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POSSIBILITIES OF DRY FERMENTATION TECHNOLOGY OPTIMIZING

Summary. The paper describes a perspective technology socalled dry fermentation for biogas production. The authors discuss its weaknesses and strengths, determine parameters defining possibilities of the process optimizing and describe experimental equipment for the optimal parameter verification. As an example they present results of an experiment based on the utilization of the straw cattle manure for the biogas production by the dry fermentation technology.
Keywords. Dry fermentation technology, process optimizing, biogas, biomass.

MOŻLIWOŚCI OPTYMALIZACJI TECHNOLOGII SUCHEJ FERMENTACJI

Streszczenie. Artykuł stanowi opis perspektywicznej technologii tzw. suchej fermentacji, która może być wykorzystywana w produkcji biogazu. Oceniane są pozytywne i negatywne właściwości technologii, określone parametry definiujące możliwości optymalizacji procesu oraz opis eksperymentalnego urządzenia umożliwiającego sprawdzenie optymalnych parametrów. Jako przykład zostały podane wyniki eksperymentów z zastosowaniem słomianego obornika końskiego do produkcji biogazu technologią suchej fermentacji.
Słowa kluczowe. Technologia suchej fermentacji, optymalizacja procesu, biogaz, biomasa.

1. INTRODUCTION

Dry methane fermentation is an innovative anaerobic digestion technique to treat solid biomass and bio-wastes without dilution for potential energy recovery with nutrient rich fertilizer and sustainable waste management. Although dry anaerobic fermentation offers great advantages like utilization of wastes in its produced form, high organic loading rate, no liquid effluent and comparable amount of biogas production with wet fermentation, commercial dry anaerobic digestion is scarcely used so far. In order to develop feasible dry fermentation process, it is important to review the optimizing techniques and suggest possible areas where improvements could be made, including the reactor configuration, mixing, feed stocks, codigestion, pretreatment and environmental conditions within the digester.

Dry fermentation is a series of processes in which micro-organisms break down

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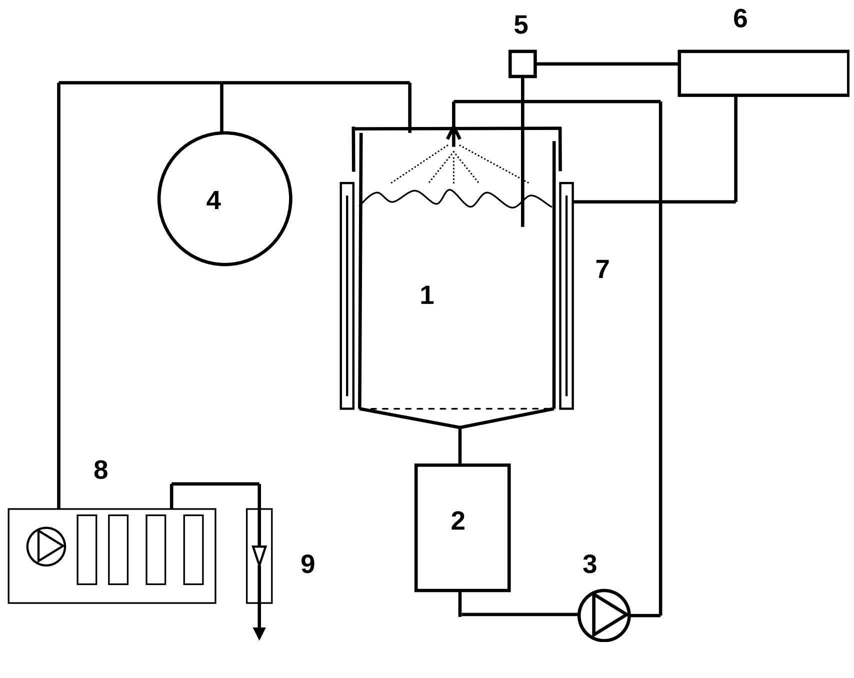
biodegradable material in the absence of oxygen. This dry fermentation process utilises renewable sources as a feedstock to produce a methane and carbon dioxide rich biogas suitable for energy production. The nutrient-rich solids left after digestion can be used as a fertiliser and compost. Almost any organic material can be processed with dry fermentation. This includes biodegradable waste materials such as waste paper, grass clippings, leftover food, sewage and animal waste.

