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CO-FERMENTATION OF SEWAGE SLUDGE IN LABORATY EXPERIMENT

ABSTRACT

Co-fermentational biogas production is the anaerobic fermentation of a homogeneous mixture of two or more substrates. The main substrate (e.g. sewage sludge or densified sewage sludge) is complemented by a secondary substrate (e.g. dairy by-products, kitchen waste, organic fraction of municipal solid waste, agricultural by-products). Co-fermentational mixtures were modelled under laboratory circumstances to establish their potential for use in energetic utilization via biogas production. The experiments were conducted using standing liquid cultures in closed batch reactors with a total reactor volume of 1 liter. Pressure changes relative to atmospheric pressure were registered with Oxitop C/B measuring heads for 4-6 days. Anaerobic fermentations were conducted under thermostatic conditions of 37 °C.

INTRODUCTION AND AIM

Growing population and increasing energy demand call for actions, like replacing depletable fossil fuels with sustainable, green approaches to energy.
Biogas generation is considered to be a renewable energy source and it has several benefits. Using by-products, residues and organic waste as biogas substrates, we can transform useless products to valuable energy carriers. [1] Biogas management also prevents methane from entering the atmosphere by its energetic utilization. Methane is a potent greenhouse gas produced during the decomposition of materials. [2] Another considerable benefit of biomethane is the fact that it can be used in every way fossil natural gas is used. [1]
In Hungary, the agricultural sector possesses an extensive biogas production potential, up to 30-77 PJ/year. Of the total calculated energy volume, agricultural byproducts compose 8-14 PJ/year. [3]
Measured parameters and the regulation of operation of biogas plants underwent a significant advancement. [4]. Main parameters that influence anaerobic degradation include the composition of substrates, biomass content, inoculum, substrate rate, temperature and the mode of operation. [5]

Literature review

Co-fermentation is the simultaneous fermentation of different materials. Materials can be of different origin, quality and nature. A co-fermentational anaerobic digestion involves combining two or more materials, usually by using a primary substrate (such as manure or sewage sludge) and additional substrates (kitchen waste or agricultural byproducts). The homogenous mixture is subject to anaerobic digestation for biogas production, hopefully resulting in an elevated biogas production compared to mono-substrate installations. [6]
Behmel et al (1996) investigated the fundamentals and risks of co-fermentation of organic wastes degradable in a biogas plant. Substrates apt for digestion can be divided into two main

groups: easily degradable material (protein, fat) and less degradable substrates (lignin, cellulose, hemicellulose).
The ideal co-substrate is cheap and easily acquired (like by-products of agriculture and food production). Often times biogas plants are constructed in close vicinity of the agricultural or food production unit. The disadvantage of this set-up is the difficulty of forecasting the amount of waste material produced in the long run.
A wide variety of co-substrates can be applied to anaerobic fermentation. Agricultural waste materials (corn stalk, foliage, manure) and industrial by-products (from beer, dairy and alcoholic beverage production) are both suitable co-substrates in anaerobic degradation. [7] A high amount of easily degradable substrates can lead to the acidification of the reactor, especially when applied in a one step process. Waste materials rich in sugar and starch are easily degraded into lactic acid and propionic acid. Thus, pH value decreases and the decreased pH value along with the high propionic acid concentration can be toxic to certain microorganisms.
A typical example of co-fermentational degradation is mixing the organic fraction of municipal solid waste with sewage sludge or manure. Following necessary pretreatment, organic fraction of municipal solid waste can only be applied as a co-substrate to anaerobic fermentation, since it typically contains materials that are hard to degrade (paper, timber, cellulose). Organic fraction can be an ideal co-substrate to both sewage sludge and manure.
Co-fermenting different mixtures of materials (municipal sewage sludge, agricultural and food waste) result in increased biogas production, the total volume of the fermenter is better utilized. If the digester is simultaneously fed with easily and difficultly degradable material, the degradability of all substrates improve. [8] The main substrate provides primary nutrients (N, P) and micronutrients (Ca, Fe, Mg, Mn, Co etc.). Ideal macro- and micronutrient sustenance leads to an improved degradation of co-substrates compared to the degradation of mono-substrates.
The disposal of kitchen waste, food industry byproducts, waste materials and expired food is a significant problem due to their high organic matter content. The sewage treatment plant in Pellérd (owned by Tettye Forrásház Co.) has a biogas plant operated primarily with sewage sludge, however it is capable of digesting other substrates as well. Kitchen waste as a co-fermentational substrate is sometimes applied.
A crucial aspect when switching between mono-substrate and co-fermentational operation of sewage sludge-fed biogas plants is the need to conserve the balance of the microbial community. -It is essential to take into account the composition of the present bacteria culture when choosing substrates, especially when utilizing municipal solid waste and plant-based materials. [9]

MATERIALS AND METHODS

Co-fermentational experiments

For our co-fermentational experiments, corn silage, cellulose, densified sewage sludge and activated sludge were used.
Corn silage is produced using lactic fermentation process under anaerobic conditions. Cellulose is a linear structure polysaccharide, composing of hundreds or thousands of glucose molecules. Cellulose can be digested exclusively by cellulose digesting microorganisms. In our experiments, microcrystalline cellulose of high chemical purity was utilized.
Activated sludge and densified sewage sludge was provided by the local sewage treatment plant. Dry matter content and organic dry matter content of densified sewage sludge were

determined by drying the samples at 105 °C for 24 hours and then heating them to 600 °C. Average dry matter and organic dry matter of densified sewage sludge resulted in 3.3% and 72.6%, respectively.

