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Fermentation of Forage Maize Silage without Liquid Manure

Currently process disorders are increasingly being observed in agricultural biogas plants, when little or no liquid manure is used for the fermentation of renewable raw materials. The investigation presented here verifies that a lack of trace elements is one of the possible reasons for the process disorders. By adding technical substrates, this deficiency could be balanced in lab experiments and long term process stabilization was achieved.

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Keywords

Biogas, methane, forage maize silage, anaerobic digestion without liquid manure, trace elements

Before the amendment of the German renewable energy sources act (EEG) in the year 2004, agricultural biogas plants in Germany were mainly fed with liquid manure and biogenic residual matter [3]. With this amendment the use of energy crops has been greatly supported for the first time, so that the range of input of the added substrate has clearly undergone a significant change in the past years [5, 6]. More and more biogas plants are solely or mainly operated with energy crops und do without adding the stabilising effect of manure.

Process disorders when operating without manure

In the past months there have been clear signs of increasing process disorders with biogas plants fed solely one-sidedly. Especially with completely stirred tank reactors, which have been operated quasi continuously and manure free, the first few months after starting procedures (executed on the basis of a digester filled with liquid manure) were free of disorders, with an organic loading rate of up to 4 kg ODM per m^3 liquid volume/ day. In spite of unchanged feeding, a number of plants revealed a considerable increase in volatile fatty acid concentration in the fermentating substrate with a simultaneous shift of the acid pattern to propionic acid after six to twelve months. The cause for the very gradual and late development of the destabilisation process may be an increasing lack, as well as the building up of the concentration of inhibiting materials. Within the process a balance is achieved only after three to five retention times depending on the supplied substrates. As the retention times may partly be over 100 days at continuously fed plants, and only a little fermenting substrate is chanelled from the digesters during the starting phase, it takes a long time until more than 95% of the basic material of the process has been displaced (*Fig. 1*). Remains of the initial input of liquid manure are still present. Accordingly, disorders of the process biology of the biogas plants, which have had a long retention time, sometimes only appear after one year.

The aim of this research is to guarantee a longlasting, stable manure free fermentation of energy crops.

Pre test

The starting point of the research was the question, which contents in the manure are responsible for stabilizing the biogas process. To achieve this, the effect on a formerly stable co-fermentation process without the addition of manure was initially examined. The examinations were done in lying, completely stirred tank reactors with a liquid volume of 17 litres in the biogas laboratory of the University of Hohenheim [2]. The starting point was a co-digestion of maize silage with cattle manure, which was put into operation for more than three retention times in the mesophilic range (37 °C), with an organic loading rate of 2.5 g ODM I^{-1} d^{-1}. The digesters were fed once a day, i.e. quasi continuously. The average retention time was limited to 35 days by adding tap water. Before starting the test all the digesters registered a fatty acid concentration below 300 ppm acetic acid equivalents. Transfering them into a manure free fermentation was executed by substituting the daily collected manure with tap water – the retention time remained unchanged, the organic loading rate was reduced by the organic substance in the manure (0.3 g ODM $I^{-1}d^{-1}$) to 2.2 ODM $I^{-1}d^{-1}$.

After stopping the manure supply, remarkable process disorders appeared, already during the first retention time, which could not be rectified even by halving the daily supply of maize silage. Within the first three retention times, the buffering capacity in the fermentation substrate was reduced by 63%, the DM-content by 50%, the ammonium concentration by 52% and the trace element concentration, essential elements for the methanogenic micro organisms [4] by 25 to 75%.

Adding water to reduce the retention time, resulted in a reduction of the ammonium- and trace element concentrations, although this only happened to the same extent as formerly in the longterm stable co-fermenta-

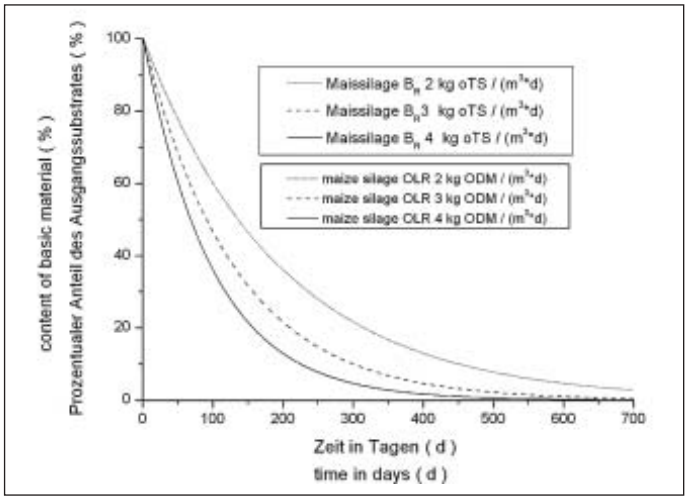

Fig. 1: Displacement of the ibasic material within the digester, depending on the organic loading rate

tion. The changes mentioned thus are only due to the lack of the contents in the manure – another dilution wasn't done, as the manure was only substituted by water, which was not added as well.

