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Air Quality Monitoring and Characterisation at Two Commercial Broiler Farms

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Odour and non-methane volatile organic compound (NMVOC) emissions were assessed over the complete production cycles at two tunnel ventilated broiler farms in Australia. A real-time odour monitoring system, *i.e.* artificial olfaction system, was used to measure in-shed odour concentrations and, when combined with ventilation rate data, provided continuous odour emission measurements. NMVOC composition of poultry odour samples was analysed using gas chromatography-mass spectrometry-olfactometry combined with a range of sample collection/pre-concentration methods. NMVOC results were then examined to establish which chemical species were the key odorants. Volatile organic compounds identified within the emissions included alcohols, aldehydes, ketones, carboxylic acids and terpines. Air quality, based on odour and NMVOC in the broiler sheds, was found to vary significantly between farms due to numerous management and environmental factors. Consequently, the development of a general emission model that fits all situations is not feasible. However, the instrumental approach adopted proved useful in better understanding the dynamics and nature of odorous emissions from poultry facilities.

Keywords: air quality, poultry, odour, volatile organic compounds, artificial olfaction system

1. Introduction

Machine-based odour assessment techniques using instruments, *e.g.,* artificial olfaction system (AOS) and gas chromatography-mass spectrometry/olfactometry (GC-MS/O) provide the potential to build a comprehensive database of odour and non-methane volatile organic compound (NMVOC) emissions data for modern intensive poultry farming.

Until recently, the human nose and dynamic olfactometry have been the only tools available for the assessment of odours. Dynamic olfactometry is, however, limited because: 1) it is laboratory-based

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and requires trained human panellists; 2) it is unsuitable for routine assessments because cost and labour requirements are prohibitive; 3) odour samples are unstable (AS/NZS 4323.3:2001 requires analysis within 30 hours of collection but recommends that samples be analysed within 4–5 hours); 4) samples need to be collected at times that enable olfactometry assessment within the required period rather than collecting samples at times when odour emissions are problematic, for example at night and/or early in the morning when it is impractical to collect samples and assess them (Guo *et al.*, 2003); and 5) samples are collected over a short time period, which enable understanding of constant emissions, but may not be representative if emission rates are variable.

An AOS is an instrument consisting of a gas sampling apparatus and a number of gas sensors interfaced to a computer or other computation device. The AOS can complete tasks such as identification of a gas or odour or classification of odour samples, which are particularly useful for continuous monitoring of odours and for discriminating between different odours (*e.g.,* abattoir versus piggery). AOS can also be calibrated using dynamic olfactometry, which enables quantification of odour concentration (Sohn *et al.*, 2008 and 2003) in terms of odour units ($ou{\cdot}m^{-3}$), the standard unit for odour measurement.

Additionally, increased knowledge regarding the chemical composition of poultry odour (through measuring NMVOCs) is considered critical for identifying the odour source and developing mitigation techniques. The integration of chemical analysis and olfactory techniques by coupling an olfactory detection port (ODP) to a GC-MS/O allows individual odorants to be separated and identified individually, as well as allowing the odour contribution for each compound to be characterised in terms of character and intensity. The techniques using GC-MS/O can be used for the analysis and identification of odorous compounds but more attention is directed towards understanding the formation of key odorants and their fate in the environment.

This study is focussed on quantifying and improving understanding of the emission of odour and NMVOCs from tunnel ventilated broiler sheds by: 1) application of an AOS to continuously monitor and measure odour emissions; and 2) quantification and evaluation of specific poultry shed odorants using GC-MS/O.

2. Experiments

2.1 Measuring odour emissions using an artificial olfaction system

The AOS system was used to continuously measure odour concentration over complete production batches at Farm A (June to July, 2006) and B (April to June, 2007). The discrete odour measurements were obtained from samples analysed by dynamic olfactometry.

