Markus Schlattmann, Manfred Speckmaier and Andreas Gronauer, Freising

Biogas Tests Performed in Various Digester Types

Gas yields from various substrates cited in literature differ extremely and are difficult to compare, due to diverse testing-conditions. Many gas yield results were obtained from tests performed in laboratory scale digesters. How and to what extent these values can be transferred to larger scale digesters is largely unknown. First results indicate a certain loss in biogas-yields when comparing the results of batch-experiments with continuously operated systems, or comparing smaller sized digester-types with larger ones.

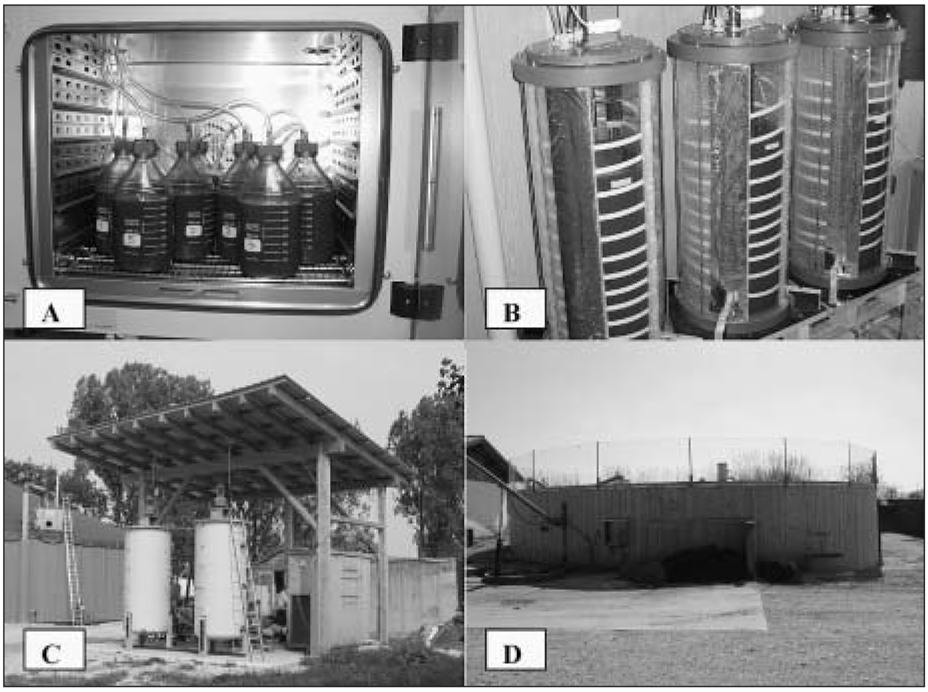

Fig. 1: Investigated types of digesters

Dipl.-Ing. agr. Markus Schlattmann and Dipl.-Ing. Manfred Speckmaier are junior scientists in the working group „residual material management" at the Institute for Agricultural Engineering, Farm Buildings and Environmental Technology of the Bavarian State Research Center for Agriculture (leader of the working group: Dr. agr. Andreas Gronauer), Vöttinger Str.36, 85354 Freising;
e-mail: *markus.schlattmann@lfl.bayern.de*
The studies were financed by the Federal Ministry of Education and Research.

Keywords

Biogas, gas yield, transferability, batch, continuous flow, laboratory digester

Within the amendment of the statute for renewable energies 2004 (Erneuerbare Energien Gesetz; EEG), further upgraded proceeds for energy were determined especially for agricultural biogas-plants using renewable primary resources only. Therefore new potentials for agricultural biogas technology can be expected. Engineering and economic efficiency calculations of the plants however, are often based on gas yield-experiments that are accomplished under significantly varying test conditions. (fermenter-design, temperature, batch-/ discharge operation, characteristics of the substrate). Hence differing data about gas yields are stated in literature (approximately for cow-manure: 100 - 150 l CH_4 • (kg VS)$^{-1}$ [1] up to 200 - 260 L_n CH_4 • (kg VS)$^{-1}$ [2]). As a result, the economic efficiency calculation for the dimensions of the plant is always marked with uncertainties.

Direct transfer of laboratory results of batch tests under optimised , well manageable conditions to continuously charged anaerobic reactors seem to be questionable and result in further uncertainties. So different types of digesters were applied parallel with the same substrate, in order to investigate the fermenting process regarding gas-yield, gas-quality and chemical parameters.

