Roitsch, Jenny and Büscher, Wolfgang

Process evaluation and optimization of NawaRo-biogasplants

Biogas plants are gaining an increasing presence in the agricultural business. Due to amendments to the Renewable Energy Sources Act in 2009, the use of liquid manure will be subsidized by the government if the proportion is more then 30 %. Yet, in spite of this financial incentive, it is assumed that crops will remain the dominate material used depending on the performance and location of the biogas plant. The fermentation of renewable materials without the process stabilizing qualities of liquid manure makes high demands on the (bio)technology and the biogas plant itself. This project aims to characterise and optimise biogas plants in order to achieve fermentation of selected primary products without the use of liquid manure. A quality management system is used to demonstrate the effectiveness of the process.

Keywords
Biogas, renewable primary products, process evaluation, quality management

Abstract

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Many biogas plants don't have the opportunity of using liquid manure as fermentation substrate. This means fluidity for dilution and homogenising and buffering effect during the fermentation process is missing. It also means the dry matter content in the substrate is substantially higher with the possibility that this could effect the mixing and pumping equipment. Based on first experiences with this plant type it is assumed that biogas plants operating without continuous input of liquid manure would have a more instable biological process with plant management accordingly more difficult.

As part of a research project a process assessment of biogas plants with renewable primary product input was conducted to establish optimisation potential from a critical point analysis taking account of technical and biological aspects. Intensive study of plants took place over 12 months so that a complete year cycle could be evaluated. The basic task was to assess process stability in comparison with that in conventional biogas plants where liquid manure is added to crop input. Involved for this comparison were laboratory results from suitable plants. As an additional optimisation method a quality standard for renewable primary product biogas plants was applied.

Method

Working together with the Agricultural Inspection and Research Institute (LUFA) North-West in Oldenburg the following parameters were investigated every two weeks: pH, dm content, organic dm content, conductivity, salt content, NH_4-N content, VOA/TAC relationship and fatty acid content. Additionally, the fermentation substrate from the fermenter was tested for trace element deficiency. Input material contents were also analysed. Special fermentation tests (VDI 4630) delivered information on the fermentation residue in post-fermentation storage. For assessing all technical and energy process parameters the daily input amount, as well as the mass fractions of the substrate components, were recorded. Operational time and intervals from solid material input metering, mixers and pumps were documented. Further important process parameters were temperature, gas amount, thermal and electrical outputs, the plant's own-electricity consumption as well as working hours of the heating plant. Also recorded and analysed were biogas plant operational malfunctions so that optimisation of technical aspects could be ensured. Selected as optimisation method was the quality standard for renewable primary product biogas plants. The main task of the QM system is optimisation of processes for technology, environmental protection, human competence, transparency of production and economic efficiency [1]. The results from this QM system flow into the critical point analysis. This standard includes the parameters quality management, plant working requirements technical equipment and process-organisational requirements as well as monitoring and safety [5].

