Pilot- and full-scale evaluation of a peroxide-based additive that reduces gaseous emissions and retains biogas potential from stored pig slurry

D Hughes*, S Nolan*, C.E. Thorn*, M McDonagh**, R Friel*, V O'Flaherty**

GlasPort Bio Ltd., University of Galway, Ireland*; School of Natural Sciences and Ryan Institute, University of Galway, Ireland**

Corresponding author*, email: camilla@glasportbio.com

Abstract: Gaseous emissions from stored livestock slurries are a significant source of greenhouse gases (GHG) and ammonia, accounting for more than 10% of agricultural emissions in the US and EU. Nitrogen and carbon losses via gaseous emissions reduce the slurry value as a fertiliser and as a feedstock for renewable energy generation. A novel, peroxide-based additive was trialled on stored pig slurry in 1m^3 units on-site at a commercial pig farm in Ireland. GHG and ammonia emissions were reduced by up to 75%, and the carbon content of slurry was maintained by the retention of carbon dioxide and methane, gases which are normally lost to the atmosphere. This retention of carbon was exemplified by the 56% increase in biomethane potential from the treated slurry. Indeed, additive-treated slurry made a richer feedstock when anaerobically mono-digested, increasing biogas yield by 100% during pilot-scale anaerobic digestion with similar increases in preliminary full-scale AD trials.

Keywords: AD, Agriculture, Manure

Introduction

The EU is home to 134 million pigs, representing the largest EU livestock category (Statista, 2023). Pig meat constitutes 34% of the global meat trade, with demand increasing (OECD – FAO, 2021). Despite being non-ruminants, pigs account for 18% of the total global GHG emissions from the livestock industry while emitting significant amounts of ammonia (NH_3) (Dennehy et al., 2017), predominately through their excreta. These gases are detrimental to animal welfare, while also contributing to global warming and reduced air quality. Additionally, gaseous losses from manures lower the nitrogen and carbon content therein, so reducing both the N-fertiliser replacement value and the biogas potential, respectively. The agricultural sector is thus under increasing pressure to manage livestock more effectively in order to increase outputs while reducing emissions (Loyon, 2018). Treatment technologies in the form of slurry additives represent an under-utilised means of mitigating gaseous losses from stored manure (Petersen et al., 2013). To this end, a novel peroxide-based slurry additive, with previously demonstrable efficacy at laboratory-scale using dairy cattle slurry (Thorn et al., 2022), was assessed for its suitability in reducing emissions from pilot-scale experimental units of stored pig slurry. The effect of the additive on biomethane potential and biogas output following anaerobic digestion of treated versus untreated slurry was investigated using a combined approach of BMP assays, 100L pilot-scale CSTR digesters and full-scale AD.

Material and Methods

Pilot-scale trials were performed in 1m^3 intermediate bulk containers (IBCs) fitted with heated jackets, to mimic the temperature of beneath-housing slurry storage (22°C), and filled with 750L of fresh weaner slurry. The peroxide additive was applied at the start of the experiment (0.87g kg^{-1}) via injection into the slurry. Continuous air flow over the surface was applied at a rate of 2.12m^3/hr. Gaseous emissions were continuously measured for methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O) and NH_3 from the IBC outlets using a photoacoustic multi-gas analyser (Gasera, Finland). An untreated control was also assessed. At the end of the 30-day trial, samples from treated and control units underwent biomethane potential (BMP) assays, and were used as feedstocks in pilot-scale anaerobic digesters of 100L capacity. Feasibility of peroxide addition at full scale was tested in pig houses treated with additive (0.87g kg^{-1}) weekly for 30 days. Treated slurry was taken for full-scale AD assessment in an onsite mono-substrate AD unit. The 270m^3 digester (8.32m d x 5m h) was operated at 35°C and a 10-day solids retention time (SRT).

Results and Conclusions

Emissions of CH_4 and CO_2 from the untreated IBC increased steadily over the initial 14 days before decreasing over the final 21 days of the trial as readily-digestible material was consumed by normal microbial activity. The rate of CH_4 and CO_2 emissions from the treated IBC slurry were considerably lower throughout the period, with an overall reduction of 75% in CH_4 emissions and 50% in CO_2 emissions. Throughout the trial, N_2O emissions were approximately 50% lower in the treated tank receiving the additive. Ammonia emissions were slightly elevated in the initial 4 days post-treatment application, and then fell below that of the untreated control for the remainder of the experiment with an overall 40% decrease in ammonia emissions achieved in the treated samples. The additive caused a transient inhibitory effect with this dosage rate, resulting in recommencement of methanogenesis at Day 25 **(Figure 1.1)**. This provides an indication as to subsequent additive treatment time-points if slurry is to be stored for longer than 25 days.

