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DRY-WET FERMENTATION FOR BIOGAS PRODUCTION

KOMBINĒTS SAUSAIS / MITRAIS BIOMASAS FERMENTĀCIJAS PROCESS BIOGĀZU RAŽOŠANAI

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Introduction

The benefits to use 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 an 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 2000 and 2005) [9]. 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 slurry by liquid fermentation. But the low substrate digestation of herbaceous biomass by liquid fermentation permits to use only a low amount of herbaceous biomass. For liquid fermentation, a pumpable biomass with a dry solid content less than 15 percent is necessary.

At time in Germany 0,65 million ha of agricultural land are set aside. It will be accepted that 0,55 million ha of these agricultural land can be use for cultivating renewable primary products in order to produce biogas. That gives an energy potential of 86,4 PJ/a [5]. On this account it is necessary to find competitives alternatives compared to the liquid fermentation.

One possible alternative is the dry fermentation, which provides the possibility to convert stackable biomass with a dry matter content over 25% to methan. But, up to now, the dry fermentation process does not produce the possible biogas yield which can be generated from a defined substrate. On this basis a competitive technologie to produce the maximum possible biogas yield has to be developed.

The consultancy firm Rossow in Neubrandenburg and the University of Applied Sciences in Stralsund works 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 an better substrate digestion as well as to a better substrate utilization and a higher yield of biogas production by using herbaceous biomass.

1. Need of research

At present applications to produce biogas are mainly concentrated on the wet fermentation process. Wet fermentation processes are highly developed and at the state of the art. On the other hand the knowledge and scientific information about dry fermentation processes are insufficient. For this reason further research and development is needed. The table 1. presents the major need of research about the dry fermentation process.

Table1. Need of research and development [2]

Parameter	Need of research and development
Potential	Calculation of the substrate potential
Substrate	Determining anaerobic digestion of different substrates (maximum biogas production etc.); Optimal composition of substrate; Consideration of physical properties, availability and storage of the substrates; Need of inoculation (optimum quantity of inoculation material); Ecological evaluation (substrate production sites, crop rotation etc.).
Technology/ Procedure	Need of research and development in technology construction; Development of a competitive biogas plant, increase biogas production, increase of operating safety; Further development of the batch system; Development of an combined dry-wet fermentation process;

	Optimization of process control; Development of adequate measurement technology; Economic and ecologic analysis of dry fermentation process regarding the entire process chain.
Fermentation residue	Characterization of fermentation residues; Possibilities for utilization.

According to experts the following need of research take priority:
further development of batch experiments and the combination of the dry and wet fermentation processes [2].

2. Description of the project

The collaborative project has started at April 2007 and will take two years. It is financed by the German Federal Ministry of Economics and Technology within the program PRO INNO II. The project executing organization is the German Federation of Industrial Research Associations (AIF). The objective of the project is to develop an industrial dry-wet fermentation plant. The higher degradation of herbaceous biomass by dry-wet fermentation process shall lead to smaller reactor volumes and reduced transportation costs due to reduced mass transfers in respect of the produced biogas quantity per mass unit. At the dry- wet fermentation the herbaceous biomass is fermented first by dry fermentation. Afterwards the fermentation residue from the dry fermenta-tion 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 Laboratory for Integrated Energy Systems of the University of Applied Sciences in Stralsund. At the Laboratory for Integrated Energy Systems the test facilities will be designed and built in order to conduct experiments. This part of the project includes understanding and optimizing the fermentation process by laboratory scale experiments in regard of the economic efficiency and environmental compatibility. The results of the experiments are the basis for the Project B.

The Project B will be carried out at the consultancy firm *Rossow* in Neubrandenburg. The purpose of the consultancy firm *Rossow* is the development of a competitive plant to produce biogas by dry-wet fermentation. The consultancy firm is using the results of the laboratory scale experiments to built 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.

3. Laboratory scale experiments

The objective of the laboratory experiments is to produce as much biogas as possible with a high content of methane on short retention time. Therefore the optimal time to convey the substrate from the dry fermentation to the wet fermentation has to

be assigned in regard to the influencing variables. The dry and wet fermentation processes are mainly influenced by input of the substrates, their potential biogas yield as well as the temperature of the process. Additionally the dry fermentation process is influenced by the percolation. The influence of the process parameters will be determined by analysing 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 will be *Plexiglas*. The double-walled tanks of the plants will be heated by a water jacket.

