IMPROVING THE ANAEROBIC BIODEGRADABILITY OF ALGAE BIOMASS FROM HIGH RATE PONDS FOR WASTEWATER TREATMENT

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Abstract

During the last decade, there has been a growing interest in investigating the energy potential of biofuels from microalgae cultures. To make biodiesel production economically feasible, it is suggested to digest residual biomass from lipid extraction; but the biogas potential would be reduced in comparison with the anaerobic digestion of microalgae. Up to date, the literature on microalgae digestion is very limited, an inconvenience of the process being the hydrolysis of cell walls. The aim of this study is to evaluate the effect of microwave pre-treatment on the disintegration and anaerobic biodegradability of algae biomass from high rate ponds for wastewater treatment. A pilot high rate pond was used as secondary treatment, followed by a settler for biomass separation. Thickened biomass was then pre-treated in a microwave (specific energy 200-500 kJ/kg), evaluating the pre-treatment effect by the increase in the ratios between dissolved and total COD (COD_d/COD) and volatile solids (VS_d/VS); as well as the methane production in Biochemical Methane Potential tests. The high rate pond achieved COD and NH_4-N removals around 75% and 85-90%, respectively. The microwave pre-treatment of algae biomass increased dissolved organic matter from 5.3 up to 17.6% COD_d/COD and from 3.7 up to 9.7% VS_d/VS, depending on the specific energy applied and temperature reached. Methane production results confirm that the pre-treatments leading to higher substrate disintegration, also lead to higher methane production. The best results were obtained applying a specific energy above 400 kJ/kg, with a final temperature above 75ºC.

Keywords: Algae biomass, Anaerobic digestion, Biogas, High rate pond, Pre-treatment, Wastewater

Introduction

During the last decade, there has been a growing interest in investigating the energy potential of biofuels obtained from microalgae cultures (Chisti, 2007; Sialve et al. 2009). The high lipid content of microalgae makes them an alternative to terrestrial energy crops for biodiesel production. However, this technology is still at an initial research phase. According to the literature, the cultivation of microalgae in photobioreactors to produce biofuels has a number of requirements that may limit its implementation at industrial scale. To make it economically feasible, it is suggested to use residual biomass from lipid extraction to generate biogas (Chisti, 2007). Taking into account that residual biomass would lack the most energetic components (lipids); the biogas potential would be considerably reduced in comparison with the anaerobic digestion of microalgae.

Anaerobic digestion of microalgae was first studied in the 1950s (Golueke et al., 1957; Oswald y Golueke, 1960). These authors used algae biomass from high rate ponds, pointing out biomass separation from the liquor as a major limitation of the process. Up to date, the literature on microalgae digestion is very limited compared to other substrates like sewage sludge. The review by Sialve et al. (2009) reports a specific methane production of 0.1-0.5 LCH_4/g SV, with 60-80% CH_4 in biogas, depending on process temperature (15-52 ºC) and hydraulic retention time (3-64 days). In order to improve process performance by hydrolysing the cell walls, Chen and Oswald (1998) applied a physical-chemical pre-treatment, at a range of temperatures, contact times and concentrations of NaOH; observing 33% increase in biogas production under the optimum pre-treatment conditions (100 ºC for 8 h).

The pre-treatment of substrates to increase the anaerobic biodegradability has been the subject of intense research in recent years (Carrère et al., 2010). Chemical, thermal and mechanical processes (i.e. ultrasounds and microwave) have proven successful at improving the disintegration and anaerobic biodegradability of sludge (Climent et al. 2007, Ferrer et al., 2008). Moreover, positive energy balances of these processes have been reported (Carrère et al., 2010).

The aim of this study is to evaluate the effect of microwave pre-treatment on the disintegration and anaerobic biodegradability of algae biomass from high rate ponds for wastewater treatment. Additionally, the performance of high rate ponds is also studied.

