Analysis of anaerobic fermentation process by online spectroscopic UV/Vis, NIR and MIR-measurement

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Figure 1. Metabolon site from the air

Objectives
- Development of an innovative online-measurement system for biogas plants.
- Efficient monitoring of critical process parameters in anaerobic digestion (AD).
- Adaptation of substrate inflow to maintain a stable AD process at all times.
- Optimization of biogas plant operation determining optimal operating point.
- Decrease in biogas plant operating costs.

Tasks
- Use of spectroscopic probes and data analysis to develop a novel online measurement system for biogas plants.
- Development of in situ probe for organic acids (VFA) and carbon (TAC).
- Test of a prototype MIR online-spectroscopic measurement system.
- Data analysis of spectroscopic fingerprints using Computational Intelligence, Pattern Search and Machine Learning.
- Development of a prototype calibration method for key process parameters.
- Field test and comparison of prototype with existing systems.

Methodology
- New MIR-ATR sensor developed in collaboration with industrial partners Spectral Engines (Finland) and art photonics (Germany).
- Excites molecules at fundamental frequency.
- Resonant frequency related to the bonds and mass of atoms.
- Measurement will result in an absorption/transmission spectrum.
- Analysis of this spectrum will reveal details about the molecular structure of the sample.
- Use reference measurements to calibrate the online measurements from the sensor.
- Use machine learning methods to make an online estimation of the VFA concentration from measured spectrum.
- Sensor fouling will need to be considered. Limited path length of ATR probe means that sample dilution may not be required for the MIR probe.

Existing Work
- Wolf (2013) described the process of using UV/VIS Spectroscopic probes to perform the measurement of VFA with an accuracy 88%.
- UV/VIS sensor gap of 1mm would become easily soiled if taking direct measurements.
- Substrate was diluted with 1 part substrate to 80 parts water to get a clear spectrum and mitigate the soiling problem.
- Expectation that increasing spectrum into MIR will increase accuracy compared to NIR measurements, as NIR absorptions are overtones of the fundamental wavelengths and as a result are weaker in intensity (Stuart 2004).

Planned Project Work
- Industrial partners are Spectral Engines & art photonics.
- Partners will supply experimental MIR probe in approximately 2 months.
- Set up system working with NIR probe (2 months).
- Change to MIR probe once received and get system working (3 months).
- Perform reference measurements to record calibration spectrums for input substrates of known compositions (5-6 months).
- Fit ATR (Attenuated total reflectance) probe to small scale biogas plant and perform measurements (Approximately 6 months per test).
- If possible, fit to Avea biogas plant (6 months).
- Experimental testing and verification of optimisation strategies that have been simulated assuming online measurements of VFAs (3 months per test).
- Develop machine learning methods to estimate VFA concentration from recorded spectrum (3 months).
- Analyse control methods and relate to MIR measurements of VFAs to determine whether it is possible to optimise processes further with existing sensors (4 months).
- Final project report (3 months).

References

Figure 2. UV/VIS sensor with 1mm gap, requiring substrate dilution

Figure 3. Avea fermentation and composting plant

Figure 4. Biogas test plant digesters

Figure 5. Control system for biogas test plants at:metabolon