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Methane yield from co-fermentation of ensiled fodder beet slurry

Fodder beet gives a high yield of easily fermented organic dry matter per hectare. Ensiled in liquid form this product was co-fermented with cattle manure slurry in Hohenheim biogas laboratory with the fermenter operated continuously. As control, pure cattle manure slurry was fermented so that the biogas contribution from the beet could be calculated. The best substrate-specific methane yields were 499 and 557 l/kg organic dry matter with thermophilic bacterial fermentation at 75% and 50% beet proportion in the organic dry matter over 15 and 20 days respectively.

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Operators of biogas plants continuously try to increase daily gas production through improving reactor efficiency. An aid here can be the anaerobic co-fermentation of easily fermentable organic remainders and discarded substances as well as specifically grown energy crop plants along with livestock manure slurry. When using bio-refuse there are a large number of environmental and hygienic regulations to observe. This however does not apply to remainders or rejects from crop production or from specially grown energy crops. Such substrates can therefore be applicable in farm biogas plants especially those on intensive livestock production farms. Along with maize, cereals and other energy-rich field products, fodder and sugar beet can be used as energy plants. Both of the latter offer very high yields of easily fermentable organic dry matter (odm) per ha (18 to 20 t/ha). The beet slurry conserved through ensiling in liquid form can be used throughout the year as a substrate with very low energy losses [2] for fully automatic feeding in the fermenter.

Target of this investigation was to increase biogas yield based on the introduced organic dry matter or on the available reactor capacity through the mixing of cattle manure slurry with differing proportions of liquid ensiled fodder beet slurry. Other influential factors investigated were the length of hydraulic retention and the temperatures involved.

The trial plant

comprised 15 horizontal through-flow fermenters with stopper control and a fermenting net volume of 16 l. The containers had wall heating with simple insulation. Mixing was by reel mixer. The amount of gas produced was measured by gas counter and wet gas meters in water models. The daily amount fed into the system depended on proposed daily loading (dependant on odm %, net volumes, length of time in fermenter) [1].

From the produced gas, the CH_4 and CO_2 contents were determined with an Ultramat (Siemens). The fermenter contents were regularly checked for pH and temperature and the pH was also read at the substrate exit. The odm content of the exit substrate was measured for determining break-down rate. Additionally, the investigation featured nutrient analyses of the input and exit materials.

Trial variants

For investigating the anaerobic degradation of ensiled beet slurry trial series were conducted with 25%, 50%, 75% and 100% proportions of beet in the substrate in terms of total odm as well as hydraulic retention periods of 15 and 20 days in thermophilic (54°C) and mesophilic (34°C) conditions. Each trial series was repeated three times. Controls were run parallel with pure cattle manure slurry fermented under the same parameters.

Substrate-specific gas yield

Gas yields were influenced by temperatures in the fermenter, length of fermenting period [3, 4] and proportion of beet slurry. The results are presented in detail below.

The substrate-specific gas yields in the thermophilic and mesophilic trial series were clearly different. With the thermophilic trials (54°C) and a hydraulic retention period of 15 days the biogas yield from pure cattle slurry was 318 l, with co-fermentation between 640 l (25%) and 874 l (75%) per kg odm, depending on the amount of added forage beet slurry. The difference between cattle slurry and maximum biogas yield (with 75% beet proportion) was 175% in this case. The maximum methane yield lay between 178 and 499 l/kg odm, with a clear difference between cattle slurry and maximum methane yield of 180%. According to this 75% odm forage beet slurry as proportion of the co-ferment was optimal for a high substrate-specific (biogas) methane yield with thermophilic degradation during 15 days hydraulic retention period.

In the 20-day period the biogas yield was between 262 and 982 l/kg odm, i.e., a difference of 275% between cattle slurry and maximum biogas yield (*fig. 1*). The methane yield varied from 149 to 557 l/kg odm, representing a 274% difference. Accordingly the variants with 50% beet proportion and fermenting period of 20 days under thermo-

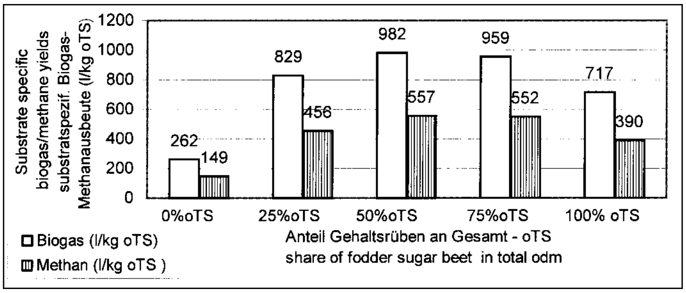

Fig. 1: Substrate specific biogas/methane yields with thermophilic fermentation (54 °C) with different proportions of liquid fodder beet silage and cattle slurry under 20 days of hydraulic retention time

