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Biogas from Energy Crops

Results from Long-term Lab Scale Experiments

Long-term experiments on biogas production from crushed rye grain and fodder sugar beets silage were carried out under lab scale conditions. In all tests on both energy crops and co-fermentation with animal waste slurry, anaerobic digestion, the biogas production was stabile. The VS-biogas yield from energy crop and slurry mixtures was proportional to the VS-portion of the single substrates. Application of a SBR (sequencing batch reactor) for anaerobic digestion of fodder sugar beets at 55°C resulted in a VS methane yield of 1.1 m^3kg^{-1} and of a methane production rate of 3 $m^3m^{-3}d^{-1}$.

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Keywords

Biogas, slurry, energy crops

Common treatment of energy crops and animal waste slurries has attracted much interest in recent years, because of the high biogas yields particularly of energy crops. Although such co-fermentation is recognised as a proven technology [1], reactors often fail as a result of too high organic loading rates (OLR). Methane yield and reactor performance can be evaluated from lab-scale experiments with energy crops in mono- and co-fermentation. These data are important for design and operation of full-scale biogas plants. There are results from continuous fermentation of grass in a pilot plant and from fodder sugar beets in lab scale over a period of some months. At mesophilic temperatures and OLR in the range of 1 to 2.6 $kg m^{-3} d^{-1}$ biogas yield of grass silage ranged from 430 to 470 $l kg^{-1}$ [2]. Experiments with fodder sugar beets in co-fermentation with cow slurry resulted in VS- methane yields from 550 to 560 $l kg^{-1}$ [3], whereas mono-fermentation of odder sugar beets at OLR of 4 $kg m^{-3} d^{-1}$ has shown a methane yield of only 470 $l kg^{-1}$ [4]. Addition of cow slurry have made the fermentation process more stabile and allowed to operate the reactor at OLR up to 4.5 $kg m^{-3} d^{-1}$. The aim of the experiments was to study the long term performance of anaerobic fermentation of crushed rye grain and fodder sugar beets in mono- and co-fermentation. Furthermore the data of reactor performance should be extended by means of application the SBR (sequencing batch reactor) for anaerobic digestion of fodder sugar beets in contrast to conventional fully mixed reactor technology.

Substrate analyses and test performance

Total solid (TS) concentration of crushed rye grain, fodder sugar beets silage and animal waste slurry was found to be 88 %, 11 % and 5.5 %, respectively and observed in a typical range. An exception was the fodder sugar beets silage used for SBR feeding. Because of the high amount of soil tare during ensiling, only 65,2 %VS of the TS were analysed. Experiments were carried out in 2•5 l mechanically stirred, air tight glass bioreactors with water jacket. The biogas produced was measured daily using a multi-chamber rotor gas meter at 20°C (RITTER). Methane concentration was measured by means of gas analyser SSM 6000 (PRONOVA). The bioreactors were operated as fully mixed reactors and fed daily at 5 days per week, except the SBR. It was fed every six hours at six days per week and after a period of sedimentation, sludge liquor was removed by means of a flexible-tube pump.

Long-term experiments in fully mixed reactors

For the start up, all reactors were inoculated with digested cow manure (TS = 14,5 $kg m^{-3}$). Because of too high values for OLR in the range of 2 to 3 $kg m^{-3} d^{-1}$ mono- fermentation of crushed rye grain and fodder sugar beets

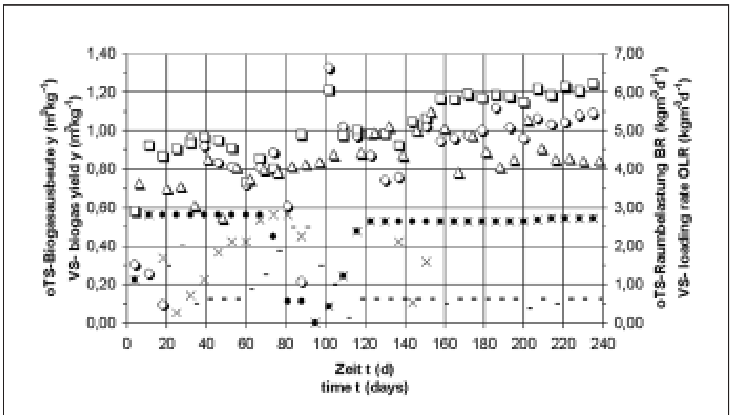

Fig. 1: VS- biogas yield and VS loading rate in semi continuously operation of 2.5 l lab fully mixed fermenters digesting crushed rye grain and fodder sugar beets silage: (Δ) y, - OLR (crushed rye grain); (❍) y, (x) OLR (fodder sugar beets silage 35°C); ❑ y • OLR (fodder sugar beets silage 55°C)

