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Odour Abatement of Poultry Litter using Odour Control Products

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Poultry litter is often highlighted to be a major source of odours associated with emissions from poultry production sheds and the post-treatment of used poultry shed litter. The addition of adsorbent to bedding material is often reported as a litter odour management strategy. Three commercial materials (activated carbon, silica gel and zeolite) that are often used as odour control products were tested in odorous litter under controlled environmental conditions. The effectiveness of the adsorbents was determined by chemical and olfactory analysis. In general, the addition of adsorbents did decrease the volatility of volatile organic compounds (VOCs) from the bedding material at dissimilar rates across the abatement trials. However, reduction in hedonic tone was not noticeable, mainly due to the emission of ammonia from the trial bedding material. The results showed that no single odour control product is capable of reducing or removing all the volatiles present in the odour emissions from poultry shed litter.

1. Introduction

Increases in the number of poultry production sheds and urban encroachment on these facilities have resulted in increasing odour complaints from local residents (Power et al., 2005). In Australia, broiler chickens are generally grown on thick bedding material spread on the floor of tunnel-ventilated sheds over a 7-9 week production cycle. Broiler production sheds are typically 100-150 m long and 12-16 m wide, have high capacity axial fans mounted at one end of the shed that are operated based on the temperature inside the shed. The primary purpose of the ventilation system is to remove the heat and moist air from the shed, but the exhaust air will also contain odours that can impact the local population. Odours are a normal part of poultry production and result from aerobic and anaerobic microbial activities within the litter and from the animals (Mackie et al., 1998; Lacey et al., 2004; Rappert and Muller, 2005). In most cases, the offensive characteristics of odour increases with the accumulation of bird waste in the bedding material over the chicken's growth cycle (Powers et al., 2005) and broiler litter is often highlighted to be a major source of odour associate with emission from broiler production sheds. Operational factors that are reported to influence the emission of odours from poultry production sheds include litter moisture content, pH, temperature, bird activity, litter properties, weather conditions, ventilation rate, air speed, manure quantity and diet (Lacey et al., 2004; Hudson and Ayoko 2009; Hudson et al. 2009).

In additional to the direct emission of odours from poultry production sheds, production sheds also produce large quantities of spent litter for storage and land application at the end of each growth cycle, which currently results from the preference by operators in Australia to use fresh bedding material for each new broiler batch. As litter and odour generations from broiler farms are inevitable, the

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amelioration of litter properties may alleviate offensive odorous emissions while providing opportunity to reuse spent litter as bedding material for new broiler batch. Two odour control approaches that have been previously applied to litter management for emission reduction are: (i) reduction of moisture content within the litter material and (ii) the addition of odour adsorbents to the litter as odour control products.

This paper aims to evaluate the application of adding odour control products to used poultry litter to determine its effectiveness for reducing odorous emissions in terms of olfactory and volatile organic compounds (VOCs) composition. Three commercial materials (activated carbon, silica gel and zeolite) were trialled by adding the additives to used broiler litter material and their effectiveness was assessed by comparing VOC composition determined by direct dynamic headspace sampling followed by thermal desorption and gas chromatograph mass spectrometry/olfactory (TD-GC-MS/O) analysis in order to characterise the odorants before and after abatement trials.

2. Material and methods

2.1 Collection of litter samples for abatement trials

Two different composite wet poultry litter samples were collected (by the Queensland Department of Employment, Economic Development and Innovation) from selected points in a 2 metre radius at two tunnel ventilated poultry sheds in Queensland, Australia during the winter (bedded with pine and eucalyptus shaving) and summer (bedded with hard wood shaving) months. Litter samples were collected at week 7 in winter and at week 6 in summer, and sealed in odour free sample bag before being transported to the UNSW Odour laboratory for abatement studies.

2.2 Experimental conditions

Three different commercial materials activated carbon (Sigma Aldrich, Castle Hill), silica gel orange (Sigma Aldrich, Castle Hill) and zeolite (Sigma, US) that are commonly used as odour control products were tested in odorous litter samples. Ten sets of 500g of litter were prepared in odour free bags and mixed with 5 %, 10 % and 25 % of activated carbon, silica gel and zeolite, respectively. Percentages of odour reducing materials added to the litter were calculated in relative to mass of broiler litter material in each bag. One set of 500 g of litter was treated as a control. Sample bags of litter mixed with odour reducing materials were placed in a ventilated fume hood with a flow rate of 0.5 m^3/s for 3 weeks at ambient temperature (approximately 23 °C). At weekly internals, litter samples (100ml) were taken from each of the abatement studies for direct dynamic headspace sampling followed by TD-GC-MS/O analysis for three consecutive weeks in order to characterising the effective of the odour adsorbent materials in terms of odorant characteristics before and after abatement trials.

