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Effect of Process Parameters on Digestion Kinetic and Methane Yield of Energy Crops

Knowledge about the fermentation characteristics of energy crops as a substrate and ascertaining their energy output potential are substantial factors in successful biogas facility management. Several energy crops were examined in both the stable mini-batch as well as in lab-scale batch digesters, to specify fermentation characteristics, the optimal mixture ratio and the methane yield potential. The results indicate clear synergy effects for some mixtures, in process kinetics as well as in the specific methane yield.

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Keywords

Anaerobic fermentation, biogas, energy crops, methan yield

Germany has currently 3000 farm biogas plants with an increase of around 100 % to the the 2001 figures (Fachverband Biogas, 2005). This new momentum has been mostly triggered by the Renewable Energy Policy Amendment (EEG) that guaranties a 6 cents/kWh bonus for „green“ electricity, produced from energy crops and manure. Since then, several new biomasses from energy crops are being used as feedstock for on farm biogas plants.

The behaviour of these new feedstocks is yet not totally understood. The potential of these capital and labour intensive substrates is in practice often not totally exploited. The use of some energy crops, e.g., those rich in protein can lead to process instability. Moreover, there is even less knowledge regarding the optimal energy crops mixture ratio, suitable for a profitable exploitation of biogas plants.

Material und Methods

The experiments presented in this paper have been conducted in three different batch digesters' types; namely the mini-batch system called „Hohenheim biogas yield test-(HBT)“ and the standard lab-scale digesters of 17 l and 31 l liquid volume. The mini-batch system called HBT has been used to determine both the digestion kinetic as well as the energy yield potential of energy crops. The HBT has been developed at the „State Institute of Farm Machinery and Farm Structures“ and was described by [3].

A specific quantity of the test-substrate (three replicates for each substrate) was weighed to keep a volatile solids ratio (VS) of 1:2 between the inoculum and the test-substrate, in order to meet the association of German engineers' guidelines-VDI (VDI Richtlinie 4630 Entwurf, 2004). The digestion was conducted at 37°C for a retention time of 35 days. Six mini-digesters are run with standard substrates in order to compare the results of different experiments. Three digesters are run with an inoculum (pre-digested cattle slurry) in order to deduce the methane yield to be attributed to the test substrate. Because of the small quantity to be weighed, the test-substrates are to be milled to obtain a representative sample. The limitation of the system is that due to the small quantity of both the test-substrate and the inoculum, sampling during digestion is inappropriate, therefore during digestion samples could only be taken from the lab-scale digesters. Five different crops where tested namely forage maize silage, winter wheat grain, clover-grass silage, fodder beet silage and rye whole crop silage. The four last substrates were mixed to maize silage in mixture ratios of 25, 50 and 75 % (on VS basis). For the HBT experiment, 60 mini-digesters were used while in the lab-scale digesters of 17 l and 31 l liquid volume capacity, maize silage and crushed wheat grain were mixed in mixture proportion of 50:50 (on VS basis).

The test-substrates were differently pretreated. The substrates were either dried-milled (at 1mm diameter sieve) as in HBT or crushed (for wheat grain) and freshly chopped (for whole crop maize). Samples where taken during the experiment duration of 35 days. Following analyses have been achieved on the substrate for: volatile fatty acids (VFAs), total and volatile solids (TS and VS). The gas volume and the gas quality (CH_4, CO_2, and H_2S) were regularly determined.

Results and discussion

The methane yields of various single energy crops and mixtures are presented in *Table 1*. The measured methane yield potential of single energy crops ranges from 0.365 to 0.430 Nm^3 CH_4/kg VS, with the highest value for winter wheat grain. Higher methane yields were recorded on different mixtures.

The specific methane yields of energy crops showed a very high correlation to the fibre contents of the substrates. *Figure 1* shows the correlation between the specific methane yields of single crops and the acid digestible fibres (ADF) content. The higher the fibre contents, the lower the specific methane yields. These results corroborate

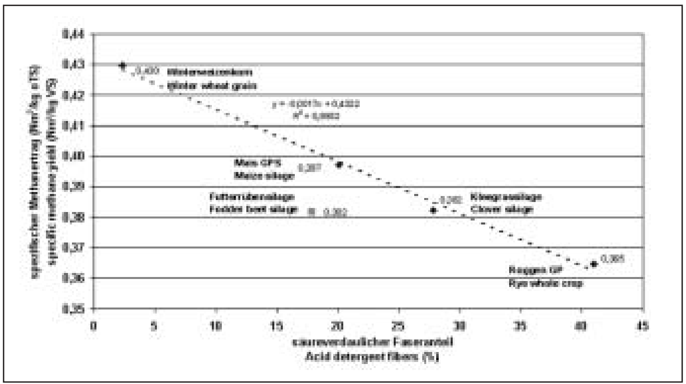

Bild 1: Spezifische Methanerträge von Energiepflanzen in Korrelation zum ADF-Gehalt (säureverdaulicher Faseranteil)

