OPTIMISATION OF BIOGAS PRODUCTION FROM GRASS BY DRY-WET FERMENTATION

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Abstract. The engineering company Rossow in Neubrandenburg and the University of Applied Sciences of Stralsund work together on the cooperation project entitled "Development of a combined dry-wet fermentation process to produce biogas from herbaceous biomass substrates". The objective of the project is to develop a dry-wet fermentation process that shall lead to a higher biogas production from herbaceous biomass. At the Laboratory of Integrated Energy Systems of the University of Applied Sciences in Stralsund the test facilities were designed and built in order to perform experiments. This part of the project includes understanding and optimizing the fermentation process by laboratory-scaled experiments. In the laboratory experiments ensiled grass will be investigated, as of the availability of land for cultivating energy crops is limited, while the grassland use by dairy and cattle farming is decreasing due to the progress in breeding and production technology.

Key word: biogas, herbaceous biomass, grassland.

Introduction

The benefits of using renewable sources for energy production are well known, and national governments as well as the European Union develop instruments to change the fossil-based energy economy towards to a sustainable energy economy, by increasing the share of renewable energies. As a result of such energy policies, bioenergy technologies were rapidly deployed. In particular biogas has an important impact in replacing fossil fuels, because it can be used for heat and power generation or as fuel in the transport sector. In Germany, the Act on Granting Priority to Renewable Energy Sources played a mayor role in advancing this development [1]. The Adoption of the German Priority Act in 2004 provided the basis for increasing use of biomass in biogas plants. As a consequence, the number of biogas plants and the installed capacity increased considerably in Germany (quintuple of the installed capacity between 2003 and 2008) [6]. This contributes to solve environmental problems, to decrease the need for imported energy and also to create and secure employment.

At present, biogas plants produce biogas mainly from maize as co-substrate mixed with slurry by liquid fermentation. But the availability of land for cultivating energy crops is limited. On this account the biogas production from grass is an interesting alternative, because in Germany the grassland use by dairy and cattle farming is decreasing due to the progress in breeding and production technology. However the low substrate digestion of herbaceous biomass by liquid fermentation permits to use only a low amount of herbaceous biomass. For liquid fermentation, a pump able to pump biomass with a dry solid content less than 15 percent is necessary. Another possibility is to produce biogas from grass by dry fermentation. The dry fermentation process gives the possibility of converting stackable biomass with a dry matter content over 25 % to methane. But, up to now, the dry fermentation process does not produce the maximum possible biogas yield that could be generated from a defined substrate. On this account, a competitive technology to produce this maximum possible biogas yield has to be developed [2].

The engineering company Rossow in Neubrandenburg and the University of Applied Sciences in Stralsund work together on the collaborative project entitled "Development of a combined dry-wet fermentation process to produce biogas from herbaceous biomass substrates". The project is conducted to develop an innovative combined dry-wet fermentation process that shall lead to a better substrate digestion, as well as to better substrate utilization and a higher yield of biogas production when using herbaceous biomass.

Description of the project

The collaborative project started in April 2007 and will take two years. The objective of the project is to develop an industrial sized dry-wet fermentation plant. At dry- wet fermentation the herbaceous biomass is fermented first by dry fermentation. Afterwards, the fermentation residue from the dry fermentation process is fermented by wet fermentation. The project is divided into two parts, because of its complexity (Project A and Project B).

The Project A takes place at the Institute for Renewable Energy Systems (IRES), of the University of Applied Sciences of Stralsund. At this institute, the test facilities were designed and built, in order to perform experiments. The results of the experiments are the basis for the Project B.

The Project B will be carried out at the engineering company Rossow in Neubrandenburg. The engineering company is using the results of the laboratory-scale experiments to build a pilot plant for dry fermentation with a volume of 15 m^3, next to an already efficient working plant for wet fermentation. On this pilot plant, experiments will be carried out to develop the following components for an industrial plant:

- Fermenter for the dry fermentation
- Devices for loading and removing the substrate and for conveying the substrate from the dry to the wet fermentation
- Percolation system
- Observation and control system.

In the following, only the project A is presented.

Materials & Methods

The objective of the laboratory experiments is optimizing the dry-wet fermentation process by varying parameters (e.g., temperature) to increase the biogas production content and minimize retention time. The influence of the process parameters will be determined by analyzing substrate, percolate, fermentation residue and biogas during the dry- wet fermentation.