2.3 Emission characterisation

Direct dynamic headspace sampling and TD-GC-MS/O analysis of the sampled litter were conducted during the odour abatement trials to characterise the samples in terms of chemical and olfactory character according to Pillai et al. (2010). Only volatiles exhibiting confirmation greater than 80 % using the mass selective detector library are reported herein. Two odour detection port (ODP) panellists assessed each abatement trial sample with panellists being screened using n-butanol according to AS/NZS 4323.3.2001.

3. Results and discussion

Considerable physical changes were observed in the tested broiler litters treated with adsorbents. Additionally, significant growth of fungi was also noticed on the surface of the control litter sub-set. A comparison of adsorbents showed that the application of activated carbon and silica gel to the bedding material produced a drier litter than that with the addition of zeolite. The zeolite application was also observed to generate dust particles during the sampling and analysis. Results obtained from the chemical analysis of the abatement litter samples, generally suggested a reduction in the concentration of VOCs in all the treated litter sets in comparison to the control samples. Some treated litters were observed to release higher yields of VOCs than the control set in the initial stages of the trials (i.e. week 1). These observations could be attributed to the heterogenic characteristic of litters and the random selection of samples from sample bags. Activated carbon and silica gel were found to perform more efficiently in adsorbing volatiles from the litters than zeolite. The adsorption of trimethylamine (TMA) was observed with litter treated with activated carbon and silica gel (Figure 1). No TMA was identified in week 2 for litters with 25 % activated carbon and with 10 % and 25 % silica gel, whereas the application of 5 % and 25 % zeolite showed an increase in the volatilisation of TMA compared to the control litter before decreasing in week 2 and being completely removed for 10 % and 25 % zeolite at week 3.

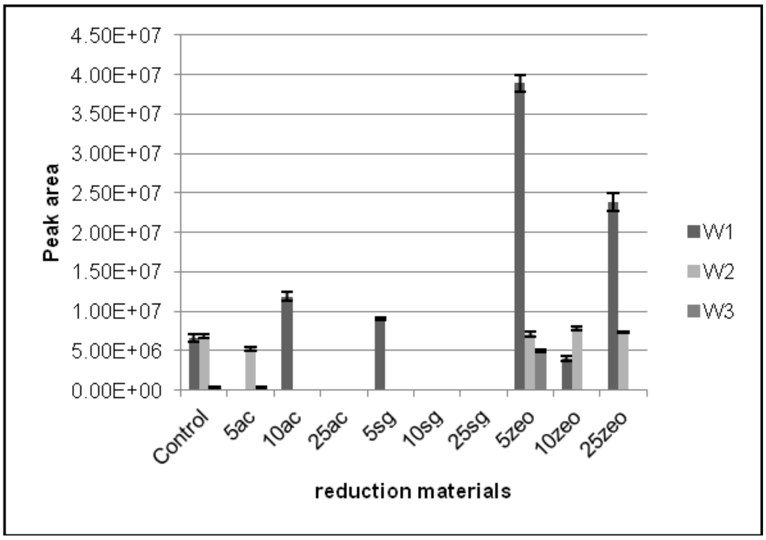
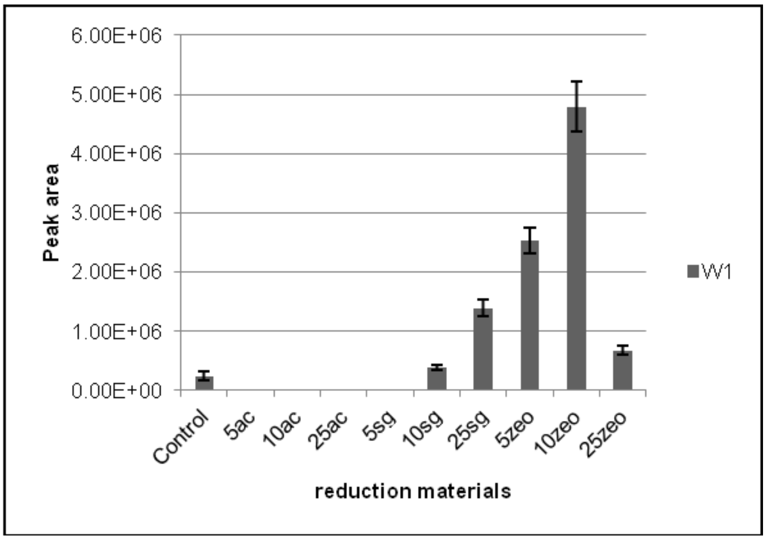


