Simon Zielonka, Andreas Lemmer, Hans Oechsner and Thomas Jungbluth, Hohenheim

Two-stage Digestion of Renewable Raw Materials

Applying Bioleaching for Utilization of Grass Silage

Currently renewable raw materials are being used in full scale biogas plants as co-substrates. Using grass silage frequently caused technical problems till now. Within the framework of this project, a process to digest grass silage as a single substrate is being developed. An intermittently operating two-stage process is used. As far as the degree of degradation and methane yields are concerned, good and promising results have been achieved.

M. Sc. agr. Simon Zielonka and Dr. A. Lemmer are scientific employees at the state institute for farm machinery and farm structures at the University of Hohenheim (Director: Dr. Hans Oechsner). The Ph.D. program of Simon Zielonka is supervised by Prof. Dr. Thomas Jungbluth, Garbenstr. 9, 70599 Stuttgart; e-mail: *zielonka@uni-hohenheim.de*

Keywords

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

In the German state of Baden-Württemberg the rising efficiency in milk production, combined with the milk quota, are resulting in a reduction of the grassland usage. It is deemed that 26 % of the current grassland will not be in use for feed production by the year 2015 [1]. The use of grass in biogas plants for the purpose of energy production is technically limited by its high fibre content. Therefore the possibility of using grass without the addition of liquid is of great interest.

Within the framework of a cooperative project „Biogas-Crops-Network“, ten German institutes are studying the fundamentals of biogas production from energy crops. The University of Hohenheim is dealing with the digestion of grass silage in a two stage biogas process based on the bioleaching principle.

Literature review

The degradation of organic substrate to methane is a four steps process. Each one of these steps is performed by several different bacteria. These bacteria have specific requirements for their growth. In fact, they each require different pH levels and the temperature ranges for their optimum performance [2]. In a “one stage biogas process” the four steps take place in the same vessel, at the same pH and the same temperature. Actually the living conditions are set to fit the needs of methanogenic bacteria since they are the most sensitive of the chain. The bacteria of the hydrolysis are more flexible in this respect and end up adapting to the living conditions of the methanogenic bacteria.

The ideal pH for hydrolysis is 4.5 to 6.3. The methanogenic bacteria achieve optimum stability and activity in the mesophilic range around 38 °C and with a pH of 6.5 to 8 [2]. Consequently the hydrolysis in a one stage process takes place in suboptimal conditions.

Objectives

Taking into account the above mentioned facts, the optimum growth requirements of different micro-organisms can be accomplished using a two stage process. The biogas process is hence divided into a hydrolysis phase and a methanogenesis phase.

Fig. 1: Test biogas plant for solid substrates of the University of Hohenheim

During the digestion of grass, the rate of conversion is limited by the performance of the hydrolysis. In the frame of this project it should be investigated whether the optimisation of the environmental conditions for the hydrolysis bacteria would improve the efficiency of the anaerobic digestion of organic matter.

Material and Methods

The experiments were conducted using the solid phase digesters of the biogas laboratory of the State Institute of Farm Machinery and Farm Structures and of the Agricultural Engineering Institute of the University of Hohenheim (*Fig. 1*). The lab facilities consist of five pairs of vertical digesters with a useable volume of 50 l per digester. The substrate has been analysed with respect to its dry matter (DM) and organic dry matter (oDM) content, chemical composition, organic and mineral nitrogen, the biogas and methane yield

potentials. The following parameters have been analysed in the digesters: pH, the electrical conductivity (salinity), volatile fatty acids, the COD, DM and oDM and temperature. The biogas yield was measured and the gas was analysed with respect to its content in CH_4, CO_2, H_2, H_2S, and O_2.

The hydrolysis and acidogenesis phases of the biomass take place in the first stage digester, also called the Hydrolysis digester, wherein the percolate (the fluid fraction) is generated. The percolate is pumped into the fixed bed methane digester, where the organic fraction of the percolate is mineralised (digested).

For each trial the hydrolysis digesters are filled with 4 kg FM of grass silage (first cut) and 10 kg of tap water. The fixed bed digesters are filled with poly-ethylene filling bodies, as settling bed for micro organisms, and 45 l of percolate. The pH of the percolate in the fixed bed digesters is around 7.5.

After filling the hydrolysis digester with grass silage, a starting phase of several days begins, during which the percolate is recirculated. During this starting phase the exchange of percolate between the stages does not take place. Meanwhile there is a concentration of organic matter in the percolate of the hydrolysis digesters. The pH remains stable in this phase and remains around 5. After this starting phase 4 kg of percolate are exchanged between the two stages daily. This exchange causes rapid digestion of the organic matter dissolved in the percolate. The exchange of the percolate with different pH causes an increase of the pH in the hydrolysis. If the pH reaches 6.5 the methane production starts. After 25 days retention time the gas production decreases remarkably and the experiment is concluded.

