Opportunities for Optimisation and Valorisation in Real-time Production & Monitoring of Anaerobic Digestion

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I. Background & Motivation

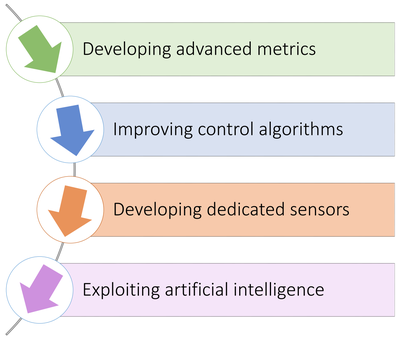
Anaerobic digestion (AD) is a nature inspired technology converting organic waste to biogas and nutrient-rich digestate. However, uptake of industrial-scale AD in the developing world, and high precision in process and outputs control have been limited by monitoring equipment and limited research on locally available feedstock.

Existing AD plants offer limited diagnosis of the biochemical balance of digesters, such as stress, build-up of inhibitors, loading capacity etc. As a result, most AD plants are not dynamically operated. No real-time metrics have been developed for use by industry to proactively optimise performance through feedstock selection and delivery, nutrient dosing, changes in organic loading rate, temperature, or new outputs, etc.

II. Aims & Objectives

This project, in collaboration with Anaero Technology, aims to develop advanced metrics enabling real time monitoring and control of anaerobic digestion.

The objectives of this project are:



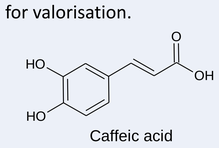
III. Key Research Areas

Microbial Community & Feedstock

Investigating microbial community response exposing to operational condition changes, including OLR, feeding mode and different substrate (FW or FW and FOG).

Phenols

Phenols form a group of natural antioxidants that occur in plants examples of which include vanillin, caffeic acid and limonene. At present, research focuses on removal of these compounds due to their inhibitory nature however monitoring their formation and consumption could provide additional understanding of AD and unlock opportunities for valorisation.



Removal of Heavy Metals

Nanoparticles with active metals like titanium (Ti) and iron (Fe) can exchange heavy metals from liquids inside AD.

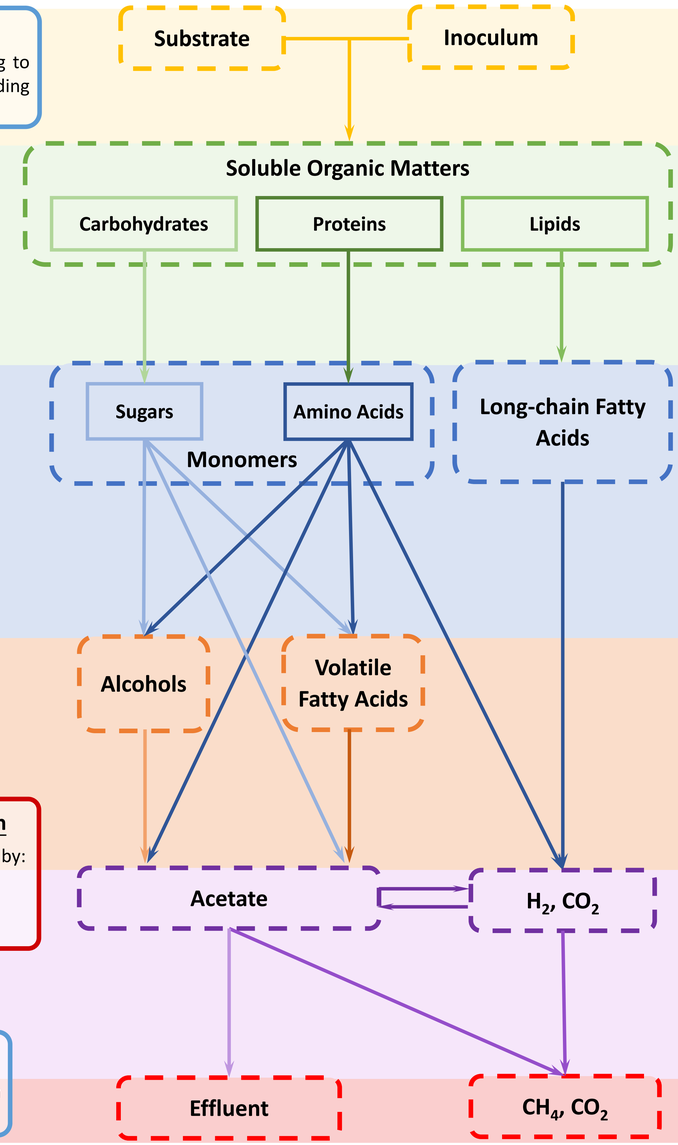
Improvements of Methane Production

The project aims to enhance methane production by:

- ❑ Studying microbe communities behaviour
- ❑ Effects from VFAs concentration
- ❑ Impacts from nano-additives.

