Science of the Total Environment 470–471 (2014) 865–875

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

Ammonia and odour emissions from UK pig farms and nitrogen leaching from outdoor pig production. A review

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HIGHLIGHTS

- Reducing the protein content of feeds reduces NH_3 emissions at all stages of manure management.
- Odour emissions also decrease as the protein content of feeds is reduced to c. 160 g kg^{-1}.
- Breeding grain with reduced protein content offers an approach to further reduce protein in diets.
- Cover slurry stores and injecting slurry into soil can reduce emissions of both NH_3 and odour.
- Mobile systems have the potential to reduce nitrogen leaching from outdoor pig production.

ARTICLE INFO

Article history:
Received 11 April 2013
Received in revised form 27 September 2013
Accepted 27 September 2013
Available online 6 November 2013

Editor: Pavlos Kassomenos

Keywords:
Pigs
Ammonia
Odour
Leaching
Abatement
Diet

ABSTRACT

We reviewed specific literature for emissions of ammonia (NH_3) and odours from all stages of pig production together with nitrogen (N) leaching from raising pigs outdoors. Emissions of NH_3 decrease with decreases in the crude protein (CP) content of pig diets, at all stages of manure management. The CPs of pig diets have been greatly reduced by matching the CP content to the protein required at each stage of the animals' growth and by using synthetic essential amino acids to minimise total CP intake. The CP contents of the dietary ingredients needed to provide energy for the animals impose further limits to reductions in dietary CP. Housing systems have been designed and evaluated which offer potential for reducing NH_3 emissions. However such designs may not be applicable at all stages of the pigs' development and the careful management needed to ensure their effective working may be costly and difficult to implement on commercial farms. The factors behind odour emissions are less well characterised. Reducing diet CP to 160 g CP kg^{-1} has been shown to reduce odour emissions but further CP reductions may increase them. Some reductions in odour emissions from buildings can be achieved by careful management of the ventilation rate but the most effective measures to reduce emissions of NH_3 and odours are to cover slurry stores and to inject slurry into soil. Changes in the feeding and management of outdoor pigs mean that N leaching losses may be up to 50% less than previously reported. No studies have been undertaken that compare the N leached from pigs raised outdoors, versus that arising from the application of pig manure from an equal number of housed pigs. As a precursor to any field study, current models could be used to provide a first estimate of any systematic differences.

Contents

Abbreviations: ADG, average daily weight gain; CP, crude protein; DM, dry matter; DON, dissolved organic N; EAAs, essential amino acids; FCR, feed conversion ratio; TAN, total ammoniacal nitrogen; SCFA, short-chain fatty acid; SEAAs, synthetic essential amino acids.

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http://dx.doi.org/10.1016/j.scitotenv.2013.09.091

1. Introduction

1.1. Ammonia

Ammonia (NH_3) contributes directly to acidification and eutrophication of sensitive ecosystems (Butterbach-Bahl et al., 2011; Dise et al., 2011) and, through secondary conversions to particles, to climate change (Renard et al. 2004). Particulate NH_3 can also have direct impacts on human health (Brunekreef and Holgate, 2002). The UNECE Convention on Long Range Transboundary Air Pollution's Gothenburg Protocol, designed to abate acidification, eutrophication, and ozone formation, aims to reduce NH_3 emissions across Europe by 17% by 2010 compared with 1990. The Protocol requires the agricultural sector to take specific measures to control NH_3 emissions. The UK has similar obligations under the EC National Emissions Ceilings Directive (2001/81/EC, NECD). The Gothenburg Protocol is now under review, and a reduced ceiling may pose challenges for the UK to meet future emission limits, unless the agricultural sector is able to implement and demonstrate further measures to reduce NH_3 emissions. Large-scale intensive pig and poultry farms are regulated by the UK Environment Agency under the Environmental Permitting regulations. In some cases, reductions in NH_3 emissions are required to enhance the protection of nearby designated habitat sites, with particular attention paid to sensitive sites such as bogs and heathland. Controls on impacts on habitat sites originating from the Habitats Directive (92/43/EEC) for Special Areas of Conservation (SACs) and the Countryside and Rights of Way Act 2000 (CROW) for sites of special scientific interest (SSSIs) may have an increasingly significant impact on emissions of NH_3, acting in synergy with the potential future requirements of the Gothenburg protocol.

1.1.1. Uncertainty in estimates of ammonia emissions

Agricultural sources of NH_3 in the UK are quantified for the UK Ammonia Emissions Inventory (AEI) by the NARSES model (Webb and Misselbrook, 2004). This model uses a mass-flow approach to estimate emissions of NH_3, calculated at each stage of manure management, from buildings to land application, as a proportion of the total ammoniacal-N (TAN) in the excreta or manure. The uncertainties around total UK NH_3 emissions have been estimated as $\pm 21\%$ (Webb and Misselbrook, 2004). Whilst the results are a satisfactory estimate of overall national emissions, the application of the emission factors used in NARSES to individual pig farms may be misleading as many farms will be very different to the average representation in the model. In many cases the studies carried out to measure NH_3 emissions made no record of the diets the pigs were fed, N excretion by the animals; prevailing temperatures within buildings, during storage or following manure applications; the type of ventilation within buildings; how the pigs were managed etc.; all factors which will vary amongst farms. There was a need therefore to critically re-evaluate the studies on which current UK emission estimates are based to determine whether emissions can be more accurately related to specific measurable and potentially controllable factors, such as floor type, ventilation system, pig growth rate, food conversion rates, and temperature. As well as taking into account differences in livestock and manure management, the efficiency of individual pig herds should also be considered, if possible, in order to more accurately estimate emissions from individual pig farms.

In addition concern has been expressed in recent years that historical measurements of NH_3 emissions following the application of manures to land have been over-estimated (e.g. Sintermann et al., 2011). The basis of these concerns is under discussion and, at present, is unconfirmed. One concern is that measurements obtained using wind tunnels tend to over-estimate absolute emissions of NH_3, although they are considered satisfactory for use in comparative studies, e.g. of abatement techniques (Loubet et al., 1999a,b). This was addressed in the NARSES model by limiting the default NH_3 emissions following the application of manures to land to the average of measurements made using micrometeorological mass balance techniques, omitting the results obtained with wind tunnels. This change reduced the estimate of UK NH_3 emissions arising from land spreading by 17.8 kt, a c. 7% reduction on the previous value (Misselbrook et al., 2008).

1.2. Odour issues

The close proximity of livestock farms to the non-farming public, who often have very different views as to what is acceptable, both visually and from the perspective of offsite odour impacts, has long been a challenge to livestock farmers. This difference of opinion has resulted in limits on the available spreading days on fields located close to dwellings to days when weather conditions are suitable or on new crop establishment when rapid incorporation of manures limits the odour. At worst this difference in perceptions has resulted