

# IWA Conferences

## Co-digestion of cultivated microalgae and sewage sludge from municipal waste water treatment --Manuscript Draft--

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# Co-digestion of cultivated microalgae and sewage sludge from municipal waste water treatment

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One way to meet the increased demand for biogas in the society is to use microalgae as substrate. These algae would be cultivated in a treatment step of photobioreactors for reject water from sludge dewatering facilities. In the present study, a co-digestion experiment was established where sludge from a municipal wastewater treatment plant was fermented with harvested microalgae cultivated in lake water from lake Mälaren. The experiment was carried out as a BMP-test (Biochemical Methane Potential) under mesophilic condition (37°C) with fermentation bottles, where 0, 12, 25 and 37%, of the sludge was replaced with harvested microalgae. The results showed that the biogas production was improved with 12% for the bottles with 12% microalgae compared with the bottles with only sludge as a substrate. In the bottles with 25% and 37% microalgae the gas production was slightly reduced compared with the bottles where only sludge was used.

## Keywords

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## INTRODUCTION

The biogas produced from anaerobic digestion of sewage sludge is an environmentally friendly fuel and the expansion of biogas production systems will be an important contribution to the global conversion from fossil to renewable energy systems (Mercalf & Eddy, 2002). Since the demand for biogas is continuously growing and the biogas substrate, such as food waste, may soon become limited it is important for biogas producers to expand the range of substrates. One way to do this is to use microalgae in co-digestion with sewage sludge. The algae can be cultivated in a treatment step of photo bioreactors for waste water (Odlare et al., 2011; Su et al., 2011). Cultivation of microalgae in nutrient rich reject water has been evaluated by Rusten and Sahu (2011) and it was concluded to be possible to utilize nutrients from sludge liquor, natural light, and CO<sub>2</sub> in the process. Co-digestion with food-waste and different additional amounts of microalgae has been studied by Nehrenheim et al. (2012). This study revealed an increased production of biogas as well as increased methane yield by the addition of algae. The use of co-digestion of substrates in order to stabilize the digestion process by improving the C/N-ratio has been mentioned by several authors (Brune et al., 2009; Khalid et al., 2011; Mata-Alvarez et al., 2011). Especially for algae biomass it has been pointed out that the anaerobic digestion is limited by high N content (Brune et al., 2009; Wiley et al., 2011) and sludge has been suggested as suitable co-digestion substrate.

This paper explores the possibilities to use harvested microalgae from Lake Mälaren, as a co-substrate to sewage sludge in biogas production under mesophilic and thermophilic conditions. The aim is to investigate if co-digestion of microalgae and sewage sludge is more efficient for biogas production compared to using the sludge alone. The hypothesis is that easily accessible carbon and the extra nutrients added by the microalgae will give a higher biogas production. The study has been carried out as a BMP-experiment (Biochemical Methane Potential) in batch fermentation bottles and the production of biogas was measured during a 35 day fermentation period. BMP-tests were developed to get an easy and reliable analytical method to decide the digestions possibility and methane potential of an organic material (Carlsson & Schnürer, 2011).

## **MATERIALS AND METHODS**

### **Microalgae cultivation**

Lake water was collected from Lake Mälaren mid June 2012. The water was used the same day in the experiment, without any prior preservation or storage. A batch experiment was set up with two glass aquariums each containing 10.5 dm<sup>3</sup> lake water and 21.5 dm<sup>3</sup> tap water. 3.5 dm<sup>3</sup> of the nutrient mix Jaworski's medium was added to each aquarium in order to ensure sufficient growth of microalgae (Odlare et al., 2011) for harvesting and utilization in the co-digestion experiment. The aquariums were placed in a room with consistent light. The light intensity was 7000 lux (100 μmol photons/m<sup>2</sup>,s) in the beginning of the cultivation period. The microalgae was harvested on July 9<sup>th</sup> 2012, 20 days after cultivation start up. The content of total solids (TS) and volatile solids (VS) in the algae slurry was measured by an external laboratory according to Swedish standard (SS 02 81 13)(SIS, 1981). The result of the measurement was 6.05 TS% and 51.0 VS% for the cultivated microalgae (Average values from duplicates).

