Project number: 6254
Funding source: EU FP7
Date: March 2018
Project dates: July 2013 - June 2017

Biogas from silage-slurry combinations

Key external stakeholders:

Grassland farmers, livestock farmers, landowners, energy providers, energy utilisers, anaerobic digestion equipment and service providers, policy makers

Practical implications for stakeholders:

Managers of anaerobic digestion facilities producing biogas sometimes obtain methane yield potential values for individual feedstocks such as silage and animal slurry.

- Caution is required when using these values since interactions between feedstocks during co-digestion can result in a greater or lesser methane output from mixtures of feedstocks than might be predicted directly from the values for individual feedstocks.
- The management targets for grass silage produced on-farm for anaerobic digestion are similar to the targets when producing silage for efficient livestock production – high yields of biomass from herbage of high digestibility, efficient silage fermentation and minimal aerobic deterioration during feedout.

Main results:

- Co-digestion of silage with slurry produced both greater (synergism) and lower (antagonism) methane outputs than would be predicted from mono-digestion of the individual feedstocks.
- The feedstock component contributed about half of the total cost of methane production when an anaerobic digestion facility was operated solely on grass silage. Even when cattle slurry was provided free of cost, the cost of methane production from mono-digestion of cattle slurry was more than double the cost for grass silage.
- Antagonistic and synergistic methane production resulted in corresponding greater and lower costs of methane production during co-digestion.

Opportunity / Benefit:

- Procedures have been identified by which a relatively simple and low cost manometric biochemical methane potential test can be used to produce similar methane outputs to a more expensive industry standard method.
- Managers of anaerobic digestion facilities sometimes obtain methane yield potentials for individual feedstocks. Caution is required when using these results, however, since interactions between these ingredients when co-digested can result in antagonistic or synergistic effects on methane output.
- There remains a requirement to develop reliable methods for accurately predicting the scale and direction (antagonistic or synergistic) of non-linear methane output that would occur when different feedstocks are co-digested.

Collaborating Institutions:

UCC/Environmental Research Institute

Contact Edward O'Riordan Email: edward.oriordan@teagasc.ie.

Teagasc project team: Himanshu Himanshu
Padraig O'Kiely (Project Leader)
Jim Grant
JJ Lenehan
Edward O'Riordan

External collaborators: Prof. Jerry Murphy, Environmental Research Institute, University College Cork
Markus Voelklein, Environmental Research Institute, University College Cork

1. Project background:

The environmental implications of burning fossil fuels necessitate the development of alternative sources of renewable, environmentally benign energy provision. Biogas production by anaerobic digestion is one component of a suite of responses to this challenge. The digestion process converts feedstocks such as municipal/industrial organic waste and agricultural crops/waste products to biogas and residual digestate. The biogas is typically 50-70% methane, and is a valuable renewable energy source. It can be used directly to produce heat or heat + electricity, or the methane can be purified and used as a vehicle fuel or injected into the natural gas grid.

Grass is overwhelmingly the most economic feed for ruminants in Ireland and our grassland is capable of meeting a substantially greater demand than at present. Farmers and contractors would provide the grass to meet the demand of anaerobic digestion once there was an economic incentive to do so. This grass would be conserved as silage, and could be digested alone or co-digested with slurry collected from housed livestock. Evidence from other fermentation processes suggests that the methane output from co-digesting grass silage and animal slurry could differ from the output predicted from mono-digestion of silage and slurry alone.

2. Questions addressed by the project:

- When undertaking an *in vitro* simulation of anaerobic digestion using a manometric biochemical methane potential test is there a combination of headspace volume and frequency of pressure release that produces comparable outputs of methane to an industry standard automated volumetric method?
- How do silage type and slurry type impact on the methane yields achieved?
- Will co-digestion of silage and slurry produce *pro-rata* methane yields with those produced by mono-digestion?
- Which ratios of these feedstocks are optimal for co-digestion?
- How is the cost of producing methane affected by grass silage characteristics, by silage provision cost, by cattle slurry provision cost, by the ratios of silage and slurry co-digested, and by the operational efficiency of the anaerobic digestion facility?

3. The experimental studies:

- *In vitro* manual manometric batch digestion and automated volumetric batch digestion equipment were used to compare contrasting biomethane potential test methodologies, and to quantify methane yields for the various feedstocks and their mixtures.
- Replicated field plots and laboratory silos provided grass and red clover silages.
- Animal slurry was obtained from tanks beneath slatted-floor buildings that accommodated livestock.
- Inoculum was obtained from an on-farm facility digesting grass silage and cattle slurry.
- The Grange Feed Cost Model was adapted to allow quantification of the impacts of characteristics of grass silage and cattle slurry on the cost of methane production.