Figure 1:Volatilisation of trimethylamine (TMA) for winter litters with the addition of 5, 10 and 25 % activated carbon (AC), silica gel (SG) and zeolite (Zeo) at weeks 1, 2 and 3 (W1, W2, W3).

The adsorption efficacies with the adsorbents were noticed instantly for sulfur containing compounds (Figure 2), ketones and volatiles fatty acids. Complete adsorption of ketones for winter litters treated with activated carbon and silica gel were observed from week 1 to week 2 compared to week 3 for zeolite. In contrast, summer litters amended with silica gel were found to emit acetone in week 2. Volatile fatty acids were reduced in week 2 with none being detected in week 3 using all adsorbents. However, excessive volatilisations of acetic acid and butanoic acid were noticed from the winter litters with 25 % silica gel and zeolite in week 1, which is most likely a result of low moisture content in the litter material that assisted diffusion of volatile fatty acids into the headspace. Water-soluble volatiles within the wet matrix are likely to be present in lower quantity in the air that subsequently reduces volatilisation. Similar conditions were observed for dimethyl disulfide for the summer litters treated with 10 % and 25 % silica gel and zeolite, respectively. Complete removal of dimethyl trisulfide was obtained for all adsorbents within week 1. Irregular interactions between the adsorbents and toluene for different litters were observed (Figure 3). Complete eliminations of toluene were obtained for 5 % and 10 % of activated carbon and zeolite for the winter litter and 10 % and 25 % of activated carbon and 10 % of zeolite for the summer litter. Analysis of variance revealed significant reduction of TMA, acetone, 2-butanone, 2,3-butanedione, acetic acid, butanoic acid, dimethyl disulfide and dimethyl trisulfide over the adsorption trial period ($P<0.05$) for the adsorbents studied, except for toluene. Variation analyses revealed similar adsorbents with different ratio of application on the litter contributed to insignificant reduction of volatiles ($P>0.05$). Instead, noticeable decreases in volatilisation were obtained for the application of 5 % and 10 % activated carbon, silica gel and zeolite but not for 25 % for each of the adsorbents.



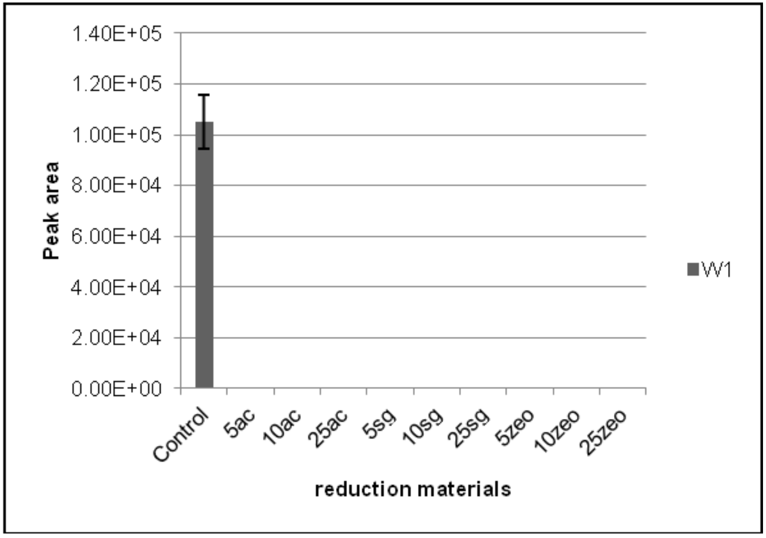


Figure 2: Variation in volatilisation of dimethyl disulfide (top) and dimethyl trisulfide (below) in summer litter with the addition of 5, 10 and 25 % activated carbon (AC), silica gel (SG) and zeolite (Zeo) after one week (W1).