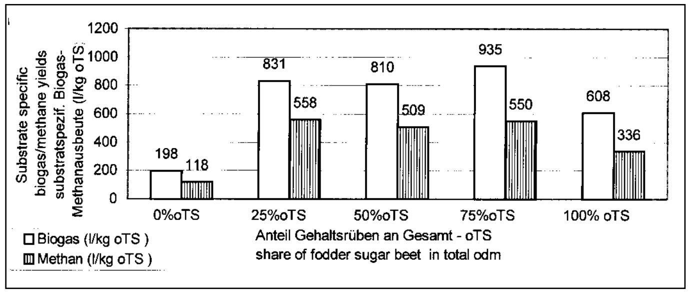

Fig. 2: Substrate-specific biogas/methane yields with mesophilic fermentation (34 °C) with different proportions of liquid fodder beet silage and cattle slurry under 20 days of hydraulic retention time

philic conditions offered the best substrate-specific biogas and methane yield.

With the trials at mesophilic (34 °C) temperature and hydraulic retention periods of 15 days the substrate-specific biogas yield lay between 124 (0%) and 734 l/kg odm (50%). The 492% difference meant that with a beet slurry portion of 50% of odm the microbially degradable dm was much better utilised compared with pure cattle slurry. The methane yield ranged from 73 to 396 l/kg odm. Thus the difference was 442%. With 20 day hydraulic retention (*fig. 2*) the biogas yield lay between 198 (0%) and 935 l/kg odm (75%) with a difference of 372%. The methane yield varied between 118 and 558 l/kg odm, i.e., an improvement of 373% at even 25% beet proportion in the dm.

Reactor-specific methane yield

Because of the good microbial degradation capacity up to 62.5% of the odm could be utilised. This gave a very intensive exploitation of the available fermenter volume as shown in the reactor-specific gas yields in *figure 3*.

The reactor-specific methane yields in the mesophilic area (34°C) over 15 days hydraulic retention was from 0.41 to 1.41 m^3/m^3•d (fig.3). Thus there was a difference of 244% between the best and the worst yield. With 20 days hydraulic retention the values were from 0.50 to 1.79 m^3/m^3•d, i.e. a difference of 258%.

In the thermophilic area (54 °C) over 15 days, the reactor-specific methane yield lay between 0.95 und 2.41 m^3/m^3•d, a difference of 154%. Over 20 days the respective figures were 0.59 and 1.84 m^3/m^3•d with 212% between pure cattle slurry and the best value from 100% beet content. Thus, despite the shorter hydraulic retention period with the beet substrtate, at given reactor volumes very high daily methane yields could be reached where, instead of the generally used mesophilic temperature, thermophilic levels were applied. This approach more than made up for the longer hydraulic retention period required. This allowed an enormous efficiency increase right up to definitely higher possible daily electricity sales.

The maximum area exploitation of 6.6 g/l•d was produced with a hydraulic retention period of 20 days, thermophilic degradation and pure beet slurry. Minimum exploitation was 3.9 g/l•d at 20 days with mesophilic degradation and pure cattle slurrry. Fermenting the beet silage on its own led to very high fermenter exploitation reduced methane yield per kg substrate and instable pH values.

Summary and perspectives

The trials indicated clear differences between mesophilic and thermophilic co-fermentation of ensiled forage beet slurry and cattle manure slurry. In order to achieve the highest methane content and greatest daily biogas yield per kg substrate, a buffering of the substrate (here with cattle slurry) was required. Until optimum buffering is achieved the biogas and methane yields increased. The highest daily reactor-specific methane production was achieved with high proportions of forage beet slurry at thermophilic temperature and over 15 days hydraulic retention period. For economic viability the farm-specific costs for beet cultivation, silage storage, labour, machinery, alternative enterprise costings and interest charges on own capital have to be taken account of. After applying all costs and taking account of the increased energy yield through electricity sales compared with gas yield from pure cattle slurry, one can then present results in individual cases which then show whether farm profits can be raised through application of ensiled fodder beet slurry in biogas plants.

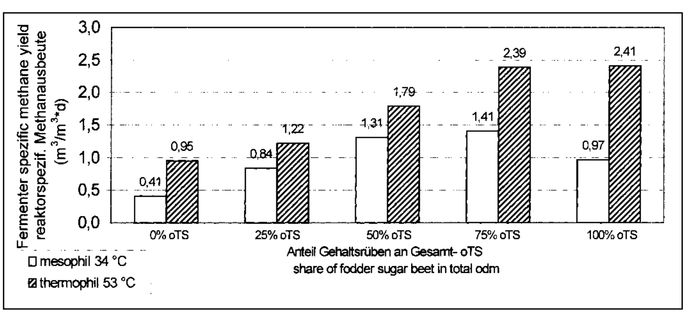

Fig. 3: Fermenter-specific methane yield with rnesophilic and thermophilic fermentation (34 °C) of liquid cattle manure and liquid fodder beet silage under 15 days of hydraulic retention time

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