4. Main results:

- Headspace volume and pressure release frequency affected headspace pressure in an *in vitro* anaerobic digestion test. Headspace pressure had a negative effect on biogas yield, a positive effect on methane concentration in biogas and thus little effect on methane yield.
- Two out of 12 combinations of headspace volume and pressure release frequency assessed in a manometric biochemical methane potential test replicated the methane output values obtained by an industry standard method (Automatic Methane Potential Test System).
- Perennial ryegrass silages produced more methane than red clover silages, and harvesting either herbage at an earlier rather than a more advanced growth stage resulted in a greater methane output.
- Grass silages produced markedly greater methane outputs than cattle slurries, with pig slurry being

Contact Edward O'Riordan Email: edward.oriordan@teagasc.ie.

intermediate.
- Co-digestion of silage with slurry produced both greater (synergistic) and lower (antagonistic) methane outputs than would be predicted from mono-digestion of the individual feedstocks.
- Optimal ratios when co-digesting silage and slurry for methane production differed with the herbage species and its growth stage at harvest.
- The feedstock component contributed about half of the total cost of methane production when an anaerobic digestion facility was operated solely on grass silage. Even when cattle slurry was provided free of cost, the cost of methane production from mono-digestion of cattle slurry was more than double the cost for grass silage.
- The total cost of methane production progressively increased as the proportion of slurry in the co-digested feedstocks mixture increased.
- Antagonistic and synergistic methane production resulted in corresponding greater and lower costs of methane production during co-digestion.
- The operational efficiency of an anaerobic digestion facility, if it alters the specific methane yield of grass silage, cattle slurry or their combination, can have an important impact on the cost of methane production.
- Management targets for grass silage produced on-farm for anaerobic digestion are similar to the targets when producing silage for efficient livestock production – high yields of high digestibility, efficient silage fermentation and minimal aerobic deterioration during feedout.

5. Opportunity/Benefit:

- Procedures have been identified by which a relatively simple and low cost manometric biochemical methane potential test can be used to produce similar methane outputs to a more expensive industry standard method.
- Managers of anaerobic digestion facilities sometimes send feedstock samples to analytical laboratories in order to obtain methane yield potentials for individual feedstocks. Caution is required when using these results, however, since interactions between these ingredients when co-digested can result in antagonistic or synergistic effects on methane output.
- There remains a requirement to develop reliable methods for accurately predicting the scale and direction (antagonistic or synergistic) of non-linear methane output that would occur when different feedstocks are co-digested.

6. Dissemination:

Main publications:

Himanshu, H., Murphy, J.D., Grant, J. and O'Kiely, P. (2018) 'Antagonistic effects on biogas and methane output when co-digesting cattle and pig slurries with grass silage in *in vitro* batch anaerobic digestion' *Biomass and Bioenergy* 109: 190-198 [https://doi.org/10.1016/j.biombioe.2017.12.027].

Himanshu, H., Murphy, J.D., Grant, J. and O'Kiely, P. (2018) 'Synergies from co-digesting grass or clover silages with cattle slurry in *in vitro* batch anaerobic digestion' *Renewable Energy* (in press).

Himanshu, H., Voelklein, M.A., Murphy, J.D., Grant, J. and O'Kiely, P. (2017) 'Factors controlling headspace pressure in a manual manometric BMP method can be used to produce a methane output comparable to AMPTS' *Bioresource Technology* 238: 633-642 [https://doi.org/10.1016/j.biortech.2017.04.088].

Popular publications:

Himanshu, H., Murphy, J.D. and O'Kiely, P. (2015) 'Biomethane production from co-digestion of forage silage and cattle slurry' *Proceedings of the 14th World Congress on Anaerobic Digestion* held at Vina del Mar, Chile from 15th November, Abstract No. 97 (IWA no. 3069439).

Himanshu, H., Murphy, J.D. and O'Kiely, P. (2016) 'Synergies from co-digestion of grass silage with other feedstocks' *Proceedings of ATBEST (Advanced Technologies for Biogas Efficiency, Sustainability and Transport) International Conference* held at Linkoping, Sweden from 7th September, p14.

Himanshu, H., Voelklein, M., Murphy, J.D. and O'Kiely, P. (2016) 'Impact of headspace volume and overhead pressure measurement frequency on specific methane yields during anaerobic digestion using micro-BMP method' *Proceedings of Biogas Science 2016* held at Szegeb, Hungary from 21th August, p34.

7. Compiled by: Edward O'Riordan

Contact Edward O'Riordan Email: edward.oriordan@teagasc.ie.