New Insights on Process Performance and Stability for Anaerobic Co-Digestion

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Summary of Key Findings

- Substrate characterization and parameter estimation was retrieved from lab analyses and BMP tests. Model calibration based on BMP data is applicable for modelling continuous reactors.
- The methanogenic microbial population in the CSTRs increases when commencing co-digestion of sewage sludge and OFMSW on a WWTP inoculum.
- The feeding strategy of continuous lab-scale digestion experiments has impact on digester performance instantaneously. The simulation results show that intermittent feeding lead to short-term inhibition of the process.

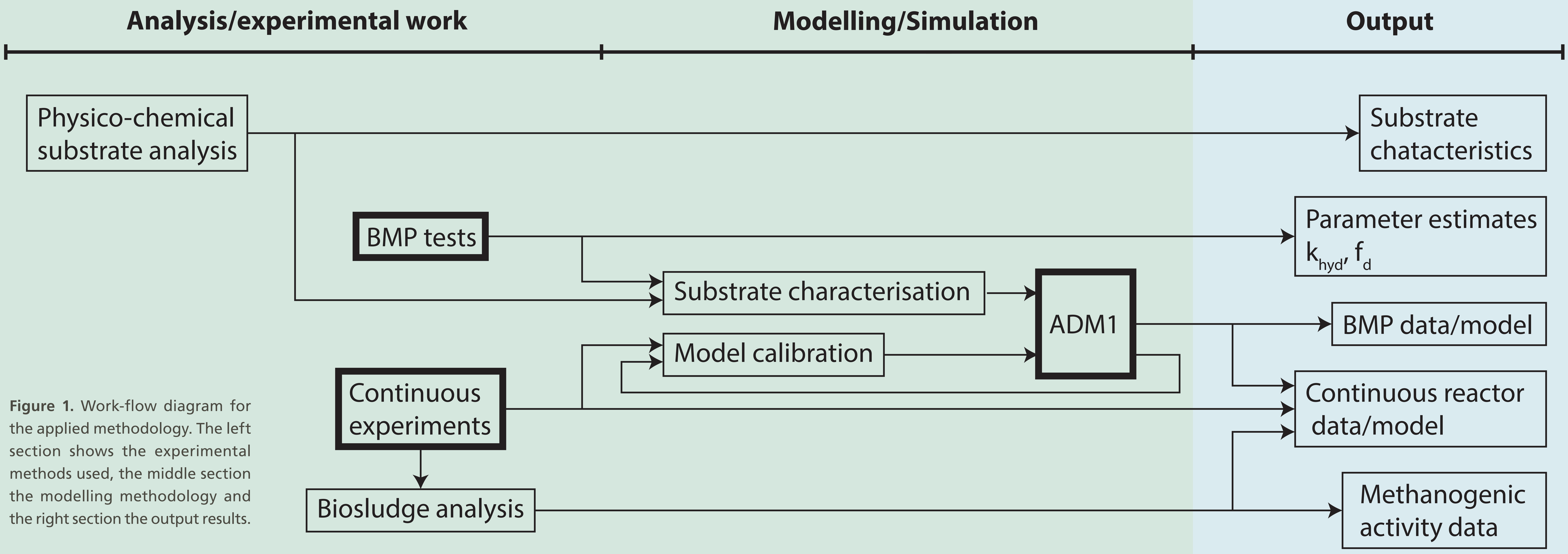

Figure 1. Work-flow diagram for the applied methodology. The left section shows the experimental methods used, the middle section the modelling methodology and the right section the output results.

Method

EXPERIMENTAL METHODS

Experiments were carried out in continous digesters co-digesting (AcoD) mixed municipal WWTP sludge and source separated food waste.

The following analyses were carried out on the substrates separately:

- Biomethane potential (BMP) tests.
- Physico-chemical tests: TS, VS, COD, CODf, TN, Kj-N, TAN, VFA, proteins, lipids.

Two continous digesters (5 litre) were operated for 66 d with an HRT of 22 d. The OLR was initially 1 kg/m³/d and increased to 2 kg/m³/d at day 33. Digester 1 (R1) was fed with a mix (1:1 on OLR) of mixed sludge and food waste, digester 2 (R2) was operated with mixed sludge only for control.

The following analyses were carried out on the digester sludge over the course of the experiments:

- Gas measurements: Flow, CH4 concentration.
- Physico-chemical tests: TS, VS, TN, TAN, ALK, VFA, pH.
- Microbial activity tests: identification and quantification of methanogenic microorganisms.

MODELLING AND SIMULATION

The experimental results were used for setting up and calibrating a process model for AcoD. The methodology for substrate characterization by Arnel *et al.* (2016) was followed, providing both influent state variables and substrate dependent parameters (i.e. hydrolysis – k_{hyd} and inhibition parameters). Moreover, a modified ADM1 – including separate hydrolysis pathways for substrates and lipid inhibition – were used for modelling both BMP and continous digesters (Arnell *et al.*, 2016; Batstone *et al.*, 2002). The model was analysed for deeper understanding of the stability and process dynamics at start-up of AcoD. Specifically, the dynamic effects at start-up, load change and feeding strategy were analyzed.

