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Two-stage Digestion of Renewable Raw Materials

Applying the Flooding Process to Utilizing Grass Silage

The input of fibre-rich renewable raw materials, e.g. grass silage, as a co-substrate in agricultural biogas plants, often caused technical problems. Within the framework of this project a process is being developed, which makes it possible to digest grass silage as a single substrate, a process which additionally through a two-stage process better supplies what the bacteria involved require. An intermittently operating two-stage process is being used, which has had good results with degradation and methane yields.

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Keywords

Batch-digester, biogas, bioleaching, fixed bed reactor, grass silage, hydrolysis, methane, percolate, two-stage

By the year 2015, around 26 % of the grassland of Baden-Württemberg is not going to be used anymore for the production of feed [1]. A technical possibility to use this area energy efficiently without the input of liquid manure is of great interest. The high fibre content of grassland growth is limiting so far the energetic use in agricultural biogas plants.

It is for this reason that within the framework of the cooperative project „Biogas-Crops-Network“ the University of Hohenheim, together with other nine German institutes, the basic principels of biogas production out of biogas crops are studied and particularly the mono fermentation of grass silage in a two stage process based on the bioleaching principle is investigated.

Present knowledge

The incomplete anaerobic biomass mineralization and its conversion to biogas take place in four stages through a multitude of micro organisms. These reach their metabolic optimum at highly different milieu conditions. For instance, the optimal pH range for the hydrolysis lies between 4.5 and 6.3 and for the methanogenesis this is between 6.5 and 8 [2]. So the hydrolysis in a one stage biogas digester takes place under suboptimal conditions. The temperature requirements also differ: considerably higher degradation degrees and methane yields have been achieved during a hydrolysis at 55 °C than at lower temperatures [3].

Objective

of the research project at the State Institute of Farm Machinery and Farm Structures is to divide the biogas production process into a hydrolysis and a methanogenesis stage through process measures. These two stage process should respond better to the living conditions of the micro organisms.

The conversion rate of the organic mass in case of high fibre content loads, like grass silage, is limited by the hydrolysis capacity. Within the framework of the research project it shall be studied whether the optimization of methane bacteria milieu conditions leads to an increase of the conversion rate of the organic substance during an anaerobic degradation. Therefore, the hydrolysis is carried out in a batch bioleaching system. Problematic in case of this so called batch system is often the uniform moisture penetration of the substrate pile. A better moisture penetration and thereby higher degradation degrees are to be expected with a complete flooding of the digester. Therefore, it has to be studied whether the expected substrate specific methane yield is affected by the operating method of the hydrolysis digester. For this purpose the two operating methods of the hydrolysis digester, percolating and flooding, are compared.

Material and method

The experiments are carried out in the solids biogas laboratory of the University of Hohenheim. The test facility is composed out of five digester pairs, each digester having a volume of approx. 50 litres. Each pair consists of a batch hydrolysis digester and a down flow fixed bed reactor as methane reactor. The solid phase of the biomass is carried over in the hydrolysis digesters to the liquid phase (percolate) through hydrolysis and acetogenesis. The conversion of the percolate's organic fractions to gas takes place in the methane reactors (fixed bed reactors).

In the case of hydrolysis, analogously to the one staged, discontinuous solids fermentation, it is possible to distinguish between the percolation method (box digester) and the flooding method. All hydrolysis digesters have been filled at the beginning of the experiment with 1 kg oDM grass silage of intensively used grassland (first cut). Afterwards, 10 litres tap water have been added to the percolation hydrolysis digester and 45 litres to the flooding hydrolysis digester. The floating of the substrate in the flooding variants has been avoided through the installation of a perforated strainer. The methane fixed bed reactors (pH value of approx.7.5) are filled with growth bodies for the micro organisms and with 45 l percolate. The filling is followed by a starting phase of four

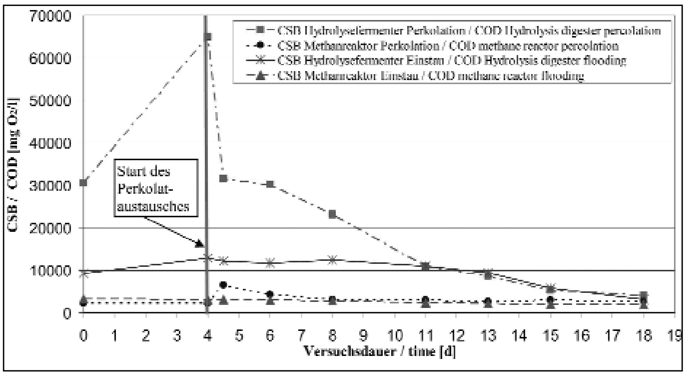

Fig. 1: COD of selected hydrolysis digesters and methane reactors in a two stage digestion of grass silage in a percolation and flooding process

