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# Monofermentation of Nutritional Wastes in Biogas Plants

## Laboratory Investigations

*In a joint project, a process engineering technique was developed for the anaerobic monofermentation of nutritional wastes with high energy concentrations and low contents of structural material. The pilot biogas plant was investigated for process engineering and hygienic parameters. Preliminary systematic investigations about the monofermentation of these nutritional wastes were carried out to obtain the necessary information about the reaction and performance of this substrate and plant operation.*

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## Keywords

Waste treatment, nutritional waste, anaerobic fermentation, methane

From community eating places like gastronomy, hospitals, canteens, student restaurants and barracks every year about two million tons of nutritional wastes are disposed in Germany. Additionally further considerable waste masses are produced in the food industry or occur from food marketing. The new EU - directive 1774/2002 [1] has to be applied since April 2003, prohibits the processing of these materials to animal feedstuff. This results in a severe waste problem with high costs for the utilisation respectively final treatment of these substrates according to the rules. The aim of these scientific investigations was to develop and test a suitable process engineering technique to utilise these nutritional wastes without additional agricultural cosubstrates, which means a "monofermentation", by generating regenerative energy in a combined heat and power plant (CHP) from the methane produced in this biogas plant.

### Material and methods

For the operation of the pilot biogas plant and for further investigations being connected to it plus for the process engineering developments, reliable basic data are decisive prerequisites for the different process strategies. Therefore three experimental variants had been led through in the biogas laboratory of the Institute of Agricultural Engineering at Hohenheim University after an initial phase of 29 days. Every experimental variant was led through with a hydraulic retention time of 26 days and a corresponding adaptation phase (*Fig. 1*).

To obtain data with an utmost of practical relevance, the following parameters had to be respected:

- preferably homogeneous substrate composition concerning nutrient and energy contents along the experimental period;
- exact temperature control in the mesophilic (40 °C) and thermophilic (55 °C) range;
- hydraulic loading rate: 3.5 and 5.1 kg odm/m$^3$ reactor volume • days (odm m$^{-3}$ RV d$^{-1}$);
- two stage process including a test of the load limit and a hydraulic loading rate of 10.1 kg odm m$^{-3}$ RV d$^{-1}$, related to the methanisation stage;
- stabilisation of process and adaptation in the intermediate phases.

Following these specifications the experimental design was set up, which is shown in *table 1*.

To control the process, daily $p_H$ - values, temperatures in the reactors, gas volume and gas composition had been registered. Beyond that, the decomposition rates had been computed weekly. Along the whole experimental phase fatty acid contents had been analysed regularly. Moreover the input and fermented substrates had been analysed for $BOD_5$ and $COD_5$ - values. In the present article the results of the $p_H$ - investigation and the reactor specific methane yields are presented to evaluate the stability and efficiency of the process.

### Results

The results being presented are mean values of the repetitions from partial experiments being described in the experimental design (Table 1) with n = 3 respectively n = 6. During phase I, the input volumes had been increased slowly up to the desired loading rate

*Table 1: Experimental design*

| Phase | Loading rate [kg odm m$^{-3}$ RV d$^{-1}$] | Kind of fermentation | Time of-experiment [d] | Repetitions [n] | Scope of temperature thermophil (55 °C) | meso-phil (40 °C) | Number of inputs per day |
|---|---|---|---|---|---|---|---|
| I | increasing | mono | 29 | 6 | • | • | 1 |
| | 5,1 | mono | 26 | 6 | • | • | 1 |
| II | 3,5 | mono | 26 | 3 | • | • | 1 |
| | 5,1 | mono | 26 | 3 | • | • | 1 |
| III | 10,1 | mono | 26 | 3 | • | • | 3 |

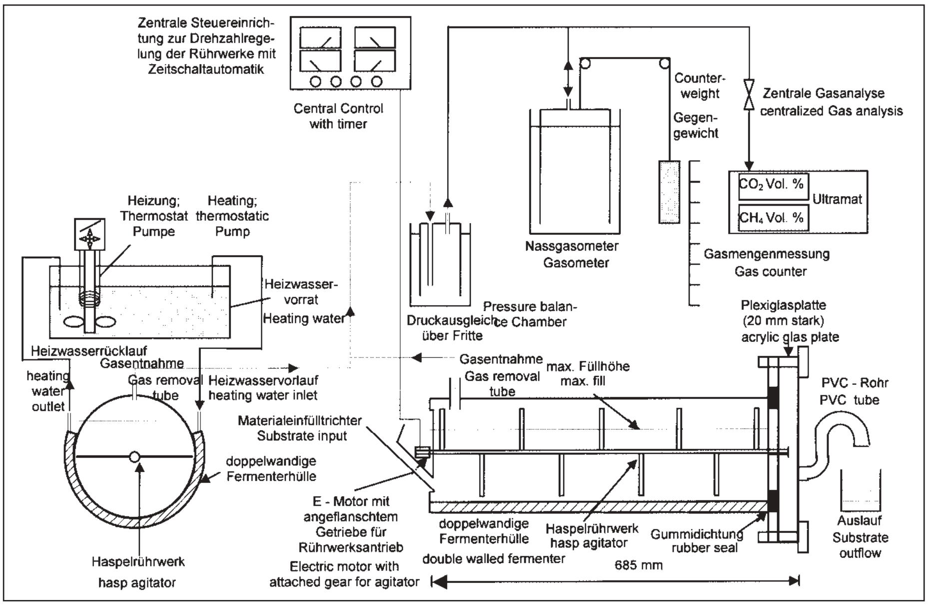


*Fig.1: Scheme of a horizontal Hohenheim laboratory biogas unit (16 l net volume, semicontinuous flow) with hasp agitator, gas storage and gas analysis*