Our measurements were conducted in glass reactors of 1-liter volume with measuring heads Oxitop B/C produced by WTW. After assembling the desired mixture of co-substrates and sludge, reactors were closed with airtight seals and placed in 37 °C thermostatic environment. Measuring heads register pressure changes relative to atmospheric pressure every 16-24 minutes. The pressure increase inside the fermenters is the result of biological processes. Measuring heads also store measurement data until the data is retrieved by Oxitop OC 110 controller. Data received from the controller was processed using Achat OC software. Illustrations were created using Microsoft Excel.

RESULTS AND DISCUSSION

Co-fermentational experiements

Densified sewage sludge was fermented on its own, without adding activated sludge. This experiment resulted in an average of 162 hPa pressure change in 4 days. Prior to conducting co-fermentational experiments, corn silage and cellulose were fermented on their own as mono-substrates. Table I shows the set-up of these preliminary experients, along with the acquired maximal pressure increase and the necessary time to acquire it.

Table I

Setup of our preliminary experiments measuring substrates as unique biogas substrates

Substrate	200 ml of densified sewage sludge	10 g corn silage dissolved in 100 ml distilled water	5 g microcrystalline cellulose dissolved in 100 ml distilled water
Activated sludge	-	100 ml	100 ml
Maximal pressure change	162 hPa	373 hPa	382 hPa
Time required to achieve maximal pressure change	96 hours	40 hours	72 hours

In our co-fermentational experiments, densified sewage sludge was used as our primary substrate and was complemented with either corn silage or cellulose. Activated sludge was also added to some fermenters, so a comparison is possible between results obtained with solely densified sewage sludge and results in fermenters containing both densified sewage sludge and activated sludge as inoculants (see Figure 1 and 2).

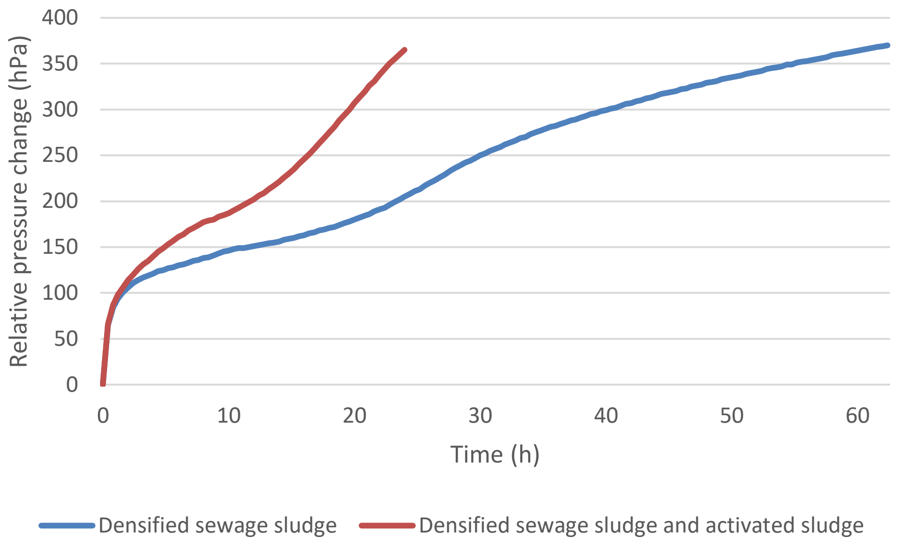

Figure 1

Biodegradation kinetics obtained from co-fermentation of densified sewage sludge and corn silage

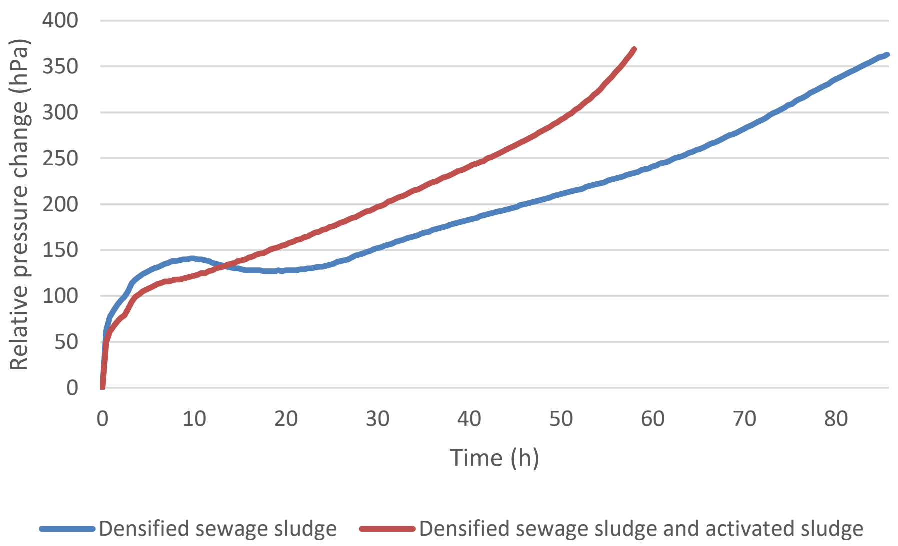

Figure 2

Biodegradation kinetics obtained from co-fermentation of densified sewage sludge and cellulose

CONCLUSION

Co-fermentation of densified sewage sludge with corn silage and cellulose resulted in a greater pressure change (400 hPa vs 162 hPa) in a lower amount of time (1 and 2 days respectively vs 4 days) compared to the gasification of densified sewage sludge on its own. Pressure change was 267% greater in 25% or 60% less time. The difference between degradation times of cellulose and corn silage is probably due to the corn's broader carbohydrate spectrum. Oligosaccharides in corn silage are more easily accessible, therefore the biodegradation could take place at an earlier stage.

Densified sewage sludge and agricultural byproducts can be valuable assets to biogas production as complementary substrates in co-fermentational installations.

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