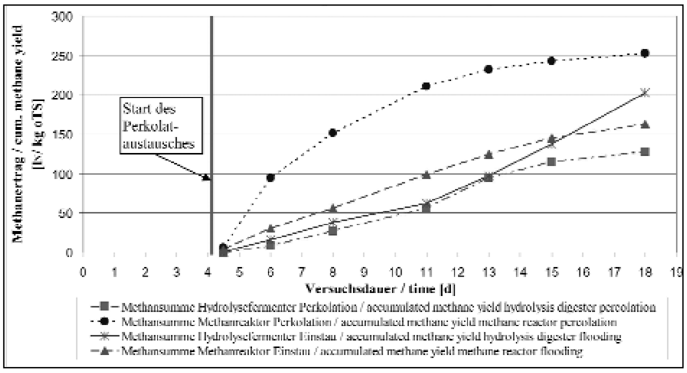

Fig. 2: Accumulated methane yield of selected hydrolysis digesters and methane reactors in a two stage digestion of grass silage in a percolation and flooding process

days in which the hydrolysis digesters are percolated internally and no percolate is exchanged between the digesters. After this starting phase, 4 kg of percolate are exchanged daily between the digesters. This experiment ended after 18 days. In the experiments, for the substrate and the fermentation residue, gas production potential, substance groups, organic and mineral nitrogen and DM content are analysed. For the process liquid, pH value, electric conductivity, volatile fatty acids, COD, DM content and temperature are analysed. For the gas, volume and CH_4, CO_2, H_2, H_2S, O_2 components are collected.

Comparison between flooding and percolation process

Immediately after the beginning of the experiment, the comparison between the flooding and percolation process shows clear influences on the concentration dependent parameters like COD, salinity, NH_4-N and volatile fatty acids. These are lower in the flooded hydrolysis digesters than in the percolated ones. This is extremely clear in the COD concentration. In the percolated variant, organic material accumulates in the percolate of the hydrolysis digester until the start of the percolate exchange, so that the COD concentration increases up to approx. 65000 mg O_2/ l only to decrease quickly after the start of the percolate exchange to approx. 30000 mg O_2/ l and to slowly adjust to the concentration of the methane reactor. The hydrolysis digester of the flooding variant simply shows in contrast a concentration peak of approx. 13000 mg O_2/ l (*Fig. 1*).

An increase of the pH value in the hydrolysis digester from approx. 5 to the level of the methane reactor of approx. 7.7 has been recorded after the first percolate exchange (day 4 of the experiment). The increase of the pH value in the flooded hydrolysis is only a little slower than in the percolated digesters. The methane production in the hydrolysis digesters is initiated in both systems through the increase of the pH value. Through the highly concentrated percolate of the percolation variant, the organic matter is quickly removed from the hydrolysis and transformed to methane in the fixed bed reactor. The COD load removed from the flooded hydrolysis is lower, due to the dilution. A shift of the methane production in the hydrolysis digesters compared to the percolated system can be observed.

Adding the methane yields of both stages results in a difference of the specific total methane yield of both variants of 20 l_N methane. During this experiment there is a tendency to higher degradation degrees in the variants with percolated hydrolysis. The flooded hydrolysis digesters, compared to the ones with percolation, show a higher methane content of the biogas and have the higher percentage of the total methane yield (*Table 1*). The quality of the gas produced in the fixed bed reactors is not influenced by the variations. It lies at approximately 73% methane.

Variant		Percolation	Flooding
Spec. Biogas yield	l_N/ kg oDM	735 ± 34	705 ± 6
Spec. Methanertrag	l_N/ kg oDM	394 ± 18	374 ± 12
Degradation degree	% of oDM	79.8 ± 0.3	77.4 ± 1.5
CH_4 content average of the hydrolysis gas	%	35.9 ± 0.2	44.0 ± 2.6
Hydrolysis percentage of total methane yield	%	33.8 ± 0.5	57.3 ± 2.8

)* Average and standard deviation out of two repetitions / variant; biogas and methane yields are shown without the correction of the volatile acids

*Table 1: Specific biogas- and methane yield and the degree of degradation of the variants percolation and flooding of the hydrolysis digesters of two stage digestion of grass silage shown as an average with its standard deviation)**

Conclusions and perspectives

The previous experiments defined good degradation degrees of the oDM of 75 to 85%. The quantities of the produced gas and methane also corresponded with approx. 600 to 800 or 300 to 400 l_N to the degradation degree and the methane yields from the one staged, discontinuous solids fermentation of grass silage [4]. The gas yields of the two-phase fermentation were always accomplished in less than 25 days.

Within the framework of the experiments carried out so far, it was possible to produce in the experimental variant with percolation in the hydrolysis digester approximately 4% higher methane yields and 3% higher degradation degrees (experiment duration of 18 days), compared to the flooding variant. Also the selectivity of the product gases, thus the methane proportion, which was produced in the methane digester, was higher in the percolation variant than in the comparison variant. Therefore, from the previous experiments, no advantages of the flooding method can be derived for the hydrolysis digester.

Literature

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