Presentation at the 14th Annual convention "fermentation gas and bio energy in agriculture "
November 30 to December 1, 2005
in Wolpertshausen, Germany

Organizer: Int. Biogas and Bioenergy Center of Competence (IBBK)

Lecture title: Renewable primary products in biogas plant without manure – does it work?

Presenter: Andreas Krieg, Dipl. – Agricultural Engineer
Krieg & Fischer Ingenieure GmbH
Hannah Vogt STR. 1
37085 Goettingen
www.kriegfischer.de

Biogas plants, whose input consists of vegetable materials as well as liquid manure and muck, are called REC ("Renewable Energy Crop) digesters. At this time these facilities are being promoted by the German government through cash incentives and guarantees for a limited time.

It has been common for agricultural biological gas facilities to mix vegetable materials with liquid manure or sludge from farm animal operations. Now, non animal enterprises are asking whether it is possible to sustain biogas fermentation from crops alone. This paper presents a discussion of the pros and cons, of operating fermenters without liquid manure or sludge.

In the past two years more than two dozen renewable energy crop biogas facilities using silage of various fodder plants as well as grain, potatoes and other root crops have been built. Liquid manure or sludge was not used in these pure energy crop fermenters. Krieg & Fischer Ingenieure GmbH engineers were responsible for planning half of these facilities ranging in size from 60 KW and to 1,000 KW of electrical power, which corresponds to a daily input of approximately 4 to 55 tons of fodder. However, at this time a predominant number of the so called REC plants are still operated with more or less liquid manure and sludge.

Over the last few years several energy crop anaerobic digesters have been built by different suppliers. These biogas plants have been built using different digester designs, process engineering and also slightly different input substrates. Now, after some years, we can collect experiences and analyze them. To date energy crop plants operating without liquid manure have a positive track record. These facilities are demonstrating that biogas can be sustainably produced without liquid manure.

As more facilities are built more experience is collected regarding various types of input fodder, process engineering and different types of digester or biogas plants respectively.

The records indicate that silage made from green crops such as corn and fodder grasses are preferred for energy production. Other less used crops include grain and vegetables such as fodder beets. At this time, plant breeders are working intensively to develop plants which will yield high amounts of biogas in the fermenter and optimal volumes per acre - in other words the perfect renewable energy crop.

Several process engineering concepts have been developed and applied to energy crop biogas plants. For example weight proportioned direct addition systems for the fodder or dry feed materials are widely applied. To ensure optimal fermentation the digester content needs to be mixed. In some cases engineers have selected efficient mixers and agitators that have been field proven and which efficiently homogenize the fermenter contents. In other cases, however, simply a higher number of more powerful submerged mixers are used to do the job. There are currently three process system types in use: (1) the conventional one way flow through fermenter or fermenters, (2) the sequential feedback fermenter in which there is a reintroduction of some effluent with the input material into the first container for purpose of inoculation and feed dilution and (3) batch-wise “dry“ fermentation usually involving re-circulating percolate.

The most common designs of fermentation vessels include a standing cylinder tank with a diameter to height ratio of approximately 1:1, a standing cylindrical tank with relative small height to diameter relationship and oblong lying vessels with a square cross section. Each design has its own specific agitation and mixing system designed to keep the conditions in all parts of the container as uniform or homogeneous as possible. An exemption is the less common percolation system.

In principle the fermentation process of exclusively renewable energy crops no longer presents technical or biological challenges. The industry has learned to use high quality construction material due to the corrosiveness of corn and other type of silage. Any added components need to be suitable for any "new" input substrate. In addition the operator needs to take a closer look at more refined analytical data (e.g. volatile fatty acids become more important with energy crop digesting plants than with manure digesting plants. Compared to manure digesting plants, however, the weighting of material, technical and analytical parameters are significantly different.

Depending on the kind of liquid manure used the concentrations of individual macro nutrients such as nitrogen may have a limiting effect on the anaerobic decomposition process. Normally this is not the case and the manure includes trace elements and enzymes essential to the biological process. With pure renewable energy crop fodder, depending on the plant type, a compound's upper and lower limits of macro nutrients and trace elements may be exceeded. This means that to optimize the biogas yield from the renewable energy crop fermenter the makeup of the fodder and the availability of nutrients and trace elements must be considered in more detail.