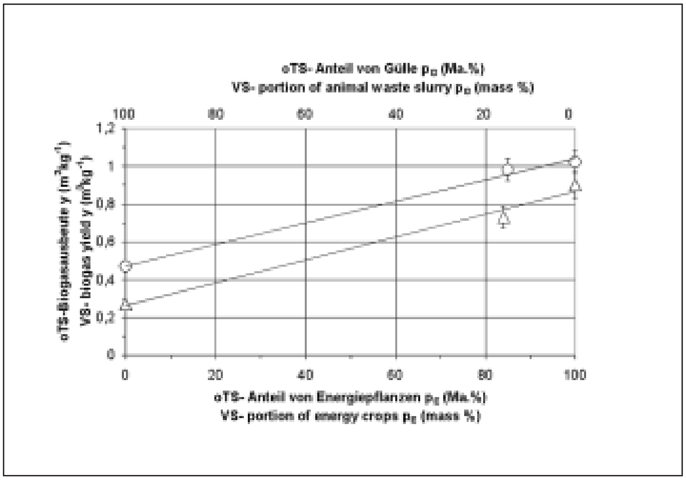

Fig. 2: VS- biogas yield for different VS- portions of animal slurry p_G and energy crops p_E from semi- continuously experiments, (❍) fodder sugar beets silage, (Δ) crushed rye grain

silage resulted in reactor failure and in a second start up (*Fig. 1*). Fully mixed reactors digesting both fodder sugar beets silage at 55 °C and mixtures with animal waste slurry (19% crushed rye grain, 70% fodder sugar beets silage) have shown no reactor failure, i.e. increase of volatile fatty acids (VFA). After about 120 days all reactors operated at stabile conditions. The implication of the experiments is that the VS- biogas yield of a mixture from animal waste slurry and the investigated energy crops is directly proportional to the biogas of the single substrates as shown in *Figure 2*. The methane content of the biogas in mono-fermentation of fodder sugar beets silage at 55°C, at 35°C and of crushed rye grain at 35 °C was measured with 55%, 58% and 54% respectively.

SBR for biogas production

The high degradation of VS in fodder sugar beets silage (about 90%) and its low VS-concentration (10 to 15%) offer the option to increase the active methanogenic biomass concentration by sedimentation in a SBR . Withdrawal of sludge liquor (supernatant) after 2 h sedimentation resulted in an increase of VS- concentration in the fermenter of 2.5%. Through this processing, the mean rates of biogas- and methane production during a 2 month period were 5.6 $m^3m^{-3}d^{-1}$ and 3.1 $m^3m^{-3}d^{-1}$, respectively (*Fig. 3*). Maximum biogas production rate was 8 $m^3m^{-3}d^{-1}$ and presents a peak value for fodder sugar beets silage.

Conclusion

From crushed rye grain and fodder sugar beets silage for both mono- and co-fermentation high biogas yields can be attained over a long time. Biogas yields observed from long term semi-continuous experiments correspond with values from batch-experiments. Special emphasis should be given to the start-up, because too fast increase of OLR results in reactor failure. The VS- biogas yield of a mixture from animal waste slurry and energy crops is directly proportional to the biogas of the single substrates. With respect to dimensioning the biogas reactor on the base of OLR, feed quality and process management should be considered.

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Fig. 3: VS concentration of fermenter c_R (❍), c_E of sludge liquor (●), VS-loading rate OLR (▲), rate of biogas production R (Δ) and VS- biogas yield y (■) in course of time from a thermophilic (55°C) operating 2,5 l fermenter fed with fodder sugar beet silage (fed batch, four times per day)