Fig. 1: Specific methane yields from enrgy crops in correlation to the ADF-content (acid digestible fibre)

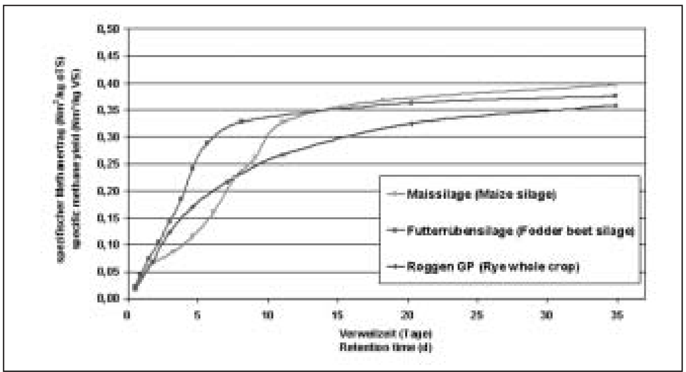

Bild 2: Gärverhalten von Roggen-GPS, Mais-GPS und Futterrüben-GPS

Fig. 2: Fermentation characteristics of rye whole-cropsilage, forage maize silage and fodder beet whole-crop silage

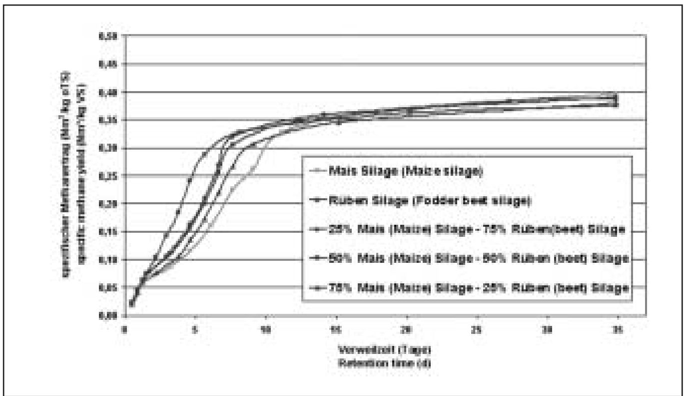

Bild 3: Methanertrag bei der Vergärung von Substratmischungen am Beispiel von silierten Futterrüben und Maissilage

Fig. 3: Methane yield during digestion of substrate mixes using the example of ensiled fodder beets and forage maize silage

Versuchsaufbau	Substrate	Mischungsverhältnisse/ Mixture proportions	Methanertrag (Nm³ CH_4/kg oTS-VS)
Mini-batch (HBT)	Maissilage	100%	0,397
	Winterweizenkorn/ Wheat grain	100%	0,430
	Maissilage + Winterweizenkorn/ wheat grain	25% - 75%	0,442
		50% - 50%	0,425
		75% - 25%	0,418
	Maissilage	100%	0,397
	Kleegrassilage/ Clover silage	100%	0,382
	Maissilage + Kleegrassilage/ clover silage	25% - 75%	0,391
		50% - 50%	0,387
		75% - 25%	0,387
	Maissilage	100%	0,397
	Futterrübensilage/ Fodder beet silage	100%	0,382
	Maissilage + Futterrübensilage/ fodder beet silage	25% - 75%	0,391
		50% - 50%	0,387
		75% - 25%	0,387
	Maissilage	100%	0,397
	Roggen GP/ rye whole crop	100%	0,365
	Maissilage + Roggen GP/ rye whole crop	25% - 75%	0,361
		50% - 50%	0,388
		75% - 25%	0,386

Table 1: Specific methane yields from energy crops at different mixing ratios

with those of [4] on the digestion of grassland growths with different raw fibres contents.

The effect of high fibre contents in the substrate did not only affect the specific methane yield obtained after 35 days, but also the digestion kinetic (*Fig. 2*). For instance, rye whole crop was not ensiled and has a neutral digestible fibre content of 62,8 %, which actually represents the content of cellulose, hemicellulose and lignin [1]. The methane yielding curve of the above mentioned substrate was slow but consistent reflecting the behaviour of a fibre rich substrate, while the methane yielding behaviour of fodder beet silage with a NDF content of 29,7 % was quick.

The crushing of winter wheat grain as pretreatment technique has proven to be sufficient showing that an intensive size reduction by milling was not necessary.

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