Using renewable energy crops will supply the microbes in the fermenter with a comparatively high portion of easily available and quickly digested carbohydrates. To maintain equilibrium within the various digesting steps the substrate must be fed several times over the day. In order for this to be practical a systematic method to meter the fodder into the fermenter and a basic level of automation is required.

It has been proven that the particle size of the substrate has a substantial influence on the effectiveness of mixing and the rate of anaerobic decomposition. Silages with an average chaff length of less than 1 cm are clearly preferable. As for fermentation of whole grain, no clear difference between feeding whole kernels, crushed and ground grain was found at retention times of 50 days and more.

The classic single stage fermentation, i.e. without feedback of fermenting substrate from a later step, can operate with a daily organic loading rate of up to 4.5 kg VS/m³/d (Volatile Solids per cubic meter per day) of fermenter volume. In all cases it is essential that the fermenting substrate is sufficiently mixed to ensure that the entire volume is truly homogeneous.

Sequential fermentation systems which feed back some of the effluent to the beginning report higher organic loading rates. Although uncommon some report loading rates as high as 7.5 kg VS/m³/d. The comparability of this characteristic between the two systems is questionable. While returning the effluent dilutes the incoming feed and tends to reduce the loading rate, some of the anaerobic decomposing takes place in the secondary and other downstream containers. This leads to the question of what fermenter volume was used in the calculation.

As for the dry batch by batch fermentation the loading rate cannot be used as a reference parameter.

Selection of operating temperature takes a secondary role when the fermentation materials are dominated by liquid manure - for pure energy crop systems it is, however, more important. Depending on the fodder, the ammonium N content in the fermenter can be between 1 and 7 g/l. It is our experience that starting at about 2.5 g/l NH4-N and above, the thermophilic temperature range has a disadvantage over the mesophilic range (36-41 ℃). It is possible that fe rmenting biology would adapt itself over time to the NH4-N concentration, but it cannot be clearly confirmed at this time.

Nevertheless, there are advantages in operating the fermenter at approx. 52 ℃. The decomposition of the substrate seems to progress more quickly and completely. It requires less energy to mix. However the methane concentration is not significantly different than from mesophilic operations.

Fermentation of mainly energy crops such as corn and other whole plant silage produces methane concentrations between 50 and 54% in the raw gas. The concentration of noxious gas compounds, e.g. hydrogen sulfide (H_2S) is comparatively small ranging from approximately 100 to 500 ppm (parts per million). Animal derived feed including liquid manure and sludge tend to sharply increase the H_2S concentration in the raw gas.

If a facility is to be operated on renewable crops alone special attention must be paid to the substrate composition and facility management. The value of operation monitoring becomes more important. Substrate utilization and process optimization in these facilities tends to be more important than in a facility used as supplemental income for an animal farm. Energy crop facilities tend to be the primarily business venture and depend on maximizing income and minimizing cost for survival.

To evaluate the health of the anaerobic decomposition process, analysis of free organic acids as well as the buffer capacity by titration is needed. By using these methods the start-up process can be managed within limits enabling the operator to achieve the rated gas output and optimize the process within 6 weeks.

The gas chromatograph can also be used to determine the organic acid concentration (acetic acid plus others). This can be reliably used to determine whether the anaerobic decomposition is in equilibrium.

The raw gas composition is a further indication of process health but the measurement must be made as soon after sampling as possible. Fermenters with a rigid cover are best suited as they have a constant gas volume. By increasing the load in the fermenting process the methane content drops and at the same time the level of H2S increases. It has also been observed that the fewer times the fermenter receives feed in a day the more variation there is in the methane and carbon dioxide concentration in the raw gas. These fermenters operate best when fed as close to continuously as possible.

It is also worth mentioning that the biological activity in a fermenter can be determined in containers with fixed covers by measuring the gas pressure. Knowing this, the first plant operators began to use the gas pressure as a guide to feeding.

Altogether these parameters provide sufficient aids for the renewable energy crop plant operators enabling them to optimize gas production and achieve utilization of over 90%. Continuing to collect and evaluate operational experience as well as conducting accompanying research are important for the future of renewable energy crop plant development.

Krieg & Fischer Ingenieure GmbH – Hannah-Vogt-Str.1 – D-37085 Göttingen – Tel.: ++49 (0)551-900363-0
www.kriegfischer.de