### **Undigested sludge and inoculums**

The substrate to be co-digested with algae in the experiment was undigested wastewater treatment sludge collected on the same day as harvesting the microalgae. The substrate is a mixture of primary sludge from the pre sedimentation and biosludge from the biological treatment. The sample was taken directly after the sedimentation step of the mixed sludge. The inoculum used in the test is sludge after the digesters at the waste water treatment plant. In this particular facility mesophilic digestion at 37 °C is applied for the stabilization of sludge. The content of total solids (TS) and volatile solids (VS) in the substrate and the inoculum was measured by an external laboratory according to the standard SS 02 81 13 (SIS, 1981). The results of the measurement were for the substrate 6.75 TS% and 54.2 VS% and for the inoculum 2.70 %TS and 54.1 %.

### **Biochemical methane potential (BMP-tests)**

The batch experiment of biogas production was conducted in 1 dm<sup>3</sup> conical bottles under mesophilic condition (37 °C) and in 0.1 dm<sup>3</sup> conical bottles in thermophilic condition (55 °C). All batches were run in triplicates. Total volume of fermented material in each flask was 700 cm<sup>3</sup> for the mesophilic BMP-test and the amount of added inoculum was 4.2 g VS (corresponding to 6 g/dm<sup>3</sup>). The total volume, in the thermophilic BMP-test, of fermented material in each flask was 70 cm<sup>3</sup> and the amount of added inoculum was 0.42 g VS (corresponding to 6 g/dm<sup>3</sup>). Eight treatments were prepared by replacing 0%, 12 %, 25 % and 37 % of undigested sludge with the cultivated microalgae. Control batches (bottles 1-3 and 16-18) were run with pure inoculum. Gentle stirring with a speed of approximately 130 rpm was applied during the whole test (model: Orbital shaker 4536).

### **Analysis of gas production and quality**

The gas production was measured by monitoring the pressure increase in the bottles with a pressure meter (modell: GMH 3161-13). Regularly gas samples were taken from each bottle for methane analysis in the biogas. The methane analysis was conducted by using gaschromatography (PerkinElmer Arnel Clarus 500, column 7' HayeSep N 60/80, 1/8" SF; FID detector 250 °C; carrier gas: helium, flow 31 cm<sup>3</sup>/min, temp injector 60 °C, test injection with a headspace sampler Turbo Matrix 110). The measured values of total biogas pressure at every measurement together with the knowledge of the gas volume and temperature in the bottles were used to determine the amount of produced biogas with the ideal gas law. Gas was produced and sampled in the headspace. The produced biogas was related to the amount VS added to each bottle and was recalculated in Ncm<sup>3</sup> (normal standard), i.e. at atmospheric pressure and at 0°C.