Continuous odour concentration data recorded by the AOS was combined with ventilation rate and weather data to calculate odour emission rate (OER) throughout the batches. The odour emission rate data can be used for further odour assessment purposes when combined with weather and atmospheric stability conditions, *e.g.*, odour impact assessment on neighbours.

The details of AOS, development of a calibration formula, and sample delivery system are given in Sohn *et al.*, (2008) and Dunlop *et al.*, (2009).

2.2 Measuring non-methane volatile organic compound emissions (NMVOC)

A sorbent tube method was chosen to collect NMVOC samples due to its robustness, sample stability, reliability, repeatability, ease of use, cost effectiveness and the ability to quantify NMVOCs. Further details on the NMVOC collection methodology are described in Parcsi et al., (2007) .

The chemical characterisation and identification of the NMVOCs was performed using thermal desorption (Markes International, UK) followed by separation and analysis using a gas chromatograph-mass selective detector (MSD) (Agilent Technologies, USA) coupled to an olfactory detection port (Grestel, Germany). An optimum method was established for the efficient speciation of the analytes captured on the sorbent tubes by varying different operating parameters in the TD-GC-MS/O (Parcsi *et al.*, 2007).

3. Results and discussion

3.1 Continuous odour records for broiler farms

Odour concentration data from the AOS was combined with ventilation rate, olfactometry and weather data to produce continuous records of OER. The continuous OER record for Farm B is shown in Figure 1.

Continuous collection of odour, ventilation and weather data at broiler farms demonstrated that: 1) in-shed odour concentration and OERs were much more variable than has been previously demonstrated; 2) OER changed throughout the batch, tending to increase throughout the batch, but declined following each pickup (a pickup is the removal of some/all birds from the shed for processing); 3) odour concentration and OER fluctuated diurnally, presumably due to changes in ventilation rate and bird activity; and 4) OERs sometimes spiked, for reasons that could not be explained by the data collected.

Daily averaged OERs from Farm A and B were calculated and then compared (Figure 2). For both farms, OERs increased until the first pickup. The highest OER was observed just before the first pickup - 30912 ou·s^{-1} at Farm A on day 32 and 45013 ou·s^{-1} at Farm B on day 36. After the first pickup, OERs for both farms decreased with the number of birds.

Odour emissions from Farm B were lower than Farm A until the end of week 4. From week 5, OERs from Farm B were higher than Farm A, possibly due to the later first pickup at Farm B - four days later than Farm A. The second pickup was also 7 days later than at Farm A. After the second pickup around day 41 of the batch, OERs from Farm A and B decreased and remained at a similar level.

3.2 Non-methane volatile organic compounds identified at broiler farm A

Collection and analysis of thermal desorption tubes using GC-MS/O provided insight into the NMVOC emissions from the broiler sheds during the poultry grow-out cycle. The GC-MS/O analysis provided a substantial list of NMVOCs (Table 1) including aldehydes and ketones (hexanal,