The test plants will be connected to gas meter, to measure the biogas yield; and to a gas analyzer, to analyze the biogas constitution continuously. Biogas is a gaseous mixture of approximately two third methane, one-third carbon dioxide (CO^2) and only a little amount of nitrogen, oxygen and hydrogen [4]. By the gas analyzer the content of carbone dioxide, methane, hydrogen sulfide, oxigen and ammonia will be analysed.

The experiments will be carried out according to the guideline VDI 4630 under mesophilic and thermophilic conditions. The mesophilic temperature range varied from 32 to 42°C and thermophilc temperature range from 50 to 57°C [4].

3.1 Dry fermentation experiments

Batch experiments with percolation will be carried out in the laboratory digesters for dry fermentation (Figure 1.). By a batch fermentation system, the input is filled in a gas-tight container and left there for a defined fermentation period. A part of the fermentation residue from a preceding batch experiment will be used as a inoculum for the next batch run. This inoculum will be mixed with a defined part of substrate and, if required, co-ferment that will be adopted for the batch run [4]. The substrate will be intermittently sprinkled with a heated, circulating process water (percolate) for an continual inoculation with bacterial matter.

The test plant offers the possibility to use a circular or crossed percolation system. By the circulate percolation system the process water of one plant will be sprinkled only over its respective fermenter. By the crossed percolation system the necessary process water from an already well working fermenter is used for inoculation of a new started process.

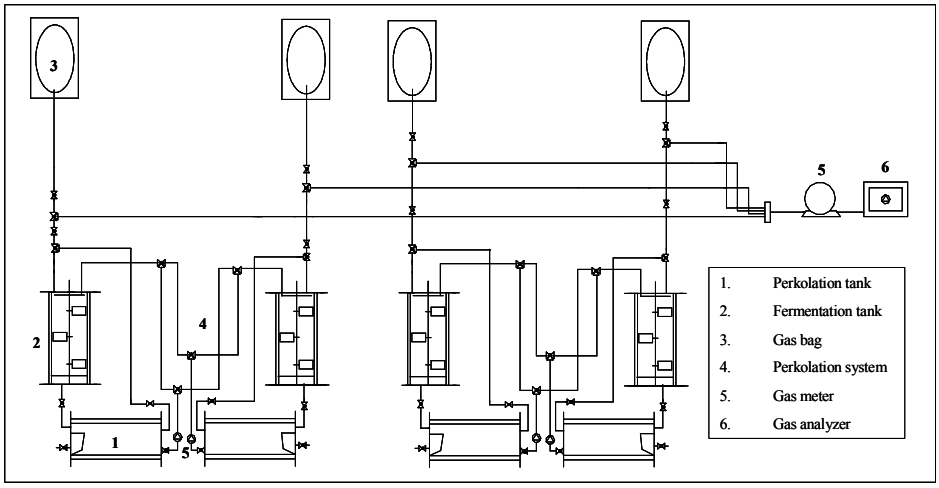

Figure 1. Test plant for dry fermentation experiments with percolation

The crossed percolation system prevents an acidification at the beginning of the fermentation process, because the acid content in the percolate is changing during the running time. At the beginning the percolate is acid, but after some working time the content of acid decreases and the content of bacterias increases [3].A manual operating device for mixing is also available, to insure that all the substrate is homogeneously wet during the process.

Same as the dry fermentation process, the system for the wet fermentation is also a batch system. The fermentation tanks have a volume of 10 litters each.To prevent segregation (sinking or swimming of solid material) a continuous mixing is required during the whole process duration.The scheme of the test plant is presented in Figure 2.