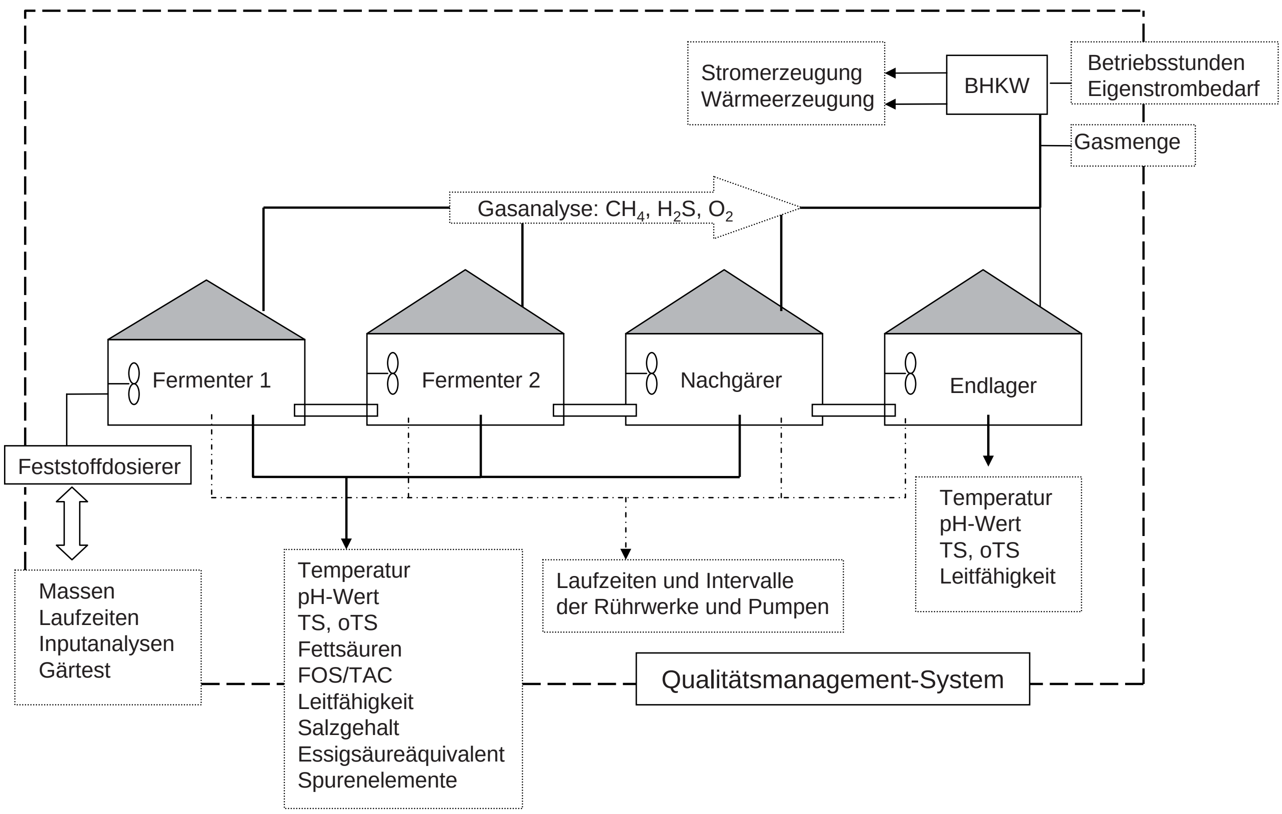
Test principles and experimental set-up

The principle demonstrated in **figure 1** shows the investigated biogas plant with its components and associated test points. Taken into account were the biological, technical and economic aspects of fermentation whereby the definitive aim was to metrologically observe every single fermenter and the plant as a whole.

Statistical basis

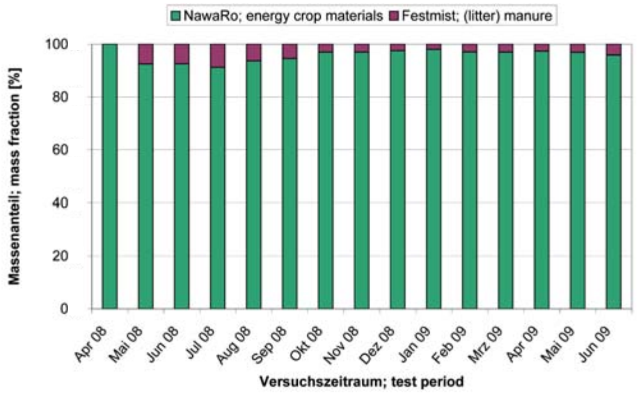
The statistical basis of the results presented here came from a renewable primary product biogas plant that went into operation in 2006. Electrical capacity: 835 kW_{el}. The plant comprised two fermenters, a post-fermenter and a storage facility for fermentation residue until it can be taken out. Fermenters one and two were alternatively supplied with fresh substrate every two hours. The input over the year was up to 95 % crop material comprising maize silage and CCM and up to 5 % so-

