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Biogas Production from Agricultural Raw Materials

Characteristic Values for Assessing Material and Energy

Investigations in 34 biogas plants show wide ranges in individual process parameters. On the one hand, the reasons for this are specific substrates, technical and managerial variables on the farms. On the other hand, this reflects the potential for optimizing energy crop digestion. Process parameters, including hydraulic retention time, average volume load and specific methane yield were determined at one biogas plant over a longer period of time, in order to be able to illustrate the temporal progression, influence parameters and optimisation potentials.

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The project is promoted by the Austrian Research Promotion Agency and supported by the “Biogas Forum Austria”.

Keywords

Biogas, anaerobic digestion, energy crops, renewable energy

The legal framework conditions in Austria (Eco-Power Act) and in Germany (Renewable Energy Sources Act) obligate the use of renewable resources in biogas plants. The number of biogas plants, which partially or exclusively digest energy crops, is continuously increasing. A higher portion of, for example, maize silage, CCM, grain and grass silage in the digestion mixture impedes the operation of biogas plants, because the buffering effect of manure on the pH value and on the microorganisms is missing.

For this reason, the monitoring of material inputs and energetic assessment of the digestion process is of increasing importance in biogas plants digesting energy crops. With the help of a gas meter and gas analyser the produced quantity and the composition of the biogas can be established. By regular sampling of the digester contents, one can promptly detect accumulations of inhibitors, which reduce the activity of the bacteria.

Materials and Methods

Within the project „Analysis and Optimisation of New Biogas Plants," 41 Austrian biogas plants were examined so far and the data of 34 plants presented in the results. The examined biogas plants were in operation in the years 2003 to 2005 and partially or exclusively digested energy crops.

Data was acquired in cooperation with the plant operators by means of a detailed questionnaire. Furthermore, samples of all input materials, as well as digestion substrates at all process stages were collected and examined in the laboratory for content analysis and fatty acid composition. Onsite pH value measurements were also carried out and by means of a mobile gas analyser, the quality of the produced biogas was examined.

At two biogas plants, detailed measurements and analyses, in the scope of the project, were carried out over a period of at least eight months.

Results of Area-wide Monitoring

Process Temperature

The spectrum of the methanogenic Archaea bacteria is diverse [1]. The methane productivity of biogas plants is determined, apart from technical and management-conditioned parameters, substantially by the existing microorganisms. Microorganisms of the thermophilic temperature range possess higher material turnover rates. Thereby, inhibitors, for example, can quickly enrich themselves on volatile fatty acids. In addition, comparative studies by [2] show higher methane productivity in the mesophilic temperature range.

The analyses of the data from the area-wide analysis show that 93.8% of the Austrian biogas plants operate in the mesophilic temperature range. Only a small number of biogas plants work in the purely thermophilic range (3.1%) or within the combined

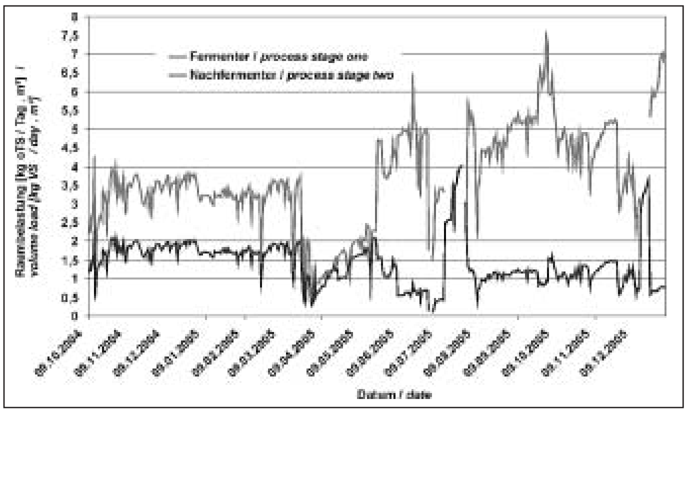

Fig. 1: Temporal progression of the average volume load in the main- and secondary digesters

range (3.1%). The combined temperature range consists of a first process step in the thermophilic range and the second process step completed in the mesophilic range.

Hydraulic Retention Time
In horizontal digesters, the hydraulic retention time of the first process step amounts to between 24 and 62 days. In vertical digesters, the hydraulic retention time is a minimum of 23 days and a maximum of 113 days. In the second process step - all of the examined biogas plants have vertical digesters - the range of the hydraulic retention time was between 20 and 187 days.

These results concur with investigations of the FAL [3], which in the context of a countrywide monitoring program of the digester stages, similarly determined a high range of hydraulic retention times of 17 to 203 days. As a result of the high VS-content with direct input of energy crops and the associated tougher degradability of the substrate, it may be necessary to have high hydraulic retention times in the upper range. Advanced analyses must show whether multi-stage biogas plants are already optimally working to full capacity. According to the FAL [3], multi-stage plants have a tendency to low efficiency.