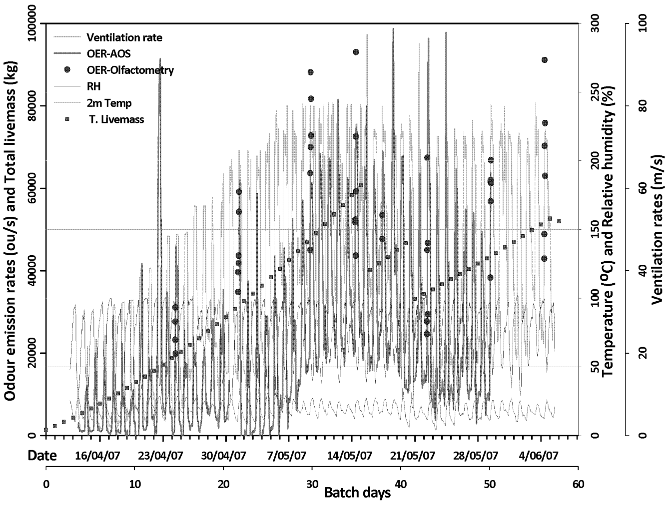

Figure 1. AOS, olfactometry, ventilation and weather data for Farm B

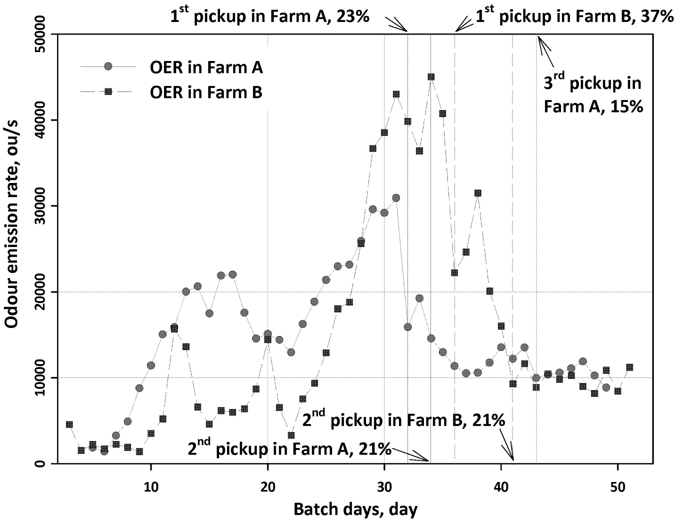

Figure 2. Comparison of daily mean odour emission rate profiles using the AOS at Farms A and B

heptanal, octanal, 2-butanone, 2,3-butanedione 3-hydroxy-2-butanone) alkanoic acids (ethanoic acid, propanoic acid, butanoic acid), terpines, and numerous other species. Whilst beyond the classification of NMVOCs, abundant sulfides (dimethyl sulfide, dimethyl disulfide, dimethyl trisulfide) were found in the vast majority of samples.

One of the most significant results from the assessment of the NMVOCs from the broiler shed emissions was the change in the chemical profile as the birds matured; from a matrix dominated by terpines from the bedding material when the birds were young, through to a matrix dominated by aldehydes, ketones and sulphides as the birds matured and the bedding became soiled with manure (Parcsi *et al.*, 2007).

Table 1. NMVOCs predominantly identified from GC-MS analysis of sorbent tubes at Farm A

Season	Farm A	
	Summer	Winter
Alcohols	1-butanol, 2-ethyl-1-hexanol, 2-butoxy-ethanol	Ethanol, 1-butanol, 2-butanol, 2-ethyl-1-hexanol
Aldehydes	3-methyl-butanal, Hexanal, Heptanal, Octanal, Nonanal, Decanal	3-methyl-butanal, Hexanal, Nonanal
Ketones	2-butanone, 3-hydroxy-2-butanaone, 2,3-butanedione, 2-heptanone	Acetone, 2-butanone, 3-hydroxy-2-butanone, 2,3-butanedione
Carboxilic Acids		Acetic Acid, Butanoic Acid
Aromatic	Benzene, Toluene, Ethylbenzene, Phenol, Trimethylbenzene, Benzaldehyde, Acetophenone, o-xylene, p-xylene, Styrene	Benzene, Toluene, Ethylbenzene, Phenol, Benzaldehyde, Acetophenone, o-xylene, p-xylene, Styrene
Terpines	α-pinene, β-pinene, 3-carene, Eucolyptol, Limonene	
Sulphur	Dimethyl disulfide, Dimethyl trisulfide	Ethanethiol, Dimethyl Sulfide, Dimethyl disulfide, Dimethyl trisulfide

