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Silage Fermentation in Accessible Box-Fermenters

A range of procedures are used for the anaerobic fermentation of materials like solid manure or fresh or ensiled crops. On farms with livestock, liquid systems are preferred, because of liquid manure. For farms with no livestock, dry fermentation systems, e.g. box-like fermenters filled by wheel-loaders, are practical. Till now forage maize silage in box-like fermenters had to be entirely inoculated with digested substrate for anaerobic digestion to occur. A sufficiently large container with leachate and intensive watering with leachate make inoculation unnecessary, and require significantly less digestion capacity. Investments are smaller and they pay off sooner.

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Discontinuous processes, like sprinkled box-like digesters have been investigated , in order to reduce the investments for the production of biogas. The filled boxes are sprinkled with process water, the so-called percolate. The percolate is collected at the bottom of the boxes, stored in a tank and re-used for the sprinkling process. In a plant with three digesters, the boxes can be filled in the following way: In the first week digester A, in the second week digester B, in the third week digester C and in the fourth week again digester A, etc..

So far, the digesters have been fed with a mixture of fermentation residues (degraded material) and fresh biomass (e.g., forage maize silage, etc.). The amount of the fermentation residue (by weight) lies generally over the amount of the fresh material, in some cases over 80 % [3]. Due to the high proportion of fermentation residues, the digesters must be dimensioned accordingly. The mixing of fermentation residues and fresh material before placing it into the digester is an additional operation step.

On the other hand, it must be assumed that methanogenic microorganisms are introduced with the percolate and that organic acids are leached out with them. The importance of this lies in the fact that more lactic acid is generated at low pH-values, which is a bactericide [2]. Due to the rapid acidification processes at the beginning of the fermentation, the initial phase must be seen as critical. This critical phase can be avoided by rinsing out and by re-distributing the organic acids to the already more advanced digesters, regarding fermentation.

In the tests with biowaste it was possible to determine that the addition of fermentation residues is not necessary [4].

The aim of the present investigation was to determine whether the digestion of an already strongly acidic substrate (like forage maize silage) is possible without the addition of fermentation residues.

Experimental set up

The forage maize corn was harvested as high-cut in the middle of September and the chopping length was 11 mm.

The tests were carried out in a climate chamber at 35 °C. Altogether eight containers (PE, 120 l) have been used. This means twice one container with an already 5,5 weeks digested biomass, 1 container with 3,5 weeks digested biomass, 1 container with forage maize silage and 1 container with percolate. The percolate was sucked off from the digester containing the digested biomass and/or forage maize silage and sprinkled from there into the digester containing biomass and/or forage maize silage.

The containers allow to control the sprinkling process, to determine the amount and quality of the biogas and to determine the pH-values of the sucked off percolate.

Tubing pumps have been used for the sprinkling process, special gas counters to measure the gas amount and gas measuring devices to determine the quality of the gas in terms of CH_4, CO_2 and O_2. The following values have been measured daily: the amount of gas produced, its methane, carbon dioxide and oxygen content, the pH-values of the percolate, the current air pressure and the air temperature.

The following variants were analysed:
- 70 l process water (percolate)
- 60 l forage maize silage
- Fermentation residues of 70 l, 5,5 weeks digested biowaste (pH-value 8),
- Fermentation residues of 70 l, 3,5 weeks digested biowaste (pH-value 8).

The same experimental set up has been operating 1,5 weeks before the beginning of the analysis, in order to adapt the bacteria from biowaste to forage maize silage. The percolation was stopped after 6 days. Thus it was guaranteed that the gas production was not influenced by the conversion phase.

Results

The methane production started immediately and showed a typical process. Within 18 days, 318 standard liters of methane per kg dry organic matter were produced.

All digesters as well as the percolate container showed after the filling with maize silage a rise of methane production, which is