Material and methods

Table 1 and *figure 1* show the types of digesters examined. According to their size they correspond with the widespread data in literature, which, however are imprecise regarding the categories „small laboratory scale",

Table 1: Investigated digesters

Type of digester	picture	number	volume	operation mode
Small laboratory scale	A	5	2 L	Batch
Large laboratory scale	B	3	36 L	Batch
Large laboratory scale	B	6	36 L	Continuous flow
Pilot scale	C	1	3500 L	Continuous flow
Pilot scale	C	1	3500 L	Batch, continuous flow
Full scale	D	1	900 m^3	Continuous flow

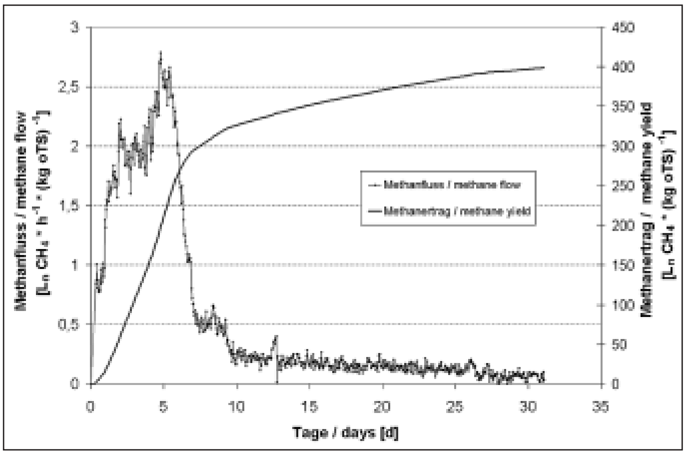

Fig. 2: Specific biogas flow and cumulative biogas production during anaerobic digestion of full scale substrate (36 L-digester, batch operation)

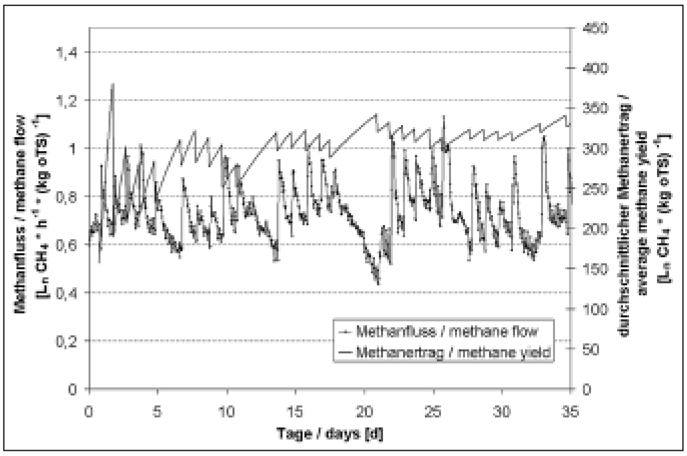

Fig. 3: Gas flow and average specific gas production during anaerobic digestion of full scale substrate (36 L-digester, daily feeding)

„large laboratory scale“, „pilot-scale“ and „full scale digester“.

Gas-yields were measured with MilliGas-counters® (2 L- and 36L-digester), cylinder-gascounter (3500 L-digester) and a V-Conus-gasflowcounter (900 m^3-digester) and recorded hourly. Gas analysis (CH_4, CO_2, O_2, H_2, H_2S) was accomplished at all digesters with gas analysing systems of the company Awite. The analysis of the biogas composition was accomplished at the gasflow (3500 L- and 900 m^3-digester) or in case of the smaller digesters out of 4 L buffer reservoirs. Input and output quantity were measured through manual weighing or by level measuring in the collection tank of the full scale digester and submitted to chemical analysis. In order to allocate a steady microbial starting point for substrate tests, a standardised microbial population was sustained through consistent feeding in a 3500L-fermenter. Further specifications to this topic as well as to the applied methodology and sampling can be found under [3].

The anaerobic reactors were run within the given experimental period at a temperature of 39 °C. They were charged with the substrate-mixture (digest, fat, maize) of the full-scale-plant in corresponding fractions rated to the filling volume of the digester. The data were collected in a relational database and therefore they can be temporally linked on an hourly basis and be compared. Though a comparison of principally different types of digesters was accomplished, the linkup of the data under norm-conditions is mandatory for a standardised representation.