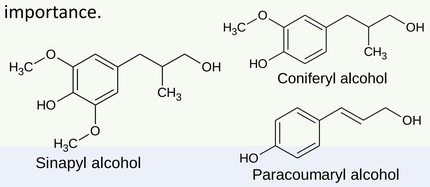
Process Modelling

Construct to model for process status estimation and optimisation.



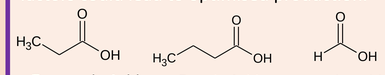
Lignin

Lignin is a monomer formed of phenylpropane based compounds consisting of aromatic alcohols e.g. coniferyl, sinapyl, and coumaryl alcohol. Handling lignin during anaerobic digestion is a challenging task due to its heterogeneity and irregular structure. Understanding how this unmetabolised residue can impact anaerobic digestion is thus of considerable importance.



Volatile Fatty Acids (VFAs)

VFAs which are the products of the first-two stages of AD, have applications across a number of industrial sectors. Studies have demonstrated viability of VFA production using AD and have shown enhanced production under alkaline conditions. Increased understanding of contributing factors could lead to optimised production.

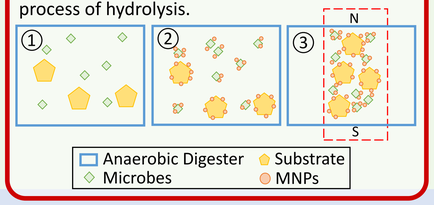


Concentration of Major VFAs

The relationship between concentrations of major individual VFAs present in the process and process status, including biogas production rate, biogas composition, microbial activities will be investigated.

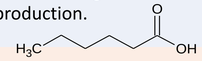
Accelerating Hydrolysis

By using magnetic nanoparticles (MNPs) to gather microbes in inoculum and their foods in substrate together. Hence accelerate the process of hydrolysis.



Carboxylic Acids

A number of studies have identified the production of medium chain carboxylic acids via chain elongation metabolic pathways indicating mesophilic and mild acidic conditions increase yield but further investigation is required to optimise their production.



Methanogenic Community & VFAs

- ❑ Investigating the methanogenic community correspond with specific concentration of VFAs and residual undigested volatile solids in the process of reductions in feed
- ❑ Investigating the potential use of VFAs as a microbial management tool monitoring the anaerobic process to improve the stability of digesters.

Trace Elements & Biogas Production

Investigating the relationship between this type of nano-additives detected in the biogas produced and process status will be carried out.

Solubilisation ↔ Hydrolysis ↔ Acidogenesis ↔ Acetogenesis ↔ Methanogenesis

IV. Methodology

In order to achieve the aims and objectives presented in Section II, a three-part methodology is designed for this project, which is shown on the right. Moreover, The team will utilise nautilus units (Figure 1) for biomethane potential (BMP) tests provided by Anaero Technology. Meanwhile, for batch biomethane potential testing, the team will use Caterpillar 30 x 1-litre autofed digesters (Figure 2), as well as Lobster units (Figure 3), a total of 60 x 5 -litre small-scale auto-fed continuous anaerobic digesters.

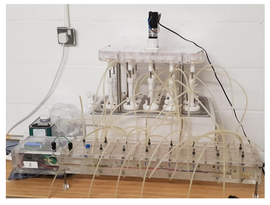


Figure 1 Nautilus BMP Test units.

Figure 2 Caterpillar machine.

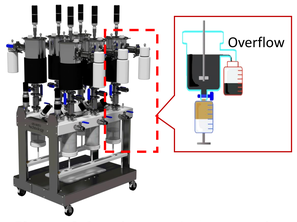


Figure 3 Continuous Lobster units.

Experiment & Data Collection

- ➢ APHA analytical methods will be used for measuring the basic parameters of feedstock.
- ➢ A program of experimental work controlling contributing factors systematically and observing variation in output will take place.
- ➢ Data generated will provide insight on all of the research areas presented in Section III.

- ❑ Concentration of lignin, phenols, carboxylic acids and VFAs
- ❑ Extraction of end-products at each stage.

- ❑ Bacterial Miseqpyro sequencing analysis with qPCR
- ❑ Bacterial toxicity tests.

Concentrations of individual VFAs, H_2, CH_4, CO, H_2S.

- ❑ Nanoparticles dissolution and stage degradation efficiencies
- ❑ Key microbes, enzymes and coenzymes activities
- ❑ Concentration and extraction of heavy metals.

Analysis & Process Modelling

- ➢ The collected data for all of the research areas will be combined in a database allowing advanced data analysis;
- ➢ Process modelling will be utilised to allow process optimisation including kinetic modelling and ADM1 modelling.

Experiment Adjustment

The types and test methods will be adjusted for the experiments, based on analysis and modelling.

Acknowledgment

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