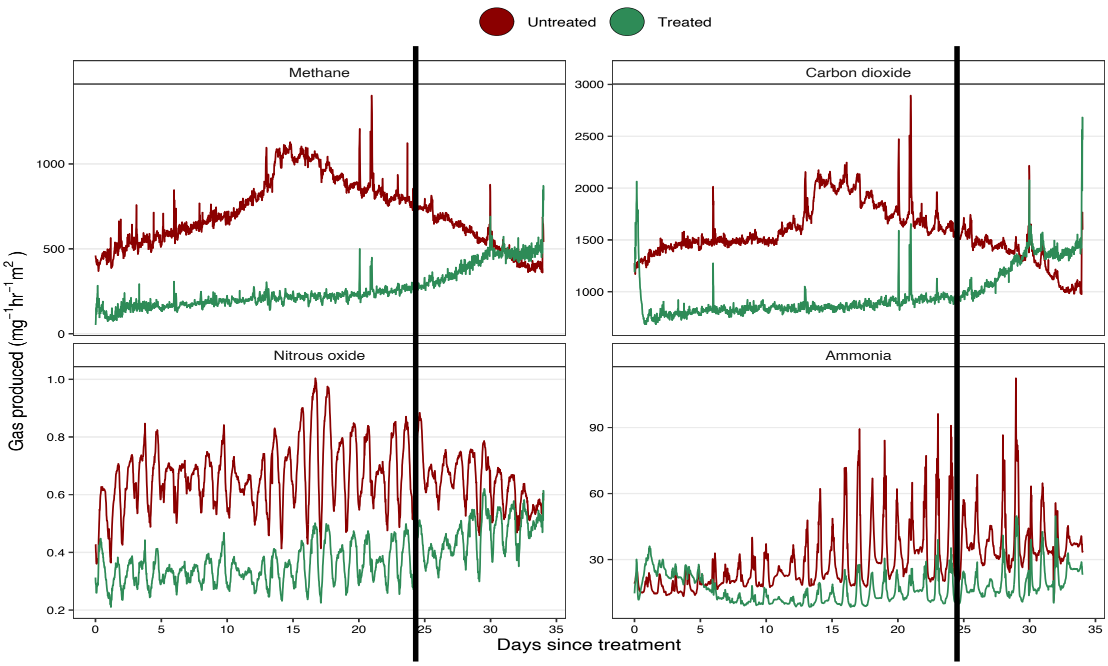

Figure 1.1: Emissions of methane and carbon dioxide from dynamic tanks over 35 days

The carbon content of the slurry was maintained by the retention of CH_4 and CO_2, which are usually emitted to the atmosphere. This was demonstrated by a **56% increase** in BMP from treated versus untreated slurry stored for 30 days (**Figure 1.2; Nolan et al., 2023**).

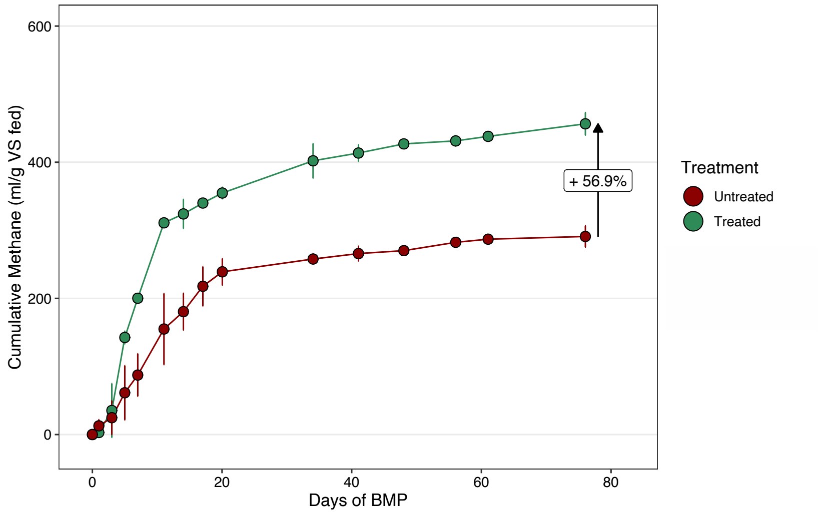

Figure 1.2: Biomethane potential in treated versus untreated slurry samples

Pilot-scale anaerobic digesters were operated using additive-treated or untreated pig manure as feedstock to determine the effect of treatment on biogas yield. Cumulative biogas after 30 days of digestion from untreated slurry was 7.7L, while 15.4L was produced when digesting treated slurry, representing a 100% increase in biogas yield (**Figure 1.3**).