Volume Load
In the calculation of the volume load, the digester volume is related to the daily substrate quantity. The volume load is expressed in kg VS and/or m^3 VS per day and m^3 digester volume. In horizontal digesters, the average volume load amounts to approximately 4.4 kg VS per day and m^3. In the vertical digester in the first process step, the average volume load is approximately 3.3 kg VS per day and m^3.

In the second process step, in which in the analyses hitherto no differentiation according to the digester type of the first process step were made, the volume load amounts to on the average 3.5 kg VS per day and m^3.

Fatty Acid Composition
Short chained fatty acids are important intermediate products in methane digestion. In fresh manure, its concentration averages 3,000 to 10,000 mg/l. In digested manure, fatty acid concentrations are generally below 1,000 mg/l. The bacteria however, can adapt themselves in a certain measure to certain concentrations. Thus, the concentration where the bacteria are damaged or inhibited is system-specific and difficult to determine.

In the examined biogas facilities, the fatty acid composition (HAC, PRO, BUT, VAL, CAP), out of at least two process steps, was analysed in the laboratory. It showed that there is a very large variation. For acetic acid, an average of 672 mg/l was found for the first process step, with a minimum of 32 mg/l and a maximum of 3,628 mg/l. For propionic acid, the range amounted to 9.9 to 7,007 mg/l with a mean of 650 mg/l. In the second process step and in final storage, the values on average were somewhat lower.

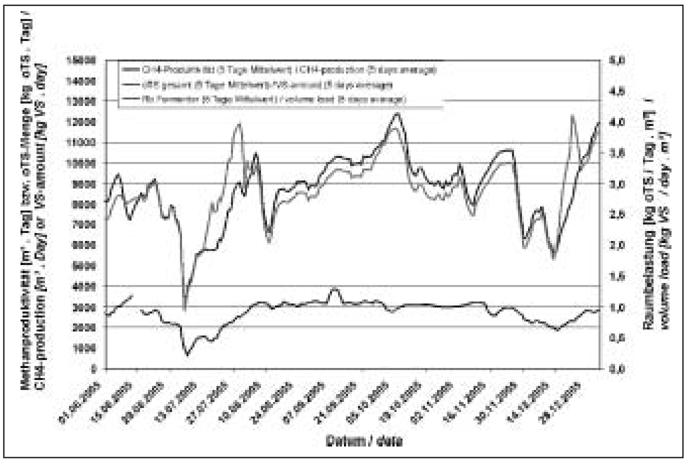

Fig. 2: Temporal progressions of CH_4 production, VS content and average volume load

Specific Methane Yield
The results show that co-fermentation of energy crops and manure produces a stable digestion process and high methane production rate. Biogas plants, which jointly digest energy crops and manure, show the highest methane production rate, on the average 0.36 m^3 CH_4/kg VS. In plants which only utilise energy crops, the specific methane yield on the average amounts to 0.33 m^3 CH_4/kg VS. Biogas plants, which utilise energy crops, manure as well as organic waste, generate an average specific methane yield of 0.33 m^3 CH_4/kg VS.

Results of Detailed Monitoring - Single Plant

While in the area-wide monitoring of each biogas plant only single values are available, long term data could be ascertained with detailed monitoring. This enables the illustration of temporal progression of single parameters.

Volume Load
The temporal progression of the average volume load, in kg VS per day and m^3 digester volume, can be represented for the main- and for the secondary digester by recording the quality and quantity of the daily supplied substrate.

The examined biogas plant showed relatively stable volume loads in the first months, in the main digester of approximately 3.4 kg VS per day and m^3 (*Fig. 1*). As of April/May 2005, vinasse was added in addition to the energy crops and at the same time the energy plant input was increased. The volume load increases at this point to a level of approximately 5 kg VS per day and m^3.

Due to the changed digestion raw material composition, at this point among other things, there is an increase in the fatty acid concentrations in the digester. By temporarily reducing the quantity of supplied substrate, it was tested whether one could prevent the further accumulation of fatty acids.

Volume Load and Methane Productivity
Figure 2 illustrates the volume load relative to the methane productivity of the biogas plant [m^3/day]. To better represent the processes, a five day average of was formed in each case. It is shown that the supplied VS quantity and the resulting volume load exhibit a clear influence on the methane productivity. With decreasing volume load, the methane productivity drops, due to the smaller availability of degradable substance.

However, it also appears that with an excess of the volume load above the threshold value, approximately 3.6 kg of VS per day and m^3 at this biogas plant, the methane productivity tends to decline. There is the assumption that by exceeding the threshold value, inhibitors of methane digestion appear, that lead to a trend reversal of the methane productivity.

Conclusion

The represented data relates to the first intermediate results. The documentation of the volume load and methane productivity over a longer period presents valuable information for the optimization of the biogas plant. Detailed evaluations of the entire data describing the influence of the volume load of fermenting raw material mixtures in usual operation on the operational behaviour of biogas plants are currently being processed.

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