 1
Target compounds and their properties.

Target compound	PTR-MS m/z	GC Retention time (min) [a]	Odour threshold range ($\mu g\ m^{-3}$)[b] 10^{-4}	10^{-3}	10^{-2}	10^{-1}	10^{0}	10^{1}	10^{2}	10^{3}	10^{4}	10^{5}	10^{6}
Hydrogen sulphide	35	1.7											
Methane thiol	49	2.2											
Dimethyl sulphide	63	2.8											
Dimethyl disulphide [c]	95	5.6											
Dimethyl trisulphide	127	11.3											
Acetic acid	61+43	12.3											
Propanoic acid	75+57	13.6											
Butanoic acid [d]	89+71	14.8											
2-Methylpropanoic acid [d]		14.0											
Pentanoic acid [e]	103+85	16.2											
3-Methylbutanoic acid [e]		15.3											
Hexanoic acid [f]	117+99	17.5											
4-Methylpentanoic acid [f]		17.0											
Phenol [c]	95	19.4											
4-Methylphenol	109	20.2											
4-Ethylphenol	123	21.1											
Indole	118	23.9											
Skatole	132	24.3											
Ammonia	18	N.A.											
Dimethyl amine	46	N.A.											
Trimethyl amine	60	1.85											

[a]Retention time in GC–SCD measurements for hydrogen sulphide, methanethiol and dimethyl sulphide, and in GC–MS measurements for the remaining compounds, except for ammonia and dimethyl amine which were not identified with chromatographic techniques.
[b]Odour detection threshold minimum and maximum based on compiled data from different authors (Ruth, 1986; Devos et al., 1990; Nagata, 2003; Le et al., 2005) are situated in the marked range, median value in the darker highlighted zone.
[c,d,e,f]Signal to noise ratios are shared by 2 compounds (marked with matching labels in superscript), see Section 3.2.