Results

If substrates of a full scale digester are fermented in a 36L-digester as batch-test, it submits to a typical methane-formation graph (*fig. 2*), which converts in sum to a gas yield of 400 $L_nCH_4 \cdot (kg\,VS)^{-1}$ within a period of 30 days. The immense drop of gas formation after the 5th day is remarkable, as no further substrate is fed to the digester. As however, hardly degradable herbal structural substances are in the substrate, methane formation can be observed beyond the 30th day. The contrast can be seen in the semi-continuous operation with the same type of anaerobic reactor (*fig. 3*).The gas production increases through daily feeding in order to decrease until the next feeding. The allocation of the produced gas is more complicated in this case than in batch operation, since the origin of the present gas production can not be assigned exactly to the preceding feedings. As a result, statements about the average gas production make sense only after a period of about 30 days; in this case it evens out at 330 $L_nCH_4 \cdot (kg\,VS)^{-1}$ and therefore is significantly lower than in batch operation. If the same substrate is given into the 3500L-digester with daily charging, it results in an average gas-yield, which evens out around 290 $L_nCH_4 \cdot (kg\,VS)^{-1}$. A comparison of different types of anaerobic reactors is only suitable through measuring the O_2-concentration (*Table 2*) in the biogas, as the injected air in the full-scale-plant for biological desulphurisation dilutes the gas correlatively. Laboratory digesters should therefore be analysed on oxygen, too. A comparison of the gas qualities shows decreasing methane concentrations with increasing size of the anaerobic reactor.

Conclusions and outlook

For the transition of fermentation tests from batch- to continuous flow operation, previous results indicate lower gas yields in the scale of more than 15 %. Reasons can be out-rinsing of not completely fermented materials as well as a permanent production of acids, which has inhibitory effects on the population of methanogenic microorganisms. These interferences do not show effects in batch tests. Apart from this, acetate out of fresh substrate is barely available at the end of the process of the batch test. Ways of metabolism via CO_2 and H_2, originating from slowly degradable materials, are used more intensively. This can be seen in increased contents of methane in the biogas towards the end of the test. Differences concerning the digester-type in semi-continuous operation might be caused by the process-realisation (e.g. the exact weighed complete dose in the laboratory digester is faced with the pump-charged heterogeneous inflow into pilot scale digesters). So far, unpublished results of accompanying microbiological analyses show increasing methanogenic activities with smaller digesters.

Within the scope of further substrate tests with characteristic input-materials (forage maize -silage, grass-silage and fat), the previous results have to be validated in the different types of fermenter in continuous flow as well as in batch operation. Furthermore, resulting data-material will be used on basis of existing models of sewage-technology [5, 6] for process-modelling and -simulation.

Digester	CH_4 [%]	CO_2 [%]	O_2 [%]	H_2S [ppm]	H_2 [ppm]
36 L	59,4	37,8	0,0	475	80
3500 L	56,3	37,2	0,2	269	78
900 m^3	52,9	35,9	0,5	181	60

Table 2: Mean composition of the raw biogas from the different types of digesters fed daily with full-scale-substrate

Literature

Books are identified by •

[1] *Oechsner, H. und A. Gosch*: Vergärbare Stoffe. KTBL-Arbeitspapier 249: Kofermentation, Darmstadt, 1998, S.17-28

[2] *Kuhn, E.*: Kofermentation. KTBL-Arbeitspapier 219, Darmstadt, 1995

[3] *Speckmaier, M., M. Schlattmann und A. Gronauer*: Upscaling-Effekte, Inputmaterialien und Prozessführung. In: High-Tech Innovationen für Verfahrensketten der Agrarproduktion. Statusseminar 2003, Potsdam, 29./30.09.2003. Hrsg.: Kramer, E. und C. v. Haselberg. Bornimer Agrartechnische Berichte, Heft 36, Institut für Agrartechnik Bornim, Potsdam, 2004, ATB Statusseminar

[4] • *Braun, H.*: Biogas - Methangärung organischer Abfallstoffe: Grundlagen und Anwendungsbeispiele. Springer-Verlag, Wien, 1982