

Determination of the rheologic behavior of fermentation broth in biogas plants



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Introduction

- The knowledge about the rheologic behaviour of the culture broth at biogas plants is of great importance, since the rheology affects the intercellular transport processes and the mixing efficiency.
- The exact determination of this parameter is crucial due to inhomogeneity of the liquid phase and the necessity to measure directly in or at the plant with a fresh sample. In order to match the requirements, a portable rig was developed, that can be used to determine the viscosity directly at the site. The method is based on the torsion measurement^[1] in a volume of 8 L of culture broth.
- The effect of added substrate degrading enzymes (MethaPlus[®] and Enzyme B1 from DSM) on the viscosity of the culture broth was investigated.

Materials and Methods

- The viscosity in samples of three biogas plants was observed for 6 months, samples were analyzed immediately after sampling
- Two reactors were operated with degrading enzymes (either MethaPlus[®] or Enzyme B1) with a final concentration of 100 ppm
- The viscosity of Newtonian and non-Newtonian fluids were measured with different viscometers to ensure reliability of the method
- The necessity of laminar flow conditions was proven with the determination of the dependencies of Reynolds- and Newton-number

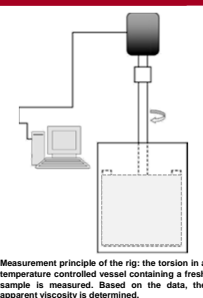
The Newtonian calibration constant c was determined when applying data of a conventional rotational viscometer and measurements of the torsion in the torsion viscometer with glycerol:

$$c = \frac{2\pi M_i}{\eta N_i D_i^3} \quad c(N_i) = 72.66N_i + 88.6 - \frac{11}{N_i}$$

The shear rate constant k was determined when applying data of a conventional rotational viscometer and the torsion in the torsion viscometer with 4 % w/w carboxymethylcellulose:

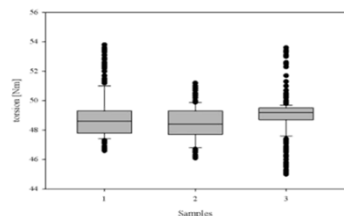
$$\dot{\gamma} = kN \quad k(N_i) = 32.26N_i - 8.8$$

Digestion experiments in the lab-scale were performed directly in the rig at a temperature of 40°C. In order to mimic concentrations near the feed zone of the biogas plant, an initial content of dry matter of 35 % was applied. The pH was controlled above 4.5. The torsion was monitored for 6 days, compounds were quantified with an HPLC-RID system to follow the acidogenic conversion of the substrate.



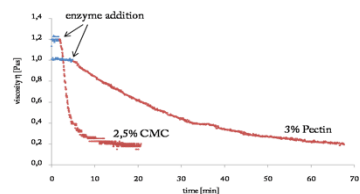
Results

- Accuracy of the torsion viscometer measurements



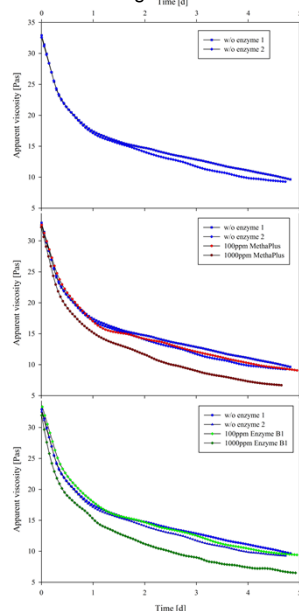
Box plot of a measurement period of one day of a fresh sample from the biogas plant (frequency of 5 min)

- Monitoring of viscosity at defined enzymatic degradation

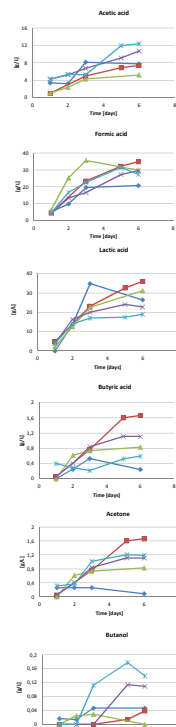


Degradation process measured with the torsion viscometer. CMC solution (2.5% w/w) and pectin solution (3% w/w) were digested with cellulase and pectinase, respectively.

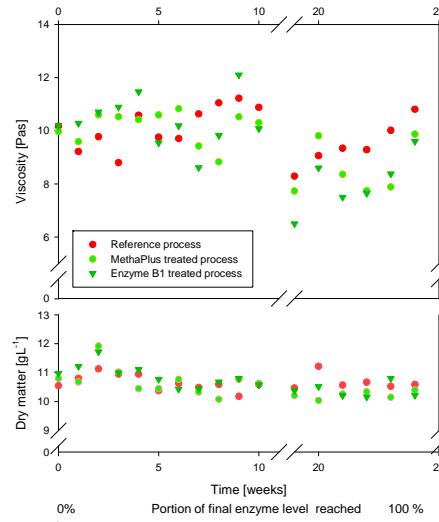
- Effect of enzyme addition in lab-scale digestion



Degradation process measured with the torsion viscometer. Concentrations of products (at the right): w/o enzyme addition, 100 ppm MethaPlus[®], 1000 ppm MethaPlus[®], 100 ppm B1, 1000 ppm B1.



- Effect of enzyme addition on the viscosity in biogas plants



95 % of the final enzyme concentration was reached after 11 weeks. During this phase, the operation of the biogas plants were similar. Due to adaptation, process conditions varied in the following. The usual fluctuation of dry matter in the samples was considered with linear normalization to the reference process. The linear dependence of viscosity and dry matter in the observed range was determined by multilinear regression.

Conclusions

- By applying the presented method, the viscosity could be determined with a high reproducibility. The decrease of the viscosity in digestion processes could be monitored.
- The impact of different shear rates on the culture broth could be observed, measurements at 40 rpm ($\dot{\gamma} = 13 \text{ s}^{-1}$) were most suitable for the purposes of this study.
- Enzyme additions in lab-scale digestions showed influences on the product spectra. B1 addition increased acetic acid synthesis up to 50 %, while addition of both enzymes stimulated formic and butyric acid formation. Lactic acid synthesis was enhanced when MethaPlus[®] was added, but decreased when B1 treatment was applied. Due to the conditions chosen in lab-scale, methanogenesis was suppressed. Acids were primarily converted to solvents (solventogenic phase). While the addition of MethaPlus[®] supported the conversion to acetone, a direct relation between B1 concentration and final butanol levels were observed. Based on these observations, it is evident, that enhanced substrate relesereduction of viscosity has a positive effect on the bacterial metabolic activity under the applied conditions.
- Higher viscosities in the untreated process compared to the enzyme treated processes were observable following 8 weeks of addition. The viscosity in the enzyme treated biogas plants was lowered up to 15 %. A longer observation time period will be necessary to proof the reliability of results concerning the effect of enzyme addition on the viscosity.

Acknowledgements

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