

Modeling of anaerobic digestion with ADM1

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Abstract

Recent increase in interest in renewable energy sources is a result of the low reserves of fossil fuels and increase in care for environment. One of the possible sources of renewable energy are fuels based on the biomass. Biomass based fuels can be obtained in physico-chemical process (i.e. pyrolysis) or in biological process (fermentation). Anaerobic digestion is one possible ways used for the conversion of biomass in to the fuel. The advantages of this process are: the simplicity of required infrastructure, broad substrate range and lack of necessity for sterility.

Anaerobic digestion is sophisticated biological process, in which biological matter is converted in to the biogas (composed of methane and carbon dioxide), water and mineral compounds. Degradation of organic matter is multistep process and involves microorganisms from different taxonomic groups. The stability of biogas production is dependent on the equilibrium between individual intermediate steps. The accumulation of volatile fatty acids results in the acidification of the reaction environment and consequently the inhibition of biogas production.

The anaerobic digestion sensitivity hinders the increase of efficiency in fermentation systems. The behavior of this type of system may be simulated with appropriate mathematical model (i.e. Anaerobic Digestion No.1 – ADM1). Use of mathematical model may be helpful in the identification of boundary conditions for which the biogas production is most efficient. However, the accuracy of the simulation depends on the accuracy of model parameters and imputed data.

The aim of the following work was to compile the set of tools that will allow the gathering of data required for the modeling of the anaerobic digestion. Collected data include the state of variables describing the initial conditions of system and model parameters describing the decay of selected substrates.

Selected potential substrates were analyzed to obtain parameters required by ADM1. The stoichiometric coefficients were calculated on the basis of the substrate composition. The decomposition and hydrolysis rates constants were optimized for the biogas production curves obtained from batch fermentation experiments.

Presented methodology was sufficient for the evaluation of model parameters for composite substrates (usually obtained from crops) such as oil cakes and seed hulls. The accuracy of parameters obtained from simulation was confirmed by the comparison with the data describing the continuous fermentation of selected substrates.

Mathematical modeling may be also helpful in the planning of the start-up procedure for anaerobic digesters. While the amount of the microorganisms is low at the beginning of the start-up process, it is the factor limiting the substrate dosing rate. The simulation dedicated for the planning of reactor start-up must be based on precise input data.

The examination of the microbial population activity revealed that the slowest biochemical processes involved in biogas production is the utilization of acetic and propionic acid. The initial value of variables describing the population of propionate and acetate consumers in ADM1 was evaluated on the basis of simple batch fermentation experiments. Obtained data was used in the simulation of anaerobic reactor start-up process. The outputs such as biogas production, pH and volatile fatty acids concentration were well reproduced by the model. The model was also able to reproduce the behavior of microorganisms population responsible for the consumption of acetic and propionic acid.

The analysis of microorganisms population with use of fluorescence in situ hybridization technique revealed the presence of butyrate consuming bacteria from *Syntrophomonas* genus and propionate utilizing bacteria from *Syntrophus* genus. The sole group of Archaea responsible for acetate utilization in analyzed samples was *Methanosaeta*. The obtaining of quantitative data referring to the microbial population requires further development of slides preparation and improvements in the digital picture analysis tool.

The use of mathematical models for the description of anaerobic digestion should aid the control of the fermentation process and help in the training of employees of biogas facilities (training simulators). Presented thesis describes tools and data sets required for the introduction of anaerobic digestion models on the wide scale.