Results

EXPERIMENTAL METHODS

- The simulated BMP tests are shown in Figure 2 substrate characteristics and influent fractionation as well as parameter estimations are provided in Keucken et al. (2018) Table 1. The input fractions and parameters were successfully used also for modelling continuous experiments (Figure 3).
- Applying AcoD with the two substrates increases the gas production at equivalent load. With a feed composition 1:1 of the two substrates the experiments show 22-42% more biogas than for a reference reactor fed with only mixed sludge (Figure 2).
- Implementation of co-digestion of sewage sludge and food waste shows rapid adaptation. The response in gas production was immediate in continuous digestion (Figure 3). This conclusion is supported by the equally rapid increase in methanogenic microbial population for AcoD (Table 2, Keucken et al., 2018).
- The methanogenic microbial population in the CSTRs increases when commencing co-digestion of sewage sludge and OFMSW on a WWTP inoculum. This effect is further pronounced at an increased load, which also promotes a change in the methanogenic microorganisms towards acetate (Table 2, Keucken et al., 2018).
- The feeding strategy of continuous lab-scale digestion experiments has impact on digester performance instantaneously. The simulation results show that intermittent feeding lead to short-term inhibition of the process (Figure 4).

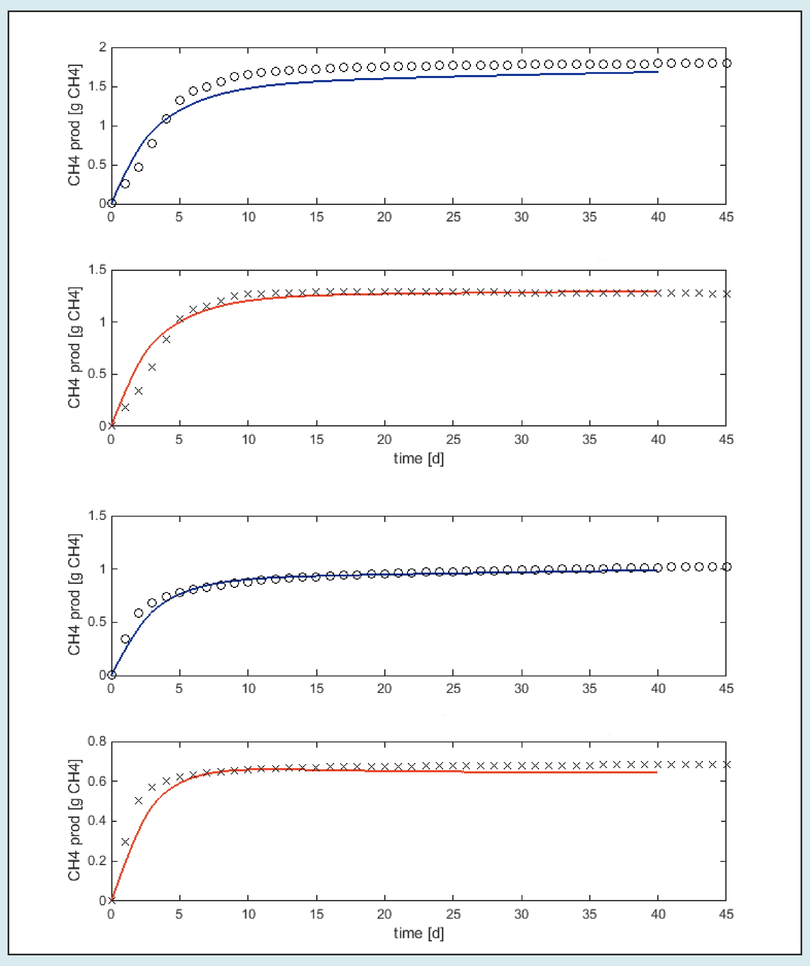

Figure 2. Cumulative methane production for biomethane potential tests of mixed sludge (a) and food waste (b). For each substrate, the total biomethane production (top) is displayed as well as net production corrected for inoculum (bottom). Markers represent data and lines are model results (ADM1).