2. MATERIAL AND METHODS

To test suitability of various biomasses for dry fermentation purposes experimental equipment was designed by research workers of the Research Centre for Renewable Energy Sources at the Slovak University of Agriculture in Nitra.

The objective of the experiment was to optimize the dry fermentation process by varying parameters (e.g. percolation period) to increase the biogas production and methan content, and to minimize retention time. The influence of the process parameters was observed by analyzing substrate, percolate, fermentation residue and biogas during the dry fermentation.

The designed experimental equipment consisted of a cylindrical double-cup tank of 80 l volume. A general scheme of the equipment showing its main parts and the percolate and biogas flow is presented in Fig. 1.



1 – fermentor *(fermentor)*
2 – percolate tank *(zbiornik na perkolat)*
3 – percolate pump *(pompa perkolatu)*
4 – gasholder *(gazociąg)*
5 – temperature sensor *(czujnik temper.)*
6 – temperature controller *(regulator temperatury)*
7 – heating of fermentor *(ogrzewanie fermentora)*
8 – biogas analyser *(analizator biogazu)*
9 – flowmeter *(miernik przepływu)*

Fig. 1. Scheme of the experimental equipment
Rys. 1. Schemat urządzenia eksperymentalnego

Measurement of the Biogas Parameters

Measured biogas parameters were:

- CH_4 (% Vol) – methane volume percentage,
- CO_2 (% Vol) – carbon dioxide volume percentage,
- O_2 (% Vol) – oxygen volume percentage,
- H_2S (ppm) – hydrosulphide volume,
- V_{BP} ($l.d^{-1}$) – biogas production.

Analysis of the biogas composition was done once a day by a gas analyser MADUR. The biogas production ($l.day^{-1}$) was measured once a day, too and it was done by a laboratory flowmeter (Fig. 3).

Measurement of the Substrate Parameters

The substrate parameters were determined from the percolate taken from the fermentor. There were recorded following parameters:

- pH level – measured by a pH – probe,
- substrate temperature Ts (°C) – measured by a temperature sensor integrated in the pH – probe.

A view on the configuration of the experimental equipment for dry fermentation with a flexible gas holder and measurement of the produced biogas volume and composition is presented in Fig. 2.

Fig. 2. Configuration of the experimental equipment for dry fermentation
Rys. 2. Budowa urządzenia do suchej fermentacji

3. RESULTS OF THE EXPERIMENT

The tested substrate consisted of 45 kg straw cattle manure. The experiment was carried out from 2. 2. to 15. 4. 2012, i.e. its duration was 74 days. Basic parameters of the used straw cattle manure were: dry matter content 32.52%, pH value 7.11. Percolate for biomass wetting was taken off from the biogas plant fermentor in volume of 7 litres and its parameters were: dry matter content 4.2%, pH value 7.4, temperature 39.5^{o} C. During the whole run of the experiment, mainly the biogas production (l.day^{-1}) and biogas composition were assessed (Fig. 3). To measure the biogas composition the analyser MADUR was used. More detailed record of the biogas composition changes during the experiment is presented in Fig. 4 and Fig. 5.

One of the main advantages of the dry fermentation is so-called batch way of feeding. Batch way of feeding means that the substrate is fed into the fermentor at once and then during the whole period of its stay in the fermentor it does not fill up. The biomass is only wetted by the percolate which is added from an external source at the beginning of the feeding, and during the operation it is filled up with substrate own sap. This ensures a very short start-up time of the fermentation process as it is seen in Fig. 3. The methane content reached 53.59% already on the eighth day. Beginning from the eighth day its content was above 50% and such values were registered even until the end of the experiment. The highest methane content, which was 68.73%, was registered on 17th day of the experiment duration. Within the whole 74 day experiment duration there was produced 1,762.25 litres of the biogas, what meant its average production 23.81 litres per day.

As an optimal interval of the biogas production by the means of the dry fermentation technologies for the given input material, proved by the experiment results (max. production V_{BP} → max, max. methane content CH_4→ max), seems to be the period from 6th to 40th day of the fermentation process.