Methods

A pilot high rate pond (0.5 m^3) was used as secondary treatment, following a hydrolytic upflow sludge blanket (HUSB) treating urban wastewater. Algae biomass was separated from the liquor by means of a settler (0.1 m^3). The performance of the process was monitored (pH, chemical oxygen demand (COD), ammonia nitrogen (NH_4-N), etc.), biomass productivity quantified and the main algae species identified using a macroscope.

Algae biomass from the settlers was centrifuged in order to increase the total solids (TS) contents up to 3-4 %. The concentrated substrate was then pre-treated in a microwave at 450 and 200 W, for different periods of time, in order to achieve a specific energy (Eq. 1) ranging between 200-500 kJ/kg (Table 1). The effect of the pre-treatment was evaluated by the increase in the ratios between dissolved and total COD (COD_d/COD), and dissolved and total volatile solids (VS_d/VS).

$$\text{Specific energy (kJ/kg)} = \frac{\text{Power (W)} \cdot \text{Time (s)}}{\text{Sample Weight (kg)}} \qquad \text{Eq. 1}$$

The anaerobic biodegradability of pre-treated substrates was compared to the control (non pre-treated biomass algae) by means of mesophilic biochemical methane potential (BMP) tests.

Results and discussion

Preliminary results on the evolution of COD and NH_4-N in the high rate pond treating the primary effluent of a HUSB are shown in Figure 1. NH_4-N removal ranged between 85-90 % throughout the experiment, while COD removal increased from 20 to 75 %. The pH was around 7-7.5 and 8.5-9 in the influent and effluent, respectively.

Figure . COD and ammonia nitrogen evolution in high rate ponds for secondary wastewater treatment.

Thickened algae biomass was pre-treated under the conditions summarised in Table 1. Notice the final temperature reached at the end of each microwave pre-treatment, around 50-55, 65-75 and 90 ºC for the lowest, medium and maximum specific energies assayed. The effect of the pre-treatment was shown by an increase in the ratios COD_d/COD (from 5.3 up to 17.6 %) and VS_d/VS (from 3.7 up to 9.7 %), depending on the specific energy applied and temperature reached. The best results were obtained applying a specific energy above 400 kJ/kg, with a final temperature above 75 ºC.

Table . Microwave pre-treatment conditions and increase in the dissolved to total COD and VS ratios.

Substrate	Power (W)	Time (s)	Specific energy (kJ/kg)	Temperature (ºC)	COD_d/COD (%)	VS_d/VS (%)
Control	0	0	0		5.35	3.74
Micro 1	450	120	270	56.4	11.95	7.02
Micro 2	450	180	405	76.1	13.33	8.22
Micro 3	450	240	540	90.4	14.05	9.71
Micro 4	200	240	240	51.4	9.29	4.92
Micro 5	200	360	360	64.3	11.25	5.98
Micro 6	200	540	540	91.2	17.65	7.88

The effect of the pre-treatment was also evaluated by the increase in methane production during BMP tests. According to the results of the first assay (Figure 2), not all pre-treatment conditions improved the methane production in comparison with the control (non pre-treated biomass). However, the results confirm that the pre-treatment leading to a higher substrate disintegration, also lead to a higher methane production (Micro 3, Micro 6 and Micro 2). In this way, the best results were obtained applying a specific energy above 400 kJ/kg, with a final temperature above 75 ºC.

Figure 2. Methane production during mesophilic BMP tests with microwave pre-treated algae biomass.

Conclusions

In this study, effect of microwave pre-treatment on the disintegration and anaerobic biodegradability of algae biomass from high rate ponds for wastewater treatment was evaluated. The high rate pond achieved COD and NH_4-N removals around 75% and 85-90%, respectively. The microwave pre-treatment increased dissolved organic matter from 5.3 up to 17.6% COD_d/COD and from 3.7 up to 9.7% VS_d/VS, depending on the specific energy applied and temperature reached. Methane production results confirm that the pre-treatments leading to higher substrate disintegration, also lead to higher methane production. In this way, the best results were obtained applying a specific energy above 400 kJ/kg, with a final temperature above 75ºC.

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