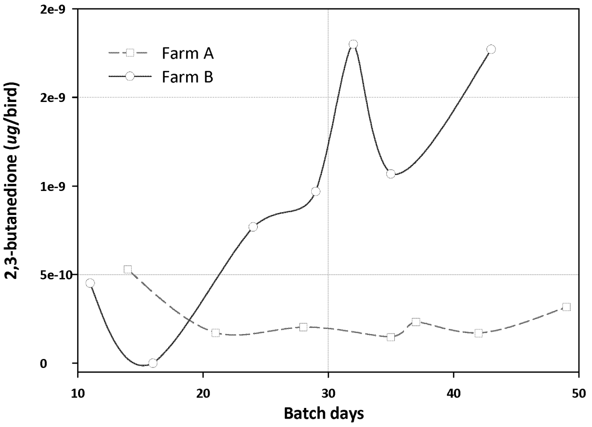

Figure 3. 2,3-butanedione from broiler farms sampling, expressed as μg/bird

3.3 Quantification of NMVOCs

Within the vast majority of NMVOC samples collected and analysed using GC-MS/O, 2,3-butanedione was consistently identified as a dominant odorant within the suite of NMVOCs present. Figure 3 illustrates the variation of the 2,3-butanedione with the growth cycle of the birds at broiler Farm A and B. Quantification of the NMVOCs in the emissions revealed significant variation during the growth cycle and also between different farms. With particular emphasis on the key odorant, i.e. 2,3-butanedione, it was observed that the concentrations of this compound varied between 2 x 10^{-5} ng per bird and 1 x 10^{-4} ng per bird during the period when the birds were 31–35 day old.

The reasonably strong correlation between the observed OERs determined by dynamic olfactometry, and the abundance of 2,3-butanedione detected within the GC-MS/O analysis indicate that it should be given a high priority within the suite of chemical compounds that are being investigated. However, it is necessary to understand that there may be further chemical interactions occurring in the environment, albeit synergistic or antagonistic, resulting in an altered global odour characteristic observed by a receptor.

4. Conclusions

This study demonstrated that:

1. When combined with continuous measurement of ventilation rate, the AOS proved to be a valuable tool for continuously measuring OERs.
2. Using the AOS, different relationships between odour concentration, OER and ventilation rate were observed at two different farms. These differences would not have been identified without the continuous monitoring capability provided by the AOS.
3. The abundance and type of chemicals changed throughout the poultry production cycle.
4. As the birds matured, the odorant profile becomes dominated by aldehydes and ketones including; 2-butanone, 3-hydroxy-2-butanone, 2,3-butanedione, 3-methyl-butanal, hexanal, octanal, aromtic compounds including toluene, benzene, acetophenone and styrene.
5. The sulfides were important from an odorant perspective. Sulfides identified as odorants within the broiler shed emissions included dimethyl sulfide, dimethyl disulfide and dimethyl trisulfide.

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References

Guo H., Jacobson L.D., Schmidt D.R. and Nicolai R.E., 2003, Evaluation of the influence of atmospheric conditions on odor dispersion from animal production sites. *Transactions of the ASAE*, 46, 461-446.

Parcsi, G. and Stuetz R. M. 2007. Improving Odour Management and Abatement Performance using Olfactory-GC-MS, Proceeding Congress on Biotechniques for Air Pollution Control, La Coruna, Spain, 11pp.

Sohn J.H., Hudson N., Gallagher E., Dunlop M., Zeller L. and Atzeni M., 2008, Implementation of an electronic nose for continuous odour monitoring in a poultry shed, *Sensors and Actuators B*: Chemical, 133(1), 60-69.

Sohn J. H., Smith R., Yoong E., Leis J. and Galvin G., 2003, Quantification of odours from piggery effluent ponds using an electronic nose and an artificial neural network, *Biosystems Engineering*, 86, 399-410.

Dunlop M., Gallagher E., Sohn J.H., Hudson N., Galvin G., Parcsi G., Wang X., Stuetz R.M., Meyer N., Modini R., Ristovski Z., McCauley I. and Matthews B., 2009, Dust and odour emissions from poultry sheds - a draft final report submitted to the Australian Poultry CRC, July 2009. DEEDI, Queensland.