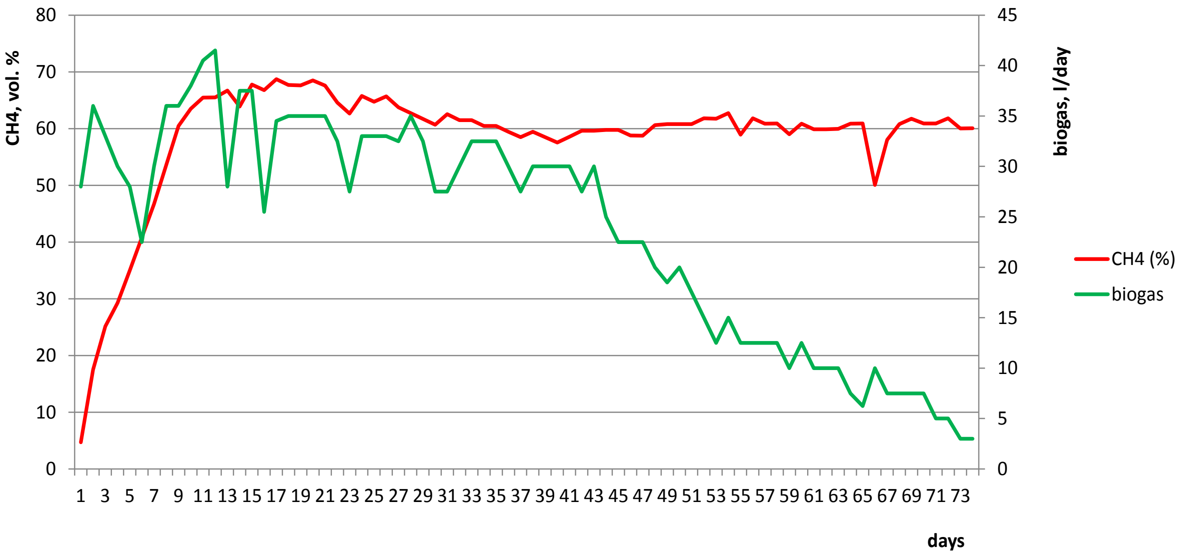


Fig. 3. Values of biogas production and methane content during the fermentation process
Rys. 3. Produkcja biogazu oraz zawartość metanu podczas fermentacji

To ensure a continuity and stability of the biogas production in the case of dry fermentation technology more fermentation tanks are necessary. These have to be filled in successive steps with time distance given by the time of the biomass stay in fermentor and by the number of the tanks/fermentors.