The small test facility for the dry- wet fermentation will be based on four laboratory digesters (active digester volume of 25 liter/digester) for the dry fermentation process and two laboratory digesters (active digester volume of 10 liter/digester) for the wet fermentation process. To have the possibility to look inside the digester, the material used for the tanks should be Plexiglas. The double-walled tanks of the plants are heated by a water jacket. The test plants are connected to a gas meter and a gas analyzer. At the gas analyzer, the content of carbon dioxide, methane, hydrogen sulfide and oxygen is measured. The experiments are being carried out in accordance to the guideline VDI 4630 [7], under mesophilic conditions. The mesophilic temperature range varies from 32 to 42 ˚C.

1. Dry fermentation

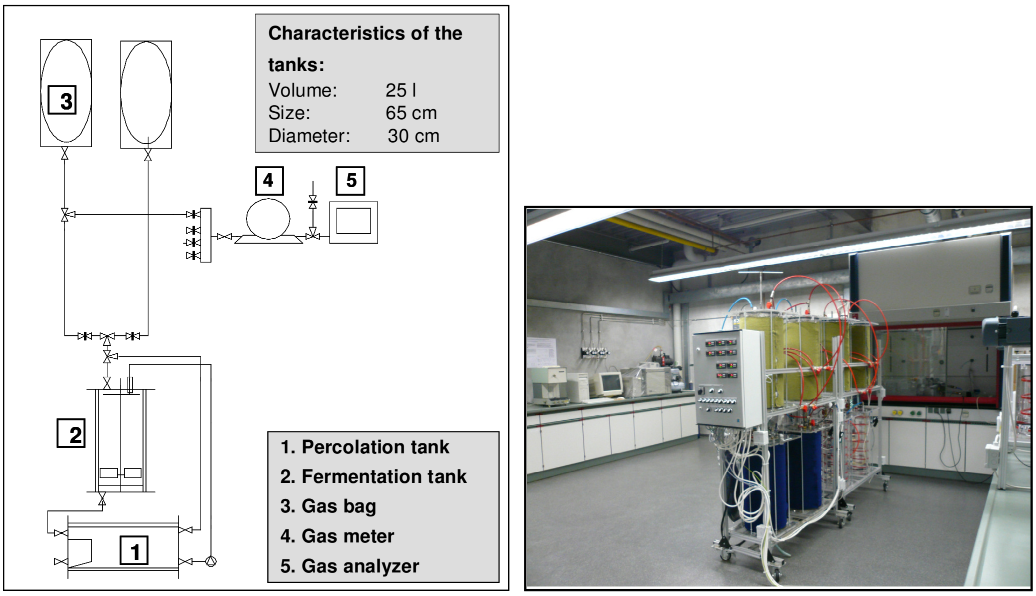

Fig. 1. **Test plant for dry fermentation experiments with percolation**

Batch experiments by percolation system and by bed system are being carried out in the laboratory digesters for dry fermentation (Fig. 1). At the dry fermentation, the substrate is mixed with an inoculum. As inoculum, a part of the fermentation residue from a preceding batch experiment is used.

At the percolation system, the input is stacked up in a gas-tight container and left there for a defined fermentation period, while being sprayed intermittently with pre-heated, circulating water. The bed system, instead, works without water. In this case, the substrate has to be mixed intensively with the inoculum. The input is also filled in a gas-tight container, and left there for a certain fermentation period. Additionally, a manually-operated mixing device is available, to ensure that all the substrate is homogeneously wet during the process.

2. Wet fermentation

In the wet fermentation, the fermentation residue will be mixed with water. Afterwards, the input is stacked up in the fermentation tank. To prevent segregation (sinking or flotation of solid material) a continuous mixing is required during the whole process duration. The scheme of the test plant is presented in Fig. 2.

