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Monofermentation of Nutritional Waste in Biogas Plants

Pilot - Biogas plant

In a joint project a process engineering technique is being developed for anaerobic monofermentation of nutritional wastes with high energy concentrations and low structural material content. In the first part of the project, systematic tests on the monofermentation of nutritional wastes were made in the biogas laboratory. Hygiene and engineering investigations followed at the pilot biogas plant in Donaueschingen.

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Keywords

Biogas, monofermentation, cogeneration

Relevant knowledge and experiences have been extracted from the first part of the research project during the laboratory investigations about the characteristics of monofermentation of nutritional wastes. They were transferred and utilised for the planning and construction of the pilot - biogas plant in Donaueschingen. With this unit the practicability of the engineering process should be testified for the commercial scale. Therefore the process engineering parameters had been regularly recorded for the single components of the biogas plant for a period of 192 days. The aim was to evaluate the performance and effectiveness of the utilised process engineering techniques. The scientific investigation aimed to prove whether the performance parameters of the laboratory experiments could be realised under practical conditions with special regard to the optimisation and standardisation of the process. In addition the hygienic parameters being decisive for the practical use of the system had been investigated by the Institute for Environmental and Animal Hygiene at Hohenheim University (head: Prof. Dr. R. Böhm) to evaluate epidemic hygiene and environmental safety.

Material and methods

Within the framework of the research project, a pilot - biogas plant has been constructed and is operated by the company "Biogas Systemtechnik Deutschland GmbH", Donaueschingen, in close co-operation with the company "Ing. Friedrich Bauer GmbH", Kemmelbach, Austria, which is schematically shown in *Figure 1*.

Investigations at the pilot - biogas plant were focussed on the following parameters:

- reaction of substrate and gas parameters during the starting phase of the biogas plant;
- precise temperature control of the horizontal fermenters in the mesophilic temperature range;
- verification of the guaranteed values being promised by the manufacturer of the plant concerning a reactor specific biogas production of 2.5 m^3 biogas per m^3 reactor volume and day (m^3 m^{-3} RV d^{-1});

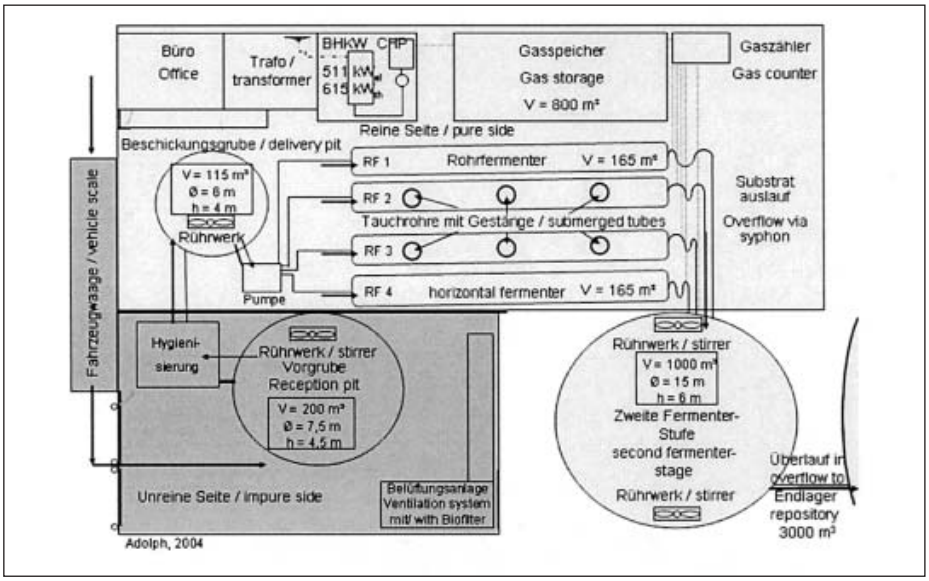

Fig.1: Scheme of the pilot-biogas plant with four horizontal cylindrical fermenters (each 165 m^3), one second stage fermenter (vertical cylinder with 1000 m^3) and gasmotor (511 kW_{el}, 615 kW_{th}) cogeneration unit

• stabilisation and optimisation of the process in the thermophilic temperature range.

Therefore the two middle horizontal fermenters had been specially equipped with installations to take samples and to collect measuring data (*Fig. 1*). In every of these two fermenters substrate samples could be extracted at three different locations and by incorporated sensors pH and temperature could be measured (marked in Fig. 1 by circles). During the whole investigation period, substrate samples had been taken weekly at in total seven locations of the unit. They got afterwards analysed for decomposition rate and concentration of volatile fatty acids. Based on these data, stability and performance of the used process engineering techniques were tested. Additionally the measuring technique for the gas production rates being installed by the plant owner provided continuously data about the gas yields from every single horizontal fermenter. The composition of the biogas was analysed by a stationary measuring system based on a gas chromatograph (Perkin Elmer®, FH Furtwangen) and by a mobile gas analyser (Siemens Ultramat 21®).