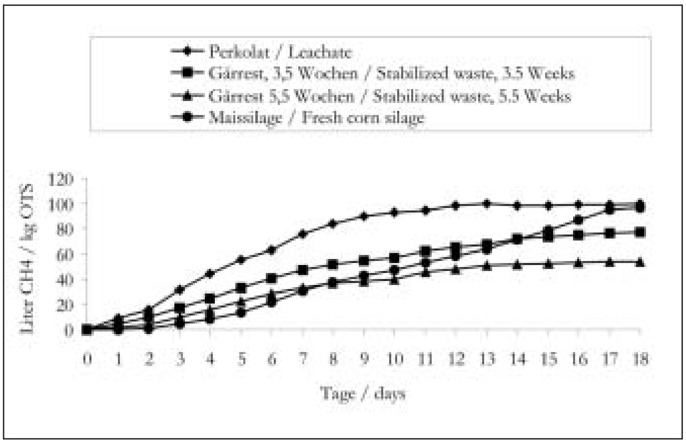

Fig. 1: Methane yield (l CH_4/kg VS) in the different digesters

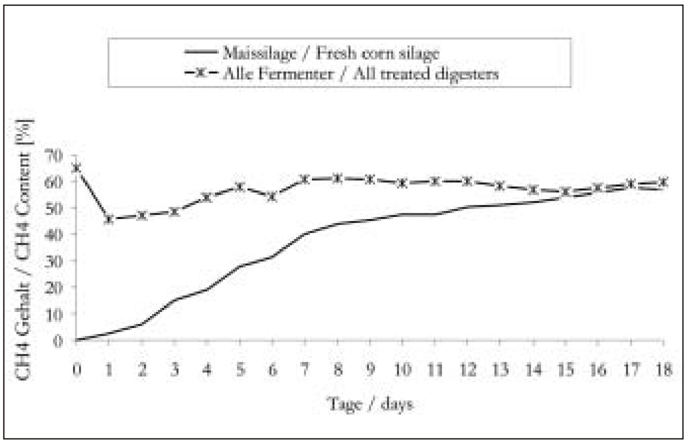

Fig. 2: Development of methane content in the biogas

well known for the case of biowaste (*Fig. 1*). In particular, the percolate tank and the digester with the fermentation residues degraded soluble fatty acids during the initial phase. The freshly, with maize silage set digester showed first a delay but then it was clearly involved in the methane production.

The methane content in the digester with maize silage rose promptly and achieved with 57% (*Fig. 2*) almost as high values as in the tests with biowaste. The digestion of maize silage showed average methane contents between 40 and 60 % in the biogas.

The pH-values of the sucked off percolate of the freshly set digester fell for only three days to values below 7. In the other digesters and in the percolate tank, the pH-values were permanently between 7.8 and 8.0.

The pH-value of the remaining process water does, however, not reflect sufficiently the pH conditions inside the digester. In this aspect, it is possible to differentiate 2 zones with in the digester. Within a 20 to 30 cm wide region, around the sprinkler, the pH-value does not correspond with the one of the percolate. In the boundary region far from the sprinkler, in the upper centimeters, the pH-value was with 5.6 significantly lower. Thus, a good distribution of the percolate is necessary in order to achieve good methane fermentation in the entire digester. For this purpose, it is advisable to use e.g. water sprinklers used in fire-protection, since they have strong nozzles of about 1 cm for the outlet and ideally formed baffle plates for the droplet distribution.

The metabolisable energy could be converted completely into biogas (*Table 1*).

The digestible organic dry matter was completely degraded (*Table 2*). This is confirmed by the measurement of the ash content before and after the test. From the ash content it is possible to determine a degradation degree of 73% of the organic dry matter.

Table 1: Energy balance

	Energy [MJ/kg DM]
MJME maize silage [MJ/kg DM]	10,6
Energy of gas phase [MJ/kg DM]	11,7

Table 2: Mass flow balance of dry matter (calculated via biogas)

dO (digestible organic dry matter)	[g/100 g ODM]
maize silage	71,63
produced methane	24,4
produced CO_2	53,7
digested organic dry matter	78

Conclusions

By pumping the process water into a common percolate tank for all the digesters, mixing of fresh material and fermentation residues in the case of maize corn silage can be avoided.

An inhibition of the fermentation could not be found. This has two potential effects:

- the volume of the digester can be reduced, or
- the reaction times can be shortened and the throughput increased.

In the first case the investments are reduced, in the second one the gas yield and thus the revenues are increased.

Also the acidification of other organic substances, such as biowaste, released e.g. by a malfunction of the pumps, has no unfavourable effects on the operability of plants that are being operated without the addition of fermentation residues.

Therefore, the renouncement of an inoculation with fermentation residues would have in every case positive effect on the economic efficiency of a biogas facility. However, sufficient water conductivity must also be given in the case of digested substrate. The fermentation residue was not analysed for its water conductivity. If necessary, mixtures with structural material must be used.

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