The ODP analysis of the litter samples during direct TD-GC-MS/O analysis suggested significant difference in the intensity of VOCs perceived between the adsorbents. Odours were only observed from the litters in the 1st week of the abatement trials for the winter litters, no odour was detected from the summer treated litters. Reductions in the number of odorant responses and their intensities were observed with increases in the ratio of activated carbon used in the abatement trial. Perceived intensities of volatiles from the litters treated with silica gel were relatively greater than for activated carbon but lower than zeolite. The litter with silica gel exhibited similar trend to activated carbon, i.e. decreases in odour response and intensity with increases in the ratio of silica gel applied to the litter. In contrast, decrease in odour response with insignificant decreases in odour intensity were observed with greater application of zeolite to the litter. Even though substantial reduction in VOC intensities were obtained using the different adsorbents, the overall reduction in odour hedonic tone was not achieved due to the pungency characteristic in odour caused by the release of ammonia from the used litter.

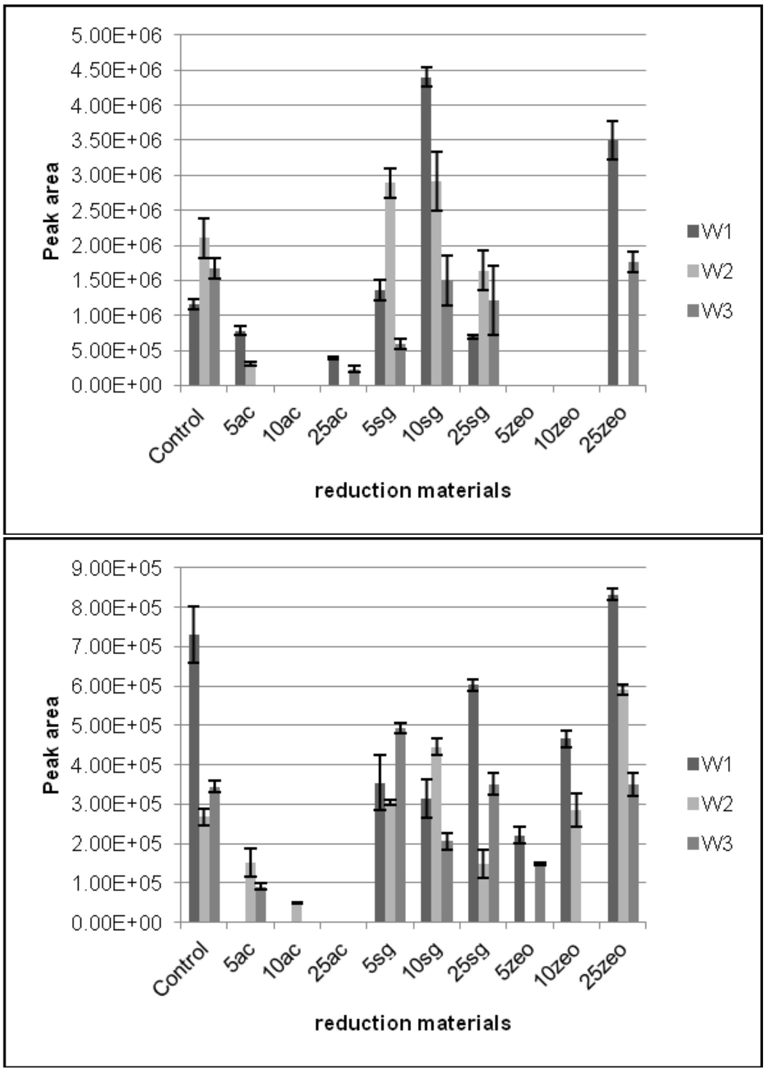


Figure 3:Volatilisation of toluene for winter (top) and summer (below) litters with the addition of 5, 10 and 25 % activated carbon (AC), silica gel (SG) and zeolite (Zeo) at weeks 1, 2 and 3 (W1, W2, W3).

4. Conclusions

The odour control abatement studies demonstrated that in general the addition of adsorbent materials (activated carbon, silica gel and zeolite) to used broiler litter did decrease the volatilisation of VOCs from the bedding materials at diverse rates across the abatement trial. Based on the chemical and sensory responses obtained, activated carbon and silica gel exhibited prominent adsorptions or reductions in litter volatiles. The results revealed noticeable efficacy for activated carbon and silica gel with interactions on excessively wet litter found in the winter month sampling conditions. The performance of zeolite was found to be comparative, but less effective. However, reduction in hedonic tone was not noticeable mainly due to the emission of ammonia from the trial bedding materials. The results show that no single odour control product is capable of reducing or removing all the volatiles present in the odour emissions from broiler shed litter.

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