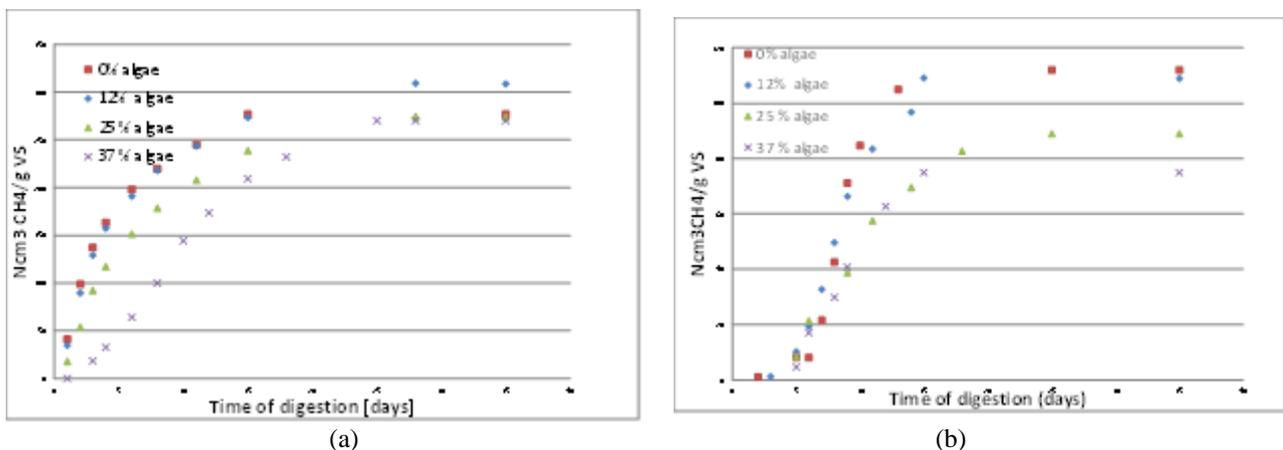
## RESULTS AND DISCUSSION

Table 1 shows the results of the BMP-tests after 35 days digestion. The methane potential varies with respect to the gas yields between the different BMP-bottles with the same amount of microalgae in the substrate. Nevertheless even with this deviation there was a difference in gas production between the bottles with different amounts of algae. The biogas production in the mesophilic conditions was improved with 12 % for the bottles with 12 % microalgae and 88 % sewage sludge compared with the bottles with 100 % sludge as a substrate. In the bottles with 25 % and 37 % microalgae the biogas production was slightly reduced compared with the bottles where only sludge was used. Under thermophilic conditions it was only a reduction of the biochemical methane potential when the microalgae were added.

**Table 1.** Biochemical methane potential of the algae and sewage sludge after 35 days of incubation

Treatment	Total accumulated methane production (Ncm <sup>3</sup> CH <sub>4</sub> /g VS)	
	Mesophilic digestion	Thermophilic digestion
0% algae	276±29	112±22
12% algae	309±46	109±29
25% algae	274±27	86±45
37% algae	270±114	75±49

Methane production curves are often divided into three stages: Lag phase, decomposition phase, and flattening phase (Carlsson & Schnürer, 2011). The lag phase is the time from the start of the experiment to the start of the methane production in the bottles. It can be seen in Figure 1(a) that there is no lag phase for the bottles with only sewage sludge, 12 % algae, and 25 % algae but a short lag phase for the bottles with 37 % algae. It seems that with a high content of micro algae the microorganisms in the inoculum are disturbed and need time to adjust to the new environment. If microalgae will be used in a full scale mesophilic digestion plant it might therefore be important not to change the relationship between sewage sludge and microalgae too fast and too much since this might cause a reduction of gas production for a period of time.



**Figure 1.** Methane potential per gram VS for untreated substrates 0, 12, 25, 37 % algae at (a) mesophilic conditions, (b) thermophilic conditions

In thermophilic conditions (shown Figure 1(b)) there is a lag phase in all the bottles. The reason for this phenomenon is because the inoculum is taken from a mesophilic digester. The microorganisms have to be adapted to the new temperature conditions before the methane production can start. If the

experiment will be redone it would be advisable to use an inoculum from a thermophilic digestion for the bottles that will be in thermophilic conditions. According to Figure 1(a) the decomposition phase in mesophilic conditions is slower for the bottles with high compositions of microalgae. This can indicate that the organic material in sewage sludge is more easily biodegraded than the organic material in microalgae. If Figure 1(a) and 1(b) is compared the decomposition phase as expected is much faster under thermophilic conditions than under mesophilic conditions. This faster decomposition phase of sewage sludge under thermophilic digestion is a well-known conclusion and has been shown in many studies, for example in the article Buhr and Andrews (1977).

## CONCLUSIONS AND FUTURE STUDIES

The results from this study showed that the use of an algae/bacteria community, cultivated in prior to digestion, can serve as a biomass substrate for biogas production together with municipal wastewater sludge. Co-digestion of microalgae and sewage sludge can be more efficient for biogas production compared using the sludge alone under mesophilic conditions and with 12 % micro algae and 88 % sewage sludge. It can also be concluded that thermophilic co-digestion between the microalgae and sludge gives lower biochemical methane potential.

The lower biochemical methane potential of higher share of microalgae in the sewage sludge (25% and 37 %) can be explained by the high content of nitrogen (N) in algae biomass. This was shown in both mesophilic and thermophilic condition.

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