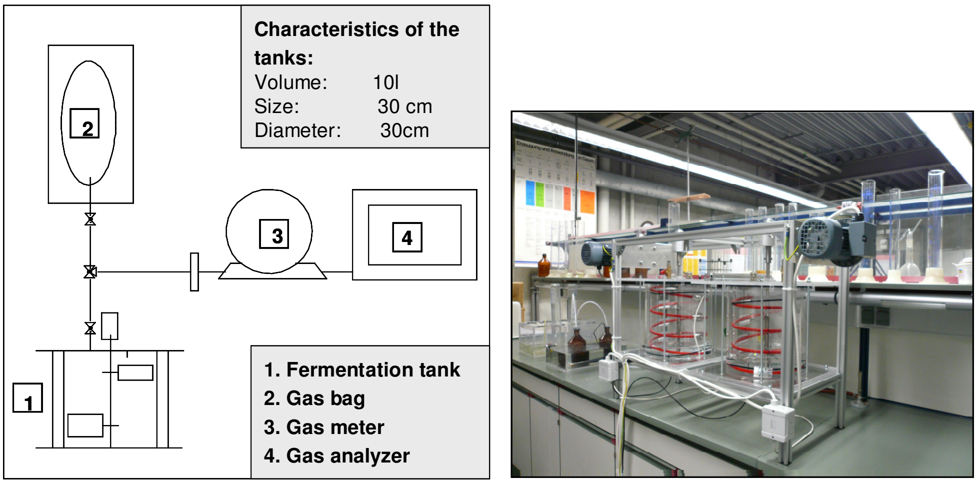

Fig. 2. **Test plant for wet fermentation experiments**

3. Substrate

At present, almost 30 % of the agricultural area in Germany is grassland. Because of the progress in the breeding and production technology, the use of grassland by cattle farming is decreasing [3]. On the other hand, the European Agriculture Policy Regulation 1782/2003 engaged the member states to conserve permanent grasslands [8]. In addition, the decline of grassland would have negative consequences for nature and environmental protection, tourism and regional economy. A chance to preserve grassland can be the anaerobic digestion of grass species in biogas plants. According to theAct on Granting Priority to Renewable Energy Sources, the operator of a biogas plant receives a bonus of 2 ct kWh^{-1} by using biomass from Landscape Management Measures. For that reason, grass harvest from Landscape Management Measures is analysed in the laboratory experiments.

At the present time, there is still a need for research, especially for the exclusive fermentation of grass silage, as far as the exclusive digestion of grass silage in biogas plants is critical, due to its nitrogen content and the pH-value. Grass silage is characterised by high nitrogen [3]. During the fermentation process, nitrogen is converted into ammonium. Ammonium is one of the most important parameters related to the inhibition of biological processes [4].

Results and Discussion

In our laboratory experiments the digestion of grass harvest from Landscape Management Measures by means of combined dry-wet fermentation leads to lower biogas yields than the dry fermentation. So the combined dry-wet fermentation does not lead to a higher biogas yield.

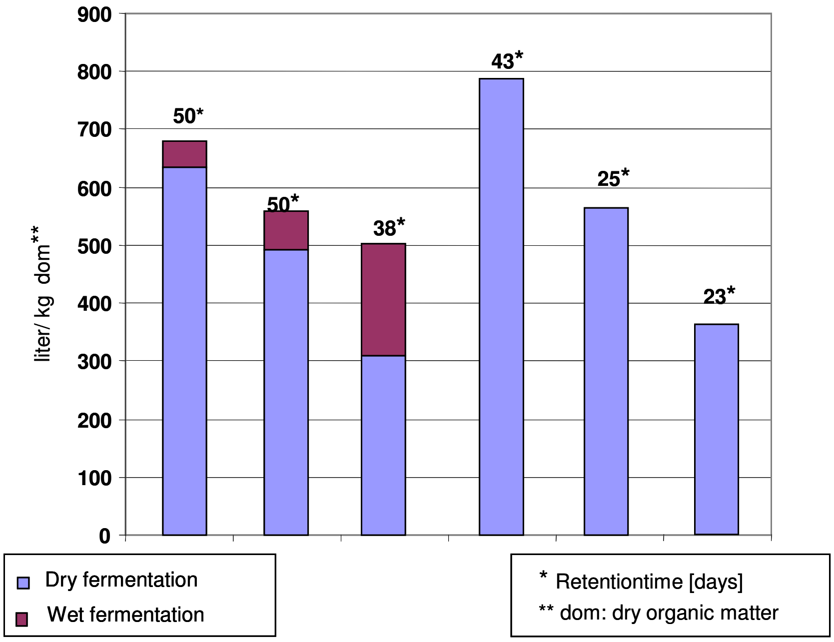

Fig. 3. **Biogas yield of the laboratory experiments: dry-wet fermentation compared with dry fermentation**

But the biogas yields of the dry fermentation in our laboratory experiments are higher than the values found in the literature (compare Table 1). Fig. 4 shows the biogas yields of the percolation system and the bed system in comparison with values found in literature, for a retention time of 30 days.