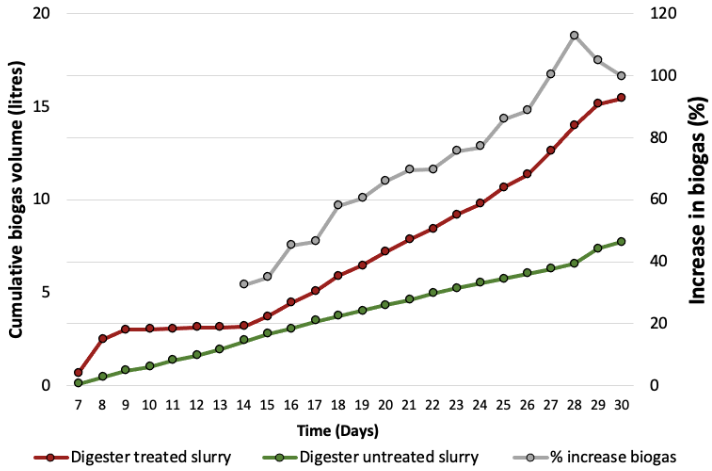

Figure 1.3: Biogas flow from treated versus untreated slurry – pilot scale

Full-scale application of the slurry additive was successfully achieved and retained CH_4 and CO_2 was demonstrated in downstream full-scale AD. Average daily biogas output using untreated slurry after long-term storage was 30 m^3/day and addition of treated slurry increased output to an average 222 m^3/day biogas output (**Figure 1.4**). The extent of the increase may be exacerbated by long term storage of untreated slurry prior to the introduction of treated slurry, and requires repeated trials. From previous batches at this full-scale site, using fresher untreated slurry the highest biogas output achieved was 110m^3/day. Using this data, we can infer that similar increases in biogas yield to those achieved at lab- and pilot-scale can be expected when utilising treated slurry in farm-based AD. This significant increase in biogas output demonstrates the effectiveness of the additive in conserving biogas potential in the slurry. The continuous loss of carbon from untreated slurry through gaseous emissions represents a loss of bioenergy potential. The application of the low-cost additive solution to conserve this potential appears to be a practical solution for the pig rearing sector.

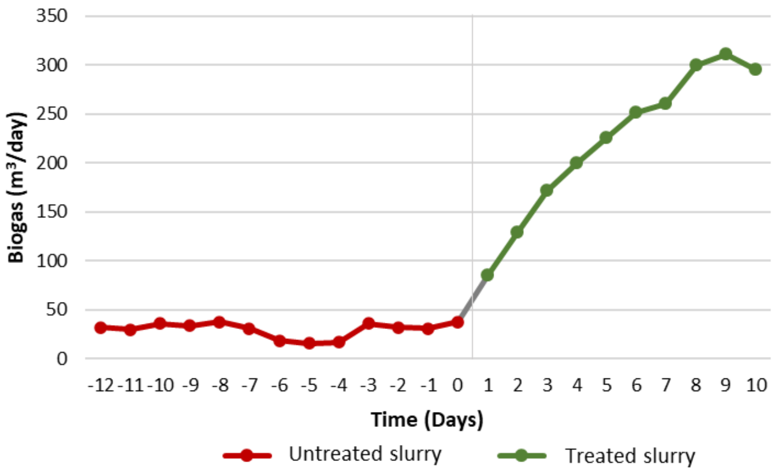

Figure 1.4: Full-scale AD biogas yield: pre-assessment untreated slurry and following introduction of treated slurry.

A single dose of a novel slurry additive was highly effective in reducing GHG and NH_3 emissions from stored swine slurry over a 30-day storage trial. The lower CH_4 and CO_2 emissions resulted in retention of biogas potential as demonstrated by BMP assays and biogas output using AD. This peroxide-based additive was also deployed successfully at full scale, and while emissions data were not available, the AD output of the treated material demonstrated that CH_4 was retained by use of the additive. It therefore represents an innovative means of retaining the resource value of stored animal manure for its efficient onward use, for example as a biogas feedstock.

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