Fig. 1



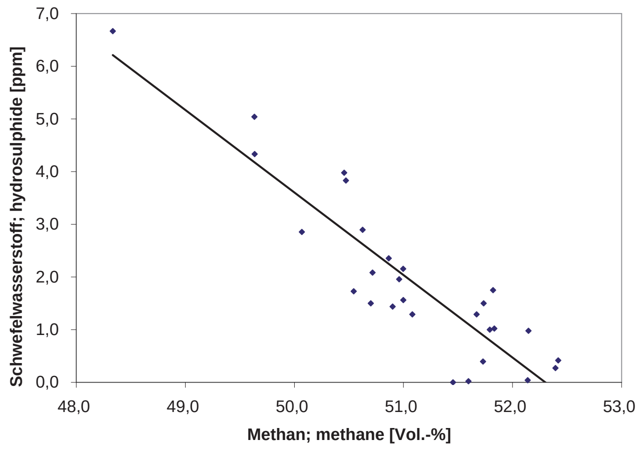
Test set-up and test points

Fig. 2



Mass fraction of the inserted input materials within the specified test period

Fig. 3



Dependency between methane and hydrosulphide

lid manure. In **figure 2** the mass fractions of substrate components for each month through the test period are presented. Substrate input was to be as uniform as possible in terms of amount and consistency [4] so that adapted microorganism populations were not brought out of balance. These requirements could be met by the described biogas plant. Especially in the period October 2008 through to June 2009 mass fractions of the individual components were very uniformly brought into the biogas plant.

Further process recording parameters are results of gas analyses whereby methane, sulphur and oxygen content are measured every half hour. The percentage proportion of the methane in the gas mix is of great interest in that this represents the energy production. The methane content recorded during the long-term investigation lay on average at 51 vol. %. Comparative literature where maize was the input showed gas output as similar at around 51.9 vol. % [3]. The high hydrogen sulphide content means there is a danger of component corrosion and also restrictions to methane bacteria activity [2]. Hydrogen sulphide content measured here indicated an average over the year of 25 ppm. This can be assessed as a low content because optimum H_2S content lies under 200 ppm [4].

In individual experiments hydrogen sulphide contents of from 0 to 10 ppm were measured when iron hydroxide was added. This increased methane proportion in the gas mix. **Figure 3** shows this association in the period following the iron input.

Critical point analysis and optimisation

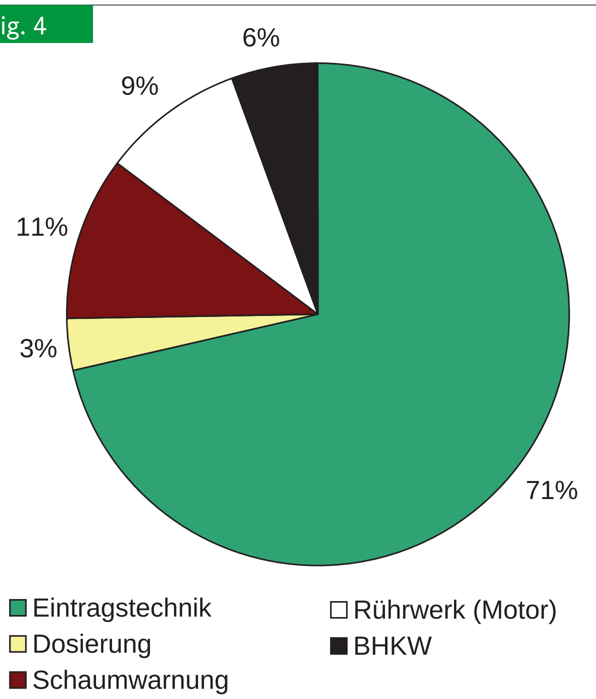
Only limited deviations or malfunctions were observed over the trial. The increase of dry matter content to > 10% in September 2008 proved problematical. However, this was rapidly reduced through separation and recirculation. Too high dry matter content in fermentation substrate can limit pumping and mixing performance. Evaluation of the malfunction messages showed that problems were mainly caused by the input technology (**figure 4**).