Preliminary results

Considering the results of experiments conducted up till now, the two phase digestion of grass silage showed stable digestion behaviour. Neither in the hydrolysis nor in the fixed bed digesters could a biological disturbance of the process be detected. In the first trials a degree of degradation of 75 to 85 % was attained. Around 60 % of the biogas was produced in the hydrolysis and 40 % of the biogas in the fixed bed digesters. The biogas generated in the fixed bed digesters had an average methane content of 69 %. The fixed bed digesters yielded 63 % of the total methane production of the two stages.

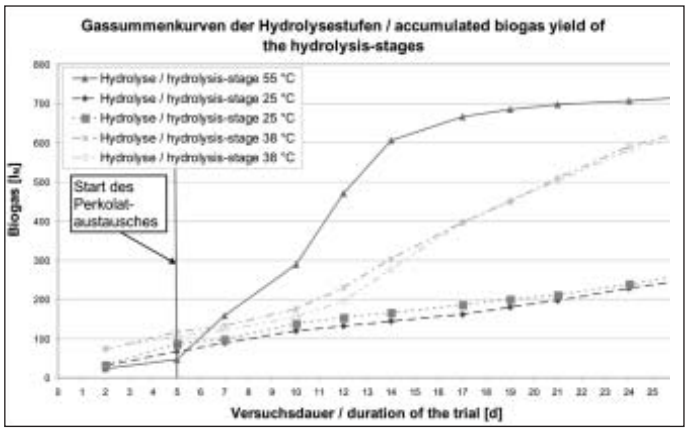

Fig. 2: Accumulative biogas yield of the hydrolysis stages in a two stage digestion of grass silage at temperatures from 25 to 55 °C

Influence of the hydrolysis temperature

Within the framework of this research, project trials were conducted looking into the influence of the temperature on the performance of the hydrolysis. In general the trial set up was the same as described above. The starting phase at the beginning of the trial lasted for four days. The trial was ended after 26 days when no more biogas was produced. Three hydrolysis temperature ranges were investigated: thermophilic (55 °C), mesophilic (38 °C) and psychrophilic (25 °C).

The thermophilic variant showed a fast and the most intense gas production (*Fig. 2*). In this variant the highest methane yield was attained in the hydrolysis as well as in the whole process. Also the highest degree of degradation was found here. The degree of degradation decreases with the temperature. In the psychrophilic variant the degree of degradation was between 35 to 40 % of the added organic dry matter.

The variation of the hydrolysis temperature has been found to have an effect on the biogas quality. The methane production in the hydrolysis was delayed in the mesophilic variant. In the psychrophilic variant this effect was not noticed during the duration of the trial (*Table 1*).

Conclusions and prospect

In the trials conducted up to now a good degree of degradation of the oDM from 75 to 85 % was achieved. The biogas and methane yields varied between 600-800 and 300-400 lN respectively and matched the degree of degradation. This biogas yields were realised in only 25 to 30 days. The grass silage revealed promising characteristics for the hydrolysis at the pH of 5. The highest degree of degradation, the highest biogas and methane yield was achieved in the thermophilic hydrolysis.

In the following trials it is planned to study the parameters that have an influence on the degree of the organic dry matter in the hydrolysis and the methane production in both stages.

Variante / Variation		Thermophil / thermophilic	Mesophil / mesophilic	Psychrophil / psychrophilic
Spez. Biogasertrag / spec. biogas yield	l_N/ kg oTS / l_N/ kg oDM	842,71	746,19	521,81
Spez. Methanertrag / spec. methane yield	l_N/ kg oTS / l_N/ kg oDM	430,64	369,34	268,95
Abbaugrad / degree of degradation	% der oTS	75,77	66,45	37,72
Mittel des CO_2-Gehaltes des Hydrolysegases / average of the CO_2 content of the Gas of the hydrolysis stages	Vol. %	56,87	58,32	71,65
Mittel des CH_4-Gehaltes des Hydrolysegases / average of the CH_4 content of the Gas of the hydrolysis stages	Vol. %	36,32	33,57	10,38

Table 1: Specific gas- and methane yield and degrees of degradation at the different temperature levels in the hydrolysis stages of the two stage digestion of grass silage

Literature

Books are marked by •

[1] *Rösch, C.*: Abschätzung der verfügbaren Grünlandflächen in Baden-Württemberg und ihr Beitrag zur Energieversorgung. Vorstellung des Abschlussberichts und der Ergebnisse des Forschungsprojekts des MLR „Energie aus dem Grünland – eine nachhaltige Entwicklung?“, Stuttgart-Hohenheim, 2007

[2] • *Wellinger, A., U. Baserga, W. Edelmann, K. Egger und B. Seiler*: Biogas-Handbuch – Grundlagen-Planung-Betrieb landwirtschaftlicher Anlagen. Verlag Wirz, Aarau, 2. Auflage, 1991

[3] *Weiland, P.*: Biologie der Biogaserzeugung. ZNR Biogastagung, Bad Sassendorf-Ostinghausen, 2003