Addition of auxiliary agents

In order to provide an identical starting point in all digesters for the subsequent test, all the digesting containers were filled with substrate from an agricultural biogas plant and they were then operated over a period of 2.5 retention times in the mesophilic range as co-fermentation of maize silage and cattle manure. The average retention time was limited to 40 days by adding tap water. The organic loading rate was initially 2.86 g ODM l^{-1} d^{-1}, whereby 0.36 g ODM l^{-1} d^{-1} came from the added cattle manure and 2.5 g ODM l^{-1} d^{-1} from the maize silage. Before the beginning of the manure free digestion, the ph-value in all the various digesters was between 7.21 and 7.23. The transfer into a manure free fermentation was done the same way as in the previous test, by substituting the manure with tap water, resulting in an organic rate of 2.5 g ODM l^{-1} d^{-1}. Nitrogen sources (*Table 1*), more buffering agents, wood fibres and trace elements were partly added to the different variants.

Result

25 to 30 days after the beginning of the test, the variants, where no trace elements had been added (*Table 1*), fell below ph 6.8 to 7.5 [1], which is the necessary neutral region for acetic acid- and methane-forming micro-organisms. At this point of time the acid concentration already was 2870 to 5070 ppm acetic acid equivalents. Only two weeks later the acid concentration of these variants already was 8830 to 10150 ppm acetic acid equivalents, the formed biogas amount was clearly below 0.6 litres per digester volume, with a methane concentration of less than 45%. The process revealed a massive disorder und was later discontinued.

The two variants, which a buffering agent or an nitrogen source, as well as wood fibres and trace elements had been added to, revealed a stable process run, continuing after the end of the third retention time. At this point of time more than 95% of the basic substrates had already been displaced from the digesters and a balance had been achieved, which prevented more disorders in the process. The overall acid concentration in the digester was partly below the registered value of 50 ppm and a maximum of 300 ppm acetic acid equivalents. The reactor specific gas yield with up to 1.6 litres per liquid volume, as well as the substrate specific methan yield of up to 335 litres per kg ODM, correspond to the level of a stable running co-fermentation.

A slowing down by an insufficient buffer capacity of the fermenting substrate for the manure free fermentation can be excluded in the tests that were executed, as an corresponding amount of buffer substances like in co-fermentation, was added in variant 1. In comparison to the checking variant, though, no stabilization was noticed. A positive influence by adding wood fibres couldn't be detected either.

Table 1: Variants conducted

Variants	Added Substances
Control	only maize silage + water
1	buffer + wood fibres
2	trace elements + N-source + wood fibres
3	trace elements + buffer

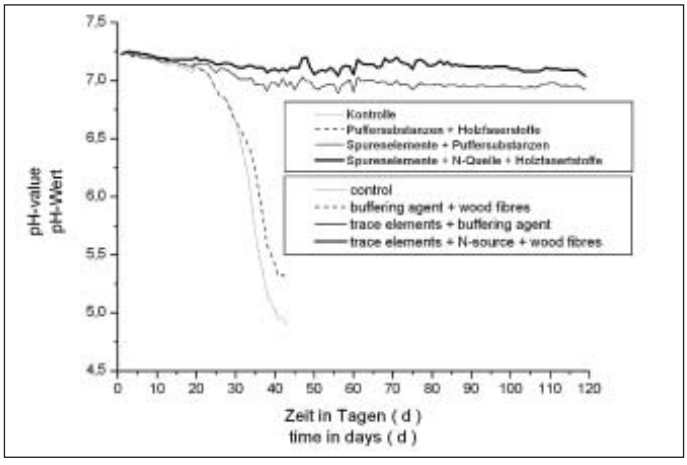

Fig. 2: Change of pH-values depending on the substances supplied

On the other hand, if trace elements were added to the process, a stable process always resulted, independently of adding N-sources or a buffer substance. Tests with only trace elements are currently being carried out.

Conclusions and future tests

When transfering a formerly stable co-fermentation of maize silage and liquid manure into a manure free fermentation, by substituting manure with water, the concentration of different substances in the digester was reduced - besides the DM-content, the buffer capacity and the ammonium concentration, the result was a reduction of all registered trace elements. It was possible to stabilize the forming of biogas by adding trace elements, contained in the manure in the form of technical substances. So we can assume that the variants, where nothing was added and which therefore became destabilized in the process, are deficient.

Literature

Books are marked by •

[1] • *Braun, R.*: Biogas - Methangärung organischer Abfallstoffe. 1982

[2] • *Lemmer, A.*: Kofermentation von Grüngut in landwirtschaftlichen Biogasanlagen. Dissertation, Universität Hohenheim, 2005

[3] *Oechsner, H.*: Aktueller Stand der Biogasproduktion. Fachtagung der Arbeitsgemeinschaft Landtechnik und ländliches Bauwesen Baden-Württemberg e. V. am 13./14. 3. 2003 in Stuttgart Hohenheim, S. 101-111

[4] *Sahm, H.*: Biologie der Methan-Bildung. Chem.-Ing.-Tech. 53 (1981), Nr. 11, S. 854 – 863

[5] *Vogtherr, J.*: Persönliche Mitteilung, Bearbeiter Bundesmessprogramm 2, Landesanstalt für Landwirtschaftliches Maschinen- und Bauwesen, 2006

[6] *Weiland, P.*: Biogas – Stand und Perspektiven der Erzeugung und Nutzung in Deutschland. DAF-Tagung „Energie aus Biomasse", Braunschweig, 25./26. Oktober 2006