3.2 Wet fermentation experiments

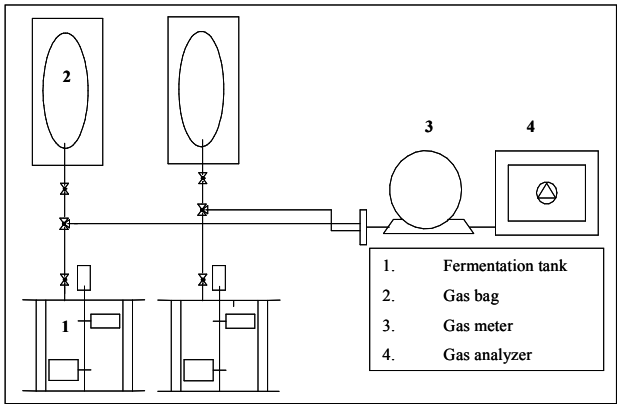

Figure 2. Test plant for wet fermentation experiments

4. Environmemtal and economical analysis

By development of the dry-wet fermentation plant, it is to consider that the plant has to be environmentally and economically promising. Up to now there is a very little information about the environmental impact and the economic efficiency of anaerobic digestion of biomass with a dry matter content over 15 %.

Since 2004, a lot of different biogas technologies were developed and built. Today, a large num-ber of these biogas plants are economically inefficient, mainly

due to planning errors and bad workmanship. This trend will be increased, based on the continuous rise in prices for substrates [7]. From an ecological point of view, the increasing use of biomass in biogas plants could lead to an intensification of agriculture. An intensification of agriculture contribute to eutrophication of seas and lakes and an decreased biodiversity.

For this reasons the environmental impact and the economic efficiency by dry-wet fermentation will be determined with consideration of the entire process chain. For the economical efficiency, an economical analysis will be drawn, and the environmental impact will be analysed by a ”Life Cycle Assessment“. A Life Cycle Assessment (LCA) is a method developed to evaluate the mass balance of inputs and outputs of systems and to organize and convert those inputs and outputs into environmental themes or categories relative to resource use, human health and ecological areas [6]”.

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Vogel T., Barz M., Ahlhaus M., Kombinēts sausais / mitrais biomasas fermentācijas process biogāzu ražošanai

Pašlaik biogāzu rūpnīcas biogāzi ražo no vircas, galvenokārt ar šķidro fermentācijas metodi. Zāles biomasas lēnais sadalīšanās process ļauj efektīvi izmantot tikai nelielu procentu no sākotnējā biomasas daudzuma.

Kopš 2007. gada aprīļa Štrālzundes Tehniskās Universites (Vācija) Integrēto enerģētisko sistēmu laboratorija vada un koordinē plašu kolaboratīvo projektu ar nosaukumu ``Kombinēta sausā/mitrā fermentācijas procesa izstrāde biogāzes ražošanai no augu izcelsmes biomasas substrātiem``. Kombinētā fermentācija ir progresīvs process, kas ļaus panākt labāku biomasas sadalīšanos un iegūt lielāku biogāzes iznākumu.

Vogel T., Barz M., Ahlhaus M. Dry-wet fermentation for biogas production

At present biogas plants produce biogas mainly from slurry by liquid fermentation. But the low substrate digestation of herbaceous biomass by liquid fermentation permits to use only a low amount of herbaceous biomass. Since April 2007 the collaborative project entitled "Development of a combined dry-wet fermentation process to produce biogas from herbaceous biomass substrates" is conducted at the Laboratory for Integrated Energy Systems of the University of Applied Sciences in Stralsund. The combined dry-wet fermentation is a progressive fermentation process that shall lead to a better substrate digestion, as well as to a higher biogas production.

Vogel T., Barz M., Ahlhaus M. Сухой-влажный процесс ферментации биомассы для производства биогаза.

В настоящее время заводы по производству биогаза производят биогаз в основном из жидкых отходов животноводческих предприятий методом жидкого брожения. В настоящее время низкая скорость разложения травяной биомассы позволяет использовать только малое количество травяной биомассы. Начиная с апреля 2007. года, партнерский проект под названием "Разработка комбинированного сухо -влажного процесса для производства биогаза из травяной биомассы" стал проводится в лаборатории Объединенных энергетических систем при Университете Прикладных Наук в Штральзунде (Германия) . Комбинированный сухо-влажный процесс ферментации является очень прогрессивным и приведёт к ускорению разложения биомассы, а также и к большему объему производству