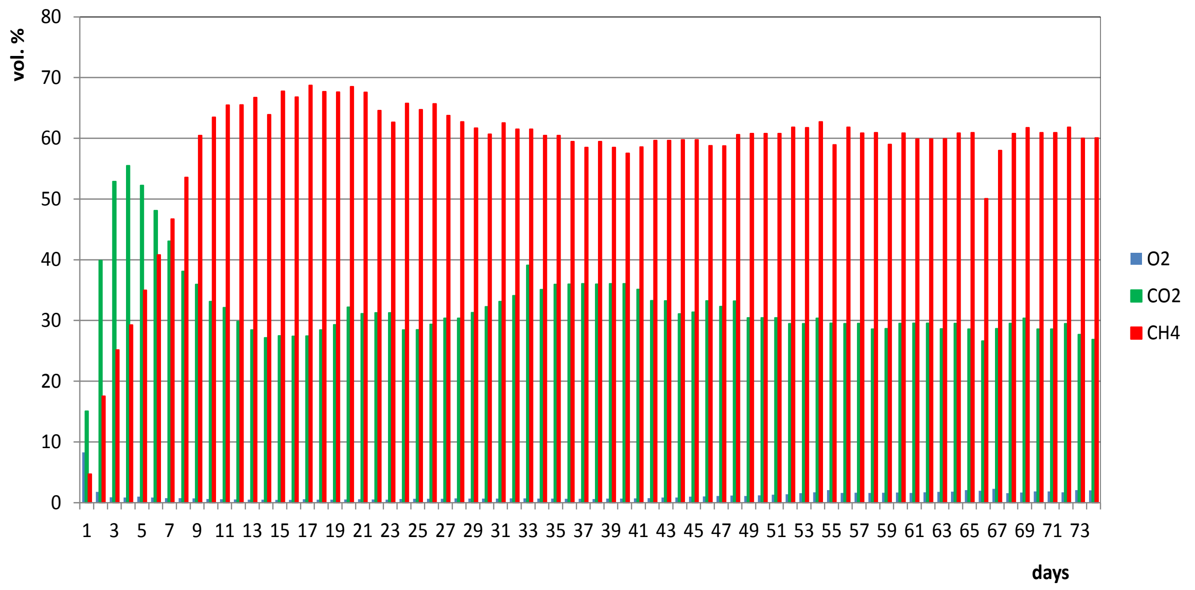


Fig. 4. Oxygen, carbon dioxide and methane content in the produced biogas
Rys. 4. Zawartość tlenu, dwutlenku węgla oraz metanu w produkowanym biogazie

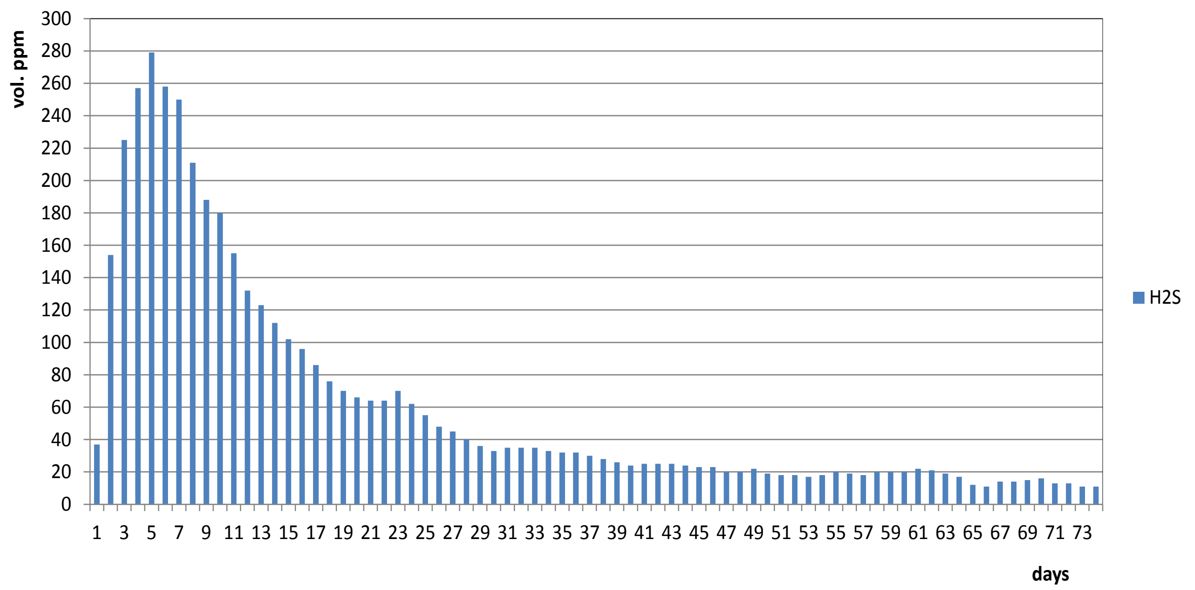


Fig. 5. Hydrogen sulphide content in produced biogas
Rys. 5. Zawartość siarkowodoru w produkowanym biogazie

4. CONCLUSION

Anaerobic digesters induce the processes of fermentation and anaerobic digestion and provide a mechanism for capturing the released by-product, biogas. Traditional digesters are classified as wet fermentation systems. They typically use high moisture waste streams, like manure, as input and add large amounts of liquid to facilitate movement required by this system. Dry fermentation technology uses numerous waste streams, such as municipal solid waste and industrial food processing waste. In this way it eliminates the need to mix the input material and to add any liquid components. The dry fermentation technology has specific advantages over the wet fermentation systems in many situations and provides customers with increased flexibility and profitability.

The experiment results showed that the tested biomass – straw cattle manure is applicable as a very suitable for biogas production based on the anaerobic dry fermentation technology but to obtain more objective results and to optimize the fermentation process it is necessary to continue in these experiments and to repeat them more times.

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