The acetic acid equivalent was selected as comparison parameter for comparing process stability between the plants with and without liquid manure input. This is the sum parameter of steam-volatile organic acids and describes biological stability. It could not be confirmed that the biogas plants without liquid manure input were less stable than the procedures with liquid manure input. All values lay in the area of 220 to 2000 mg/l and therefore in the optimum range according to [4].

Applying QS standards

Applied as optimisation method was the DLG quality standard for biogas plants that is described through the catalogue of minimum requirements and associated checklists [5]. On this ba-

Fig. 4



Interpretation of malfunction messages sis an individual quality handbook for the plant was developed. This handbook is a complete quality management documentation containing methods for securing, and also for improving, plant operational quality. Also described is the responsibility and jurisdiction for staff members as well as the planning, execution and operation of the process. The development of the quality management handbook was according to ISO 9001. The quality management system is aimed at optimisation of biogas plants through structured planning and continuous improvement processes (CIP). On the basis of a criteria catalogue containing minimum requirements and general guidelines the aim was to achieve a state-space description of the plant allowing subsequent optimisation of single working parameters. An improvement process can only be achieved through development of medium and long-term targets and supporting the plant operator through structural and process optimisation based on these. The evaluation system is based on the following

- A: Criterion fulfilled (100 points)
- B: Criterion nearly fulfilled (75 points)
- C: Criterion mainly not fulfilled (25 points)
- D: Criterion not fulfilled (0 points)
- KO: One of the components of the standard required for passing the audit is not fulfilled. In the case of KO criteria only an evaluation with A or KO is possible.

The test biogas plant passed the audit with 90.6 % whereby marking in the individual sectors was: „quality management“ 90.28 %, „operational requirements“ 93.9 % and „monitoring and safety“ 81.58 %. Weaknesses were discovered in the QM system in the areas of staff qualification and organisation, documentation, technical operation and operational inputs. Here, individual criteria were only „almost fulfilled“ or „mainly not fulfilled“.

Conclusions

The aspect of quality management in biogas production plays a decisive role because the total process chain comprises many complex single steps and work procedures. Further, quality management is the requirement for safe and controlled operation as well as indispensable instrument in process optimisation. In the foreground of biogas production stands methane production from primary material input and its microbial decomposition. Optimised gas production can only be achieved when microbial and technical processes work perfectly together. For this reason the microbial and technical sectors must be recognised through the target performance comparison principle so they can be regulated. Documented should be the way in which work procedure and processes are carried out, and which controls are present in the chain. A process optimisation can only be achieved if all actions of all single components are taken into account [6].

The long-term investigation showed that the measurement results of selected renewable raw material biogas plants lie in the target range and that no specific handling problems emerged, with the exception of the increase in dry matter content. Process stability was found to be comparable with biogas plants where liquid manure is an input. Stability problems in the fermentation process could not be determined. The evaluated results are also transferable to other renewable primary material biogas plants.

In that anaerobic decomposition represents a sensitive parameter in the fermenter, laboratory analyses should be regularly carried out in 2 to 4 week rhythm and documented. Only in this way can the plant manager estimate the process and know how to react to malfunctions in an emergency.

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Authors

M. Sc. agr. Jenny Roitsch is a member of the scientific staff in the department of Livestock Technology at the Institute for Agricultural Engineering, University of Bonn, Nussallee 5, 53115 Bonn, Germany, E-Mail: jenny.roitsch@uni-bonn.de

Prof. Dr. Wolfgang Büscher is director of the department of Livestock Technology at the Institute for Agricultural Engineering, University of Bonn, Germany, E-Mail: buescher@uni-bonn.de

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