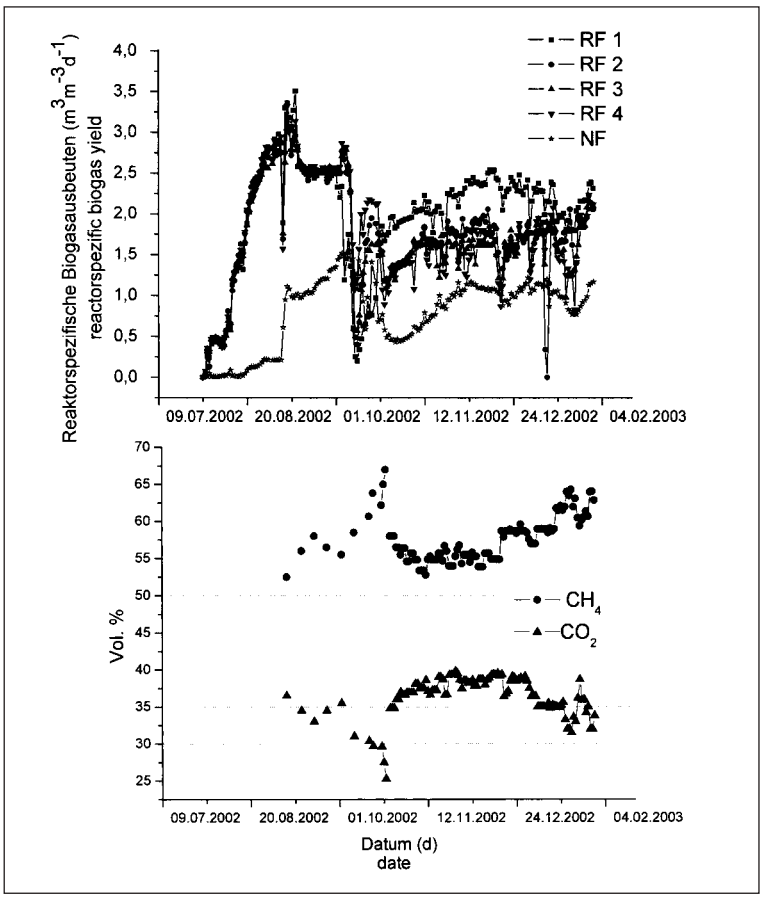

Fig. 2: Monofermentation of nutritional wastes - reactor-specific biogas yields and development of gas quality

Results

At first the control of the input masses had been done manually to slowly increase the daily input into the horizontal fermenters slowly, in order to continuously raise biogas production and to subsequently obtain an adaptation of the microbial population. The target rate was the guaranteed reactor specific biogas production of 2.5 m^3 m^{-3} RV d^{-1}. This characteristic value was achieved in all horizontal fermenters by the end of August 2002. Until the automatic input-control was activated, it was exceeded from time to time (*Fig. 2*). For around 20 days biogas production stayed constant with a methane content of in average 58.5 % CH_4 in the mixed biogas from the horizontal fermenters and from the second fermenter stage. Because of a defective biogas meter, the horizontal fermenters got overloaded in the beginning of October. This was due to incorrect signals, which were the calculation basis for determining the specific input mass of fresh substrate. Subsequently the concentration of volatile fatty acids increased rapidly up to 16500 ppm. As a result the pH - value in the horizontal fermenters dropped promptly down to values of 6.4 whereupon the input of fresh material was stopped to stabilise the process again. In order to re-establish biogas generation the daily input was increased slowly again. Furthermore fermented substrate from the second fermenter stage was recirculated until the end of the phase I. The nearly equal biogas production rates of the four horizontal fermenters at the beginning differed after that problematic phase quite significantly. The reason was that the input portions where adapted to actual pH - values. Subsequently also different gas production rates were measured in the horizontal fermenters. The reactor specific methane yields reached 1.0 m^3 CH_4 m^{-3} RV d^{-1} in the middle of phase I in all horizontal fermenters, whereas in the second fermenter stage 0.35 m^3 CH_4 m^{-3} RV d^{-1} were produced. The daily input rates in the phase of stabilised gas production were about 12 m^3 of fresh material per day with an average of 17 % odm. This resulted in a hydraulic loading rate of 3.1 kg odm m^{-3} RV d^{-1} related to the total of 660 m^3 volume of the horizontal fermenters. The values from the laboratory investigations with 0.8 - 1.25 m^3 CH_4 m^{-3} RV d^{-1} with a hydraulic loading rate of 3.5 kg odm m^{-3} RV d^{-1} in the mesophilic temperature range showed that the gas production rates in the horizontal fermenters of the commercial biogas plant corresponded at that time to those of the lab fermenters. In the horizontal fermenters 108 m^3 CH_4 t^{-1} odm was produced compared to an average of 245 m^3 CH_4 t^{-1} odm in the laboratory fermenters. The gas being generated in the second stage vertical fermenter has not been taken into account to secure comparability with the lab-experiment.

In the horizontal fermenters the concentrations of volatile fatty acids reached peak values of up to 16500 ppm. Especially the concentrations of propionic acid were after overloading the reactors at the beginning of the investigations on a level as high as 4500 ppm. At the end of the measuring period the propionic to acidic acid ratio in the horizontal fermenters was nearly 2 : 1 which is pointing at a severe instability of the fermentation biology (long version LANDTECHNIK - NET).

Perspectives

The investigations at the pilot biogas plant in Donaueschingen were concluded in January 2003 after at total 192 days. Compared to the preceding laboratory investigations in both fermenter stages higher substrate specific biogas and methane yields with better decomposition rates could be obtained due to the longer retention times of the substrate with up to 120 days compared to 26 days in the laboratory scale. But the intended processing capacity of about 22 t of fresh matter per day is not yet achieved. The better process performances which had been testified in the laboratory investigations under higher fermentation temperatures (thermophilic range) could not be verified in the pilot plant because the thermophilic process could not be conducted. Currently a second main fermenter and an additional intake and processing technique for packaged foodstuffs is installed as the next development phase. The results from the pilot plant confirmed that a monofermentation of nutritional waste is technically feasible, but that there are still several starting points to optimise the process and the strategies concerning aspects of process engineering and fermentation biology.