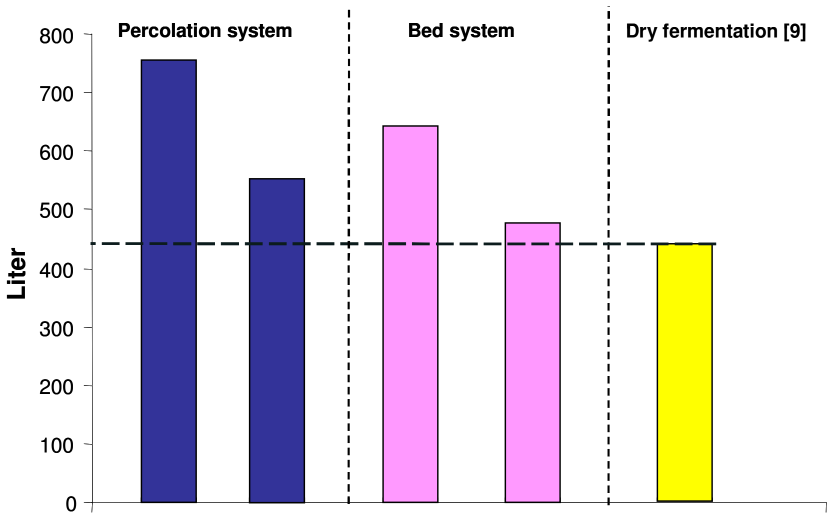

Fig. 4. **Biogas yield of the laboratory experiments in comparison with the values found in literature for a retention time of 30 days**

Table 1

Biogas yield of the dry-wet-fermentation and dry fermentation (retention time: 30 days)

	Biogas yield [l kg^{-1} dom*]
Combined dry-wet fermentation	
Percolation system	540-750
Bed system	460-640
Values found in literature	
Dry fermentation	420-540

* dom: dry organic matter

The data presented in Figure 5 show the biogas yield of the percolation system in comparison with the bed system, for different retention times. Notable is that, in the first experiment, the biogas yield of the bed system exceeded the biogas yield of the percolation system. In the following experiments, opposite results were obtained. The biogas yield of the percolation system is higher than the biogas yield of the bed system. Besides, at the bed system, the biogas yields decrease depending on the retention time. The biogas yield of the percolation system is lower at the first experiment (retention time of 50 days) than at the second experiment (retention time of 35 days). The better biogas production of the percolation system in second experiment is caused by using the percolate of the preceding experiment. So, the condition of the percolation process was adapted to the needs of the bacteria.

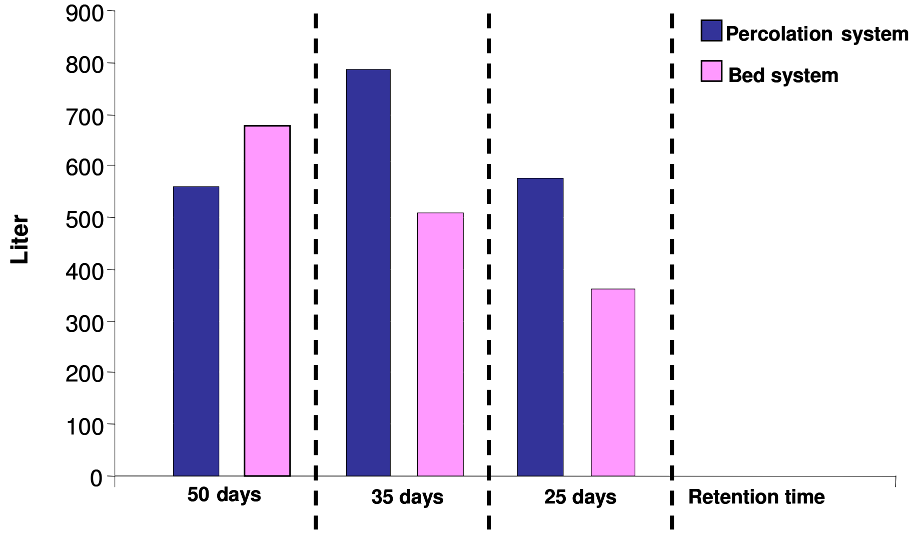

Fig. 5. **Biogas yield of the percolation system and the bed system at variable retention time**

After 5 months, the biogas production of the laboratory experiments is broken up, causing the inhibition of biological processes. One reason for the inhibition of the biological process could be the increase of nitrogen in the fermenter. During the fermentation process, the decomposition of nitrogen is low. The enrichment of nitrogen might be caused by using, as inoculum, a part of the fermentation residue from a preceding batch experiment.

Conclusions

1. The digestion of grass harvest from Landscape Management Measures by combined dry-wet fermentation lead to lower biogas yields than dry fermentation.
2. Landscape Management Measures can be used for biogas production.
3. The percolation system leads to a higher biogas yield than the bed system.
4. Up to now the biogas yield fluctuates. On this account, further experiments have to be carried out for optimizing the process to produce a stable biogas yield.

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