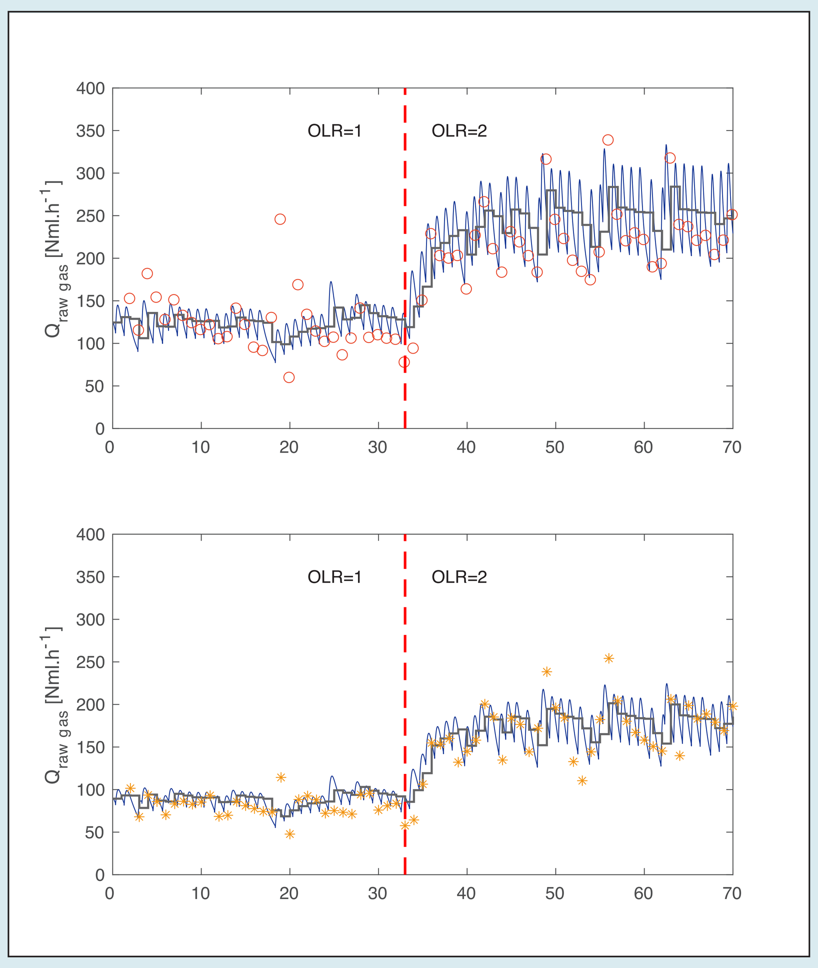

Figure 3. Gas production for continuous lab scale reactor R1 (a) and reference reactor R2 (b). Markers represent data for daily production, blue lines represent modelled production and grey lines show modelled daily production. The red dashed lines mark time for load increase.

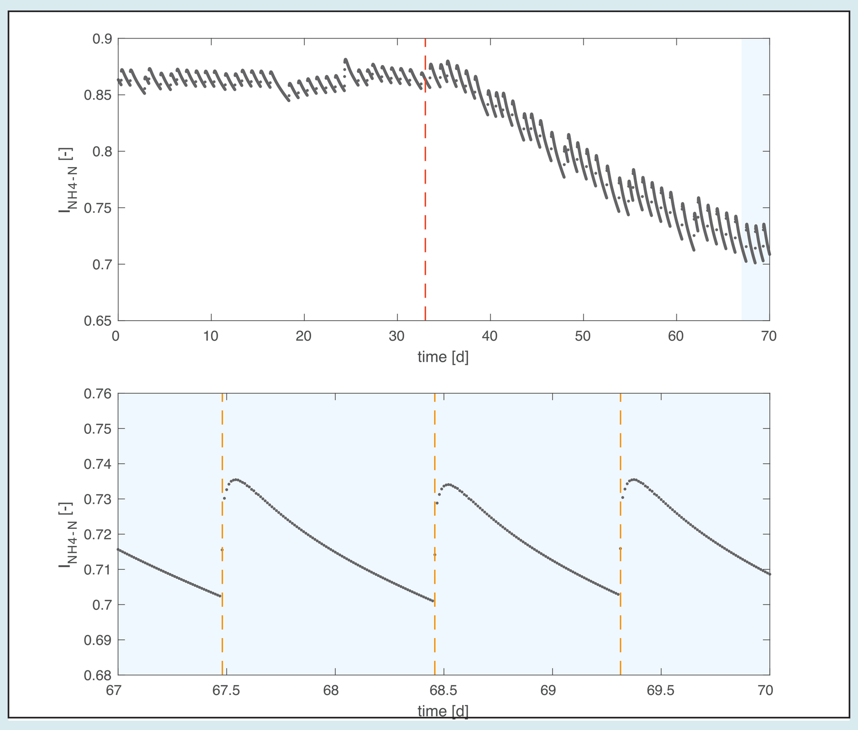

Figure 4. Modelled ammonium inhibition for reactor R1. Simulation period 70 days (a) and a three-day selection (b). The red dashed line marks time for load increase. Yellow dashed lines mark time for feeding.

Arnell M., Astals S., Amand L., Batstone D. J., Jensen P. D. and Jeppsson U. (2016). Modelling anaerobic co-digestion in Benchmark Simulation Model No. 2: Parameter estimation, substrate characterisation and plant-wide integration. Water Research 98, 138-146.

Batstone D. J., Keller J., Angelidaki R. I., Kalyuzhnyi S. V., Pavlostathis S. G., Rozzi A., Sanders W. T. M., Siegrist H. and Vavilin V. A. (2002). Anaerobic Digestion Model No. 1. Report IWA Scientific and Technical Report No. 13, IWA Publishing, London, UK.

Keucken A., Habagil M., Batstone D. J. and Arnell M. (2018). New insights on process performance and stability for anaerobic co-digestion through modelling and population analysis. IWA 11th World Water Congress and Exhibition (IWA WWC&E2018), Tokyo, Japan.