of 5.1 kg odm m$^{-3}$ RV d$^{-1}$ so that the microbes should be able to adapt and that the process should not be immediately overloaded. The reactor specific methane yields increased in both temperature ranges up to value of about 2.12 l $CH_4$ l$^{-1}$ RV d$^{-1}$ (*fig. 2*). The different inoculants required different input masses in the initial phase. This resulted in higher reactor specific methane yields at the beginning in the mesophilic temperature range. Already during phase II a smooth dropping of $p_H$ - values was apparent in both temperature ranges. In the second part of phase II, during the test of process stability, the reactor specific methane yields in both temperature ranges were in the beginning at about 2.05 l $CH_4$ l$^{-1}$ RV d$^{-1}$. In the last third, the methane yields in the mesophilic temperature range decreased clearly, so that at the end of phase II only about 1.15 l $CH_4$ l$^{-1}$ RV d$^{-1}$ were generated. In the thermophilic range, the methane yields stayed constant at about 2.10 l $CH_4$ l$^{-1}$ RV d$^{-1}$. Also the $p_H$ - values decreased at the end of phase III. In the predominant part of this experimental phase the $p_H$ - values in the mesophilic reactors were oscillating around $p_H$ 7.6. Not until the last quarter of this phase they dropped significantly so that partly also values below $p_H$ 7.0 had been measured. It can be deduced that at the end of phase III in the mesophilic operation no stable process conditions were found and that the buffer capacity of the substrate was already exhausted.

In experimental phase IV it had to be found out, whether the process will also be stable under very high input rates, as long as it is run in two stages. Both, with thermophilic and mesophilic fermentation, $p_H$ - values decreased during the 26 days of experiment in the first process stage as it was expected down to $p_H$ 5 (long version in LANDTECHNIK-NET.com). Whereas in the second stage the $p_H$ - values could be maintained till the end at about 7.0, which is in the literature the lower limit for a stable process (*fig. 2*). After about 14 days of experiment, methane generation in the first stage (hydrolyses reactors) ceased independently of the fermentation temperature. The reactor specific methane yields were also in the two stage experiment under thermophilic conditions with an average of 1.78 l $CH_4$ l$^{-1}$ RV d$^{-1}$ higher than in mesophilic range with a mean value of 1.47 l $CH_4$ l$^{-1}$ RV d$^{-1}$. The reactor specific methane yields increased until the end of the experiment in thermophilic operation, whereas the values in the mesophilic range were nearly constant (*fig. 2*). It can generally be deduced from these data that the process, although it has been divided into a hydrolysis and a methanisation stage, with a loading rate of 10.1 kg odm m$^{-3}$ RV d$^{-1}$ is no longer running at its highest efficiency, because the sums of the substrate specific methane yields in the one stage experiments had a higher level than in the two stage process. Nevertheless the process could be maintained. Especially the thermophilic temperature range seems to be more suitable to digest these large substrate masses (*fig. 2*).

### Perspectives

The laboratory investigations about monofermentation of nutritional wastes could be completed in July 2002 with promising results. From the obtained data it can be concluded that monofermentation of high-energy substrates like nutritional wastes was on principle possible in biogas plants. Also very high hydraulic loading rates of up to 10.1 kg odm m$^{-3}$ RV d$^{-1}$ had been stabilised with a two stage process, whereby the thermophilic process turned out to be better performing and less sensible. The results were used for the planning and the operation of a pilot plant together with the co-operation partners in the project.

## Literature

Books are identified by •

[1] -: Verordnung (EG) Nr. 1774/ 2002 des europäischen Parlamentes und des Rates vom 3. Oktober 2002 mit Hygienevorschriften für nicht für den menschlichen Verzehr bestimmten tierischen Nebenprodukten. Amtsblatt der europäischen Gemeinschaften 10.10.2002, L 273/1 - L 273/96.

[2] • *Wellinger, A., U. Baserga, W. Edelmann, K. Egger und B. Seiler*: Biogas Handbuch, Grundlage - Planung - Betrieb landwirtschaftlicher Biogasanlagen, 2. Auflage, Wirz - Verlag, Aarau, Schweiz, 1991

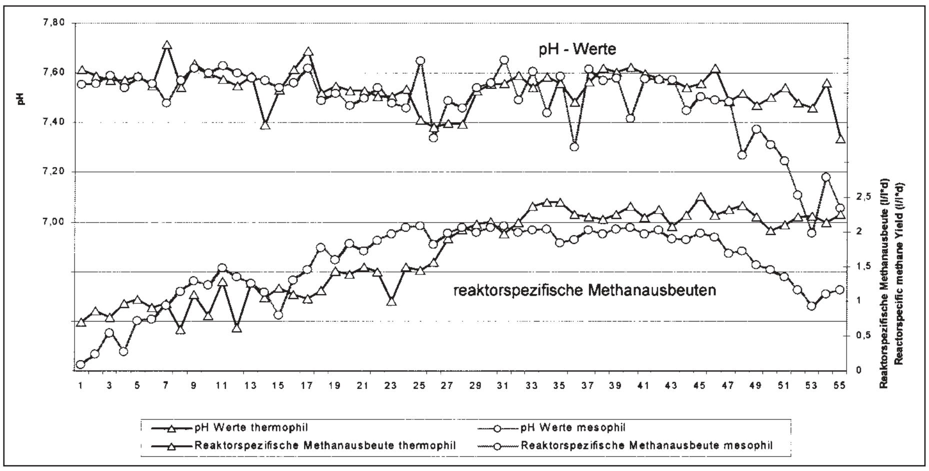


*Fig. 2: Monofermentation of nutritional wastes - effect of fermentation temperature on reactor specific methane yields and pH course*