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BIOAUGMENTATION MODELING IN ANAEROBIC DIGESTION: THE DYNAMICS OF METHANOGENESIS

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INTRODUCTION

The generation of biogas through the anaerobic conversion of organic wastes has long been considered an important technology for producing renewable energy (Kougias and Angelidaki, 2018). Due to its biological nature, however, the process is complicated and can operate under sub-optimal conditions, or in certain cases might even fail. This is especially true for anaerobic digesters exposed to high ammonia concentrations, which when in excess is known to be inhibitory to aceticlastic methanogenic archaea (Fotidis et al., 2014). Bioaugmentation is a suitable technique to recover such anaerobic processes, although the response of bioaugmented systems is difficult to forecast. Therefore, the aim of present work was to model an experiment involving bioaugmentation events, using a complex mathematical model developed for simulating anaerobic digestion systems.

MATERIALS AND METHODS

In order to simulate the bioaugmentation process, a complex bioconversion model (Angelidaki et al., 1993; 1999) was used, considering modifications as described in Kovalovszki et al. (2017) and the inclusion of hydrogenotrophic methanogens in the model (Lovato et al., 2017). Furthermore, acetic acid substrate inhibition was included for the aceticlastic methanogenic group, according to Fezzani and Cheikh (2008) and reflecting the influence of acetic acid on pH and microbial cell conditions. Finally, to provide the necessary hydrogen substrate for the growth of newly included hydrogenotrophic methanogens, propionic, butyric and long-chain fatty acid degrading pathways of the model were modified according to Eq. 3 and 6 in Angelidaki et al. (1993) and Eq. 5 in Angelidaki et al. (1999), respectively.

Validation of the bioaugmentation model implementation was carried out by simulating part of the work outlined in Fotidis et al. (2014). The simulated experiment involved an anaerobic digestor inoculated with mesophilic seeding material and fed with dairy manure, to which a step-wise increasing amount of ammonium-chloride was added for inducing microbial inhibition. On days 13 and 15, 100 mL of a bioaugmentative hydrogenotrophic methanogenic culture was introduced to the reactor, resulting in a hydraulic effect and a shift in the microbial community.

RESULTS AND DISCUSSION

Simulation results of the above described case study, by changing only the ammonia inhibition constant effective on aceticlastic methanogens, are shown in Fig. 1. As can be seen, simulation with an inhibition coefficient value of 0.150 resulted in better experimental data fit in general, however simulation with a coefficient value of 0.104 was more appropriate for explaining data originating from before the bioaugmentation events. These results indicate that aceticlastic methanogens were more severely inhibited prior to bioaugmentation, however recovered after the new hydrogenotrophic methanogenic culture was added to the reactor. A potential reason for this phenomenon might be the activity of synthrophic acetate oxidizing (SAO) bacteria native to the reactor, which are more resistant to ammonia. Together with the externally introduced methanogens, these microbes are able to reduce the amount of acetic acid, as well as the partial pressure of hydrogen in the system. Once part of the environmental stress on the more sensitive aceticlastic group was alleviated, they could restart their degrading activity and together with the syntrophic groups, reach the final level of gas production.

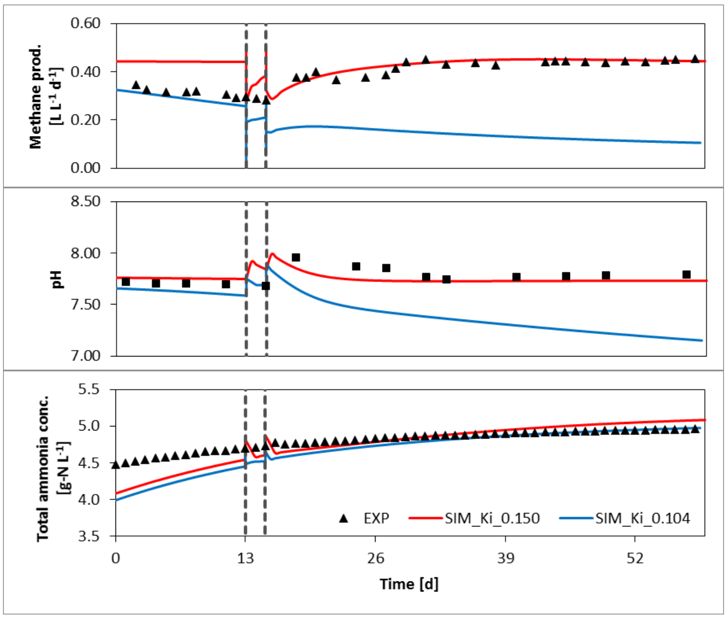

Fig. 1:Experimental and simulated methane production, pH and total ammonia concentration in the bioaugmented reactor from Fotidis et al. (2014). EXP are experimental points, while SIM_Ki_0.150 and SIM_Ki_0.104 are simulation results with a free ammonia inhibition constant of 0.150 and 0.104, respectively. Ammonia inhibition on aceticlastic methanogens was set up according to Angelidaki et al. (1999). Vertical, dashed lines mark the bioaugmentation events on days 13 and 15.

CONCLUSION

A complex bioconversion model, describing anaerobic digestion processes, was extended for the simulation of bioaugmentation scenarios. Through the *in silico* reproduction of a case study, it was shown that the interaction between aceticlastic and hydrogenotrophic methanogenic microorganisms is crucial for the maintenance of an operational system, and that SAO bacteria can play an important role in the process.

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