Bioresource Technology 185 (2015) 341–345

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Influence of starch on microalgal biomass recovery, settleability and biogas production

Raquel Gutiérrez, Ivet Ferrer, Joan García, Enrica Uggetti *

GEMMA – Engineering and Microbiology Research Group, Department of Hydraulic, Maritime and Environmental Engineering, Universitat Politècnica de Catalunya·Barcelona Tech, c/ Jordi Girona 1-3, E-08034 Barcelona, Spain

HIGHLIGHTS

- This study aimed at evaluating starch as flocculant for microalgal harvesting.
- The optimal flocculants dose (25 mg/L) led to more than 95% biomass recovery.
- Settleability was studied in elutriation apparatus measuring velocities distribution.
- Flocculants increased by 30% the particles with settling velocity higher than 6.5 m/h.
- Biochemical methane potential tests results showed a biogas yield increment of 8–15%.

ARTICLE INFO

Article history:
Received 18 December 2014
Received in revised form 27 February 2015
Accepted 1 March 2015
Available online 6 March 2015

Keywords:
Coagulant
Flocculant
Harvesting
High rate algal pond
Microalgae

ABSTRACT

In the context of wastewater treatment with microalgae cultures, coagulation–flocculation followed by sedimentation is one of the suitable options for microalgae harvesting. This process is enabled by the addition of chemicals (e.g. iron). However, in a biorefinery perspective, it is important to avoid possible contamination of downstream products caused by chemicals addition. The aim of this study was to evaluate the effect of potato starch as flocculant for microalgal biomass coagulation–flocculation and sedimentation. The optimal flocculant dose (25 mg/L) was determined with jar tests. Such a concentration led to more than 95% biomass recovery (turbidity < 9NTU). The settleability of flocs was studied using an elutriation apparatus measuring the settling velocities distribution. This test underlined the positive effect of starch on the biomass settling velocity, increasing to >70% the percentage of particles with settling velocities >6.5 m/h. Finally, biochemical methane potential tests showed that starch biodegradation increased the biogas production from harvested biomass.

1. Introduction

During the last decade the potential of microalgae as biorefinery feedstock has been widely investigated (Uggetti et al., 2014). In spite of the promising results obtained, scaling-up the technology is hampered by the high costs of the process. In particular, the biomass harvesting step represents 20–30% of microalgal biomass production costs (Barros et al., 2015).

A number of solids separation techniques are currently available in the field of water treatment technology including centrifugation, flocculation and flotation (Uduman et al., 2010; Kurniawati et al., 2014) or membrane procedures such as magnetic, vibrating and rotating membranes. In general, for the production of low-value products such as biofuels, harvesting techniques should consist in low-cost and low-energy demand methods capable of processing a large volume of culture medium. Thus, coagulation–flocculation followed by sedimentation is among the most suitable options. This process is enhanced by the addition of chemicals such as salts of aluminum or iron. In a biorefinery context, it is important to ensure that downstream products are not contaminated by chemicals (Zheng et al., 2012). For this reason, the use of natural organic flocculants like tannin based polymers or modified starch are being increasingly investigated (Vandamme et al., 2013). Indeed, potato starch could be seen as a residue from the potato industry (e.g. starch contained in potatoes peel).

The aim of the present study was to evaluate the effect of potato starch on the coagulation–flocculation and sedimentation of microalgal biomass grown in a pilot high rate algal pond (HRAP) used for wastewater treatment. The optimal dose was determined with jar tests and the settleability of formed flocs was studied

* Corresponding author. Tel.: +34 934016465.
E-mail address: enrica.uggetti@upc.edu (E. Uggetti).

http://dx.doi.org/10.1016/j.biortech.2015.03.003
0960-8524/

using an elutriation apparatus measuring the settling velocities distribution. Moreover, the effect of starch on biogas production was determined in biochemical methane potential (BMP) tests.

2. Methods

2.1. Microalgae culture

Microalgal biomass used for this experiment was cultivated in an experimental plant located at the laboratory of the GEMMA research group (Universitat Politècnica de Catalunya, Barcelona, Spain). The pilot plant consists of a HRAP in the form of a raceway pond (0.47 m^3volume) fed with a continuous flow of 60 L/day of primary treated wastewater (24 g chemical oxygen demand (COD)/m^2·d; 4 g ammonium nitrogen (NH_4^+-N)/m^2 d). The system had been in operation for 4 years prior to the experiment, and was described in detail by Passos et al. (2013). At the time the experiments were conducted microalgal population was mainly composed by *Chlorella* sp. with a total suspended solids (TSS) concentration about 200 mg/L.

2.2. Flocculant

Starch is a natural product having strong flocculating properties. Potato starch solution 1% ($C_6H_{10}O_5$) provided by Panreac (Spain) was used as flocculant. Starch addition did not modify significantly the pH of the system, which remained almost constant along the experiments (9.5 ± 0.6). The zeta potential was determined for the selected starch concentrations and resulted in values of −35.8 mV (for 10 mg/L) and −19.4 mV (for 25 mg/L).

2.3. Jar tests

The optimal dose of flocculant was determined by means of jar tests performed following standard protocols (Metcalf and Eddy, 2003). Five jar tests were carried out during February and March 2014, with starch concentrations from 5 to 80 mg/L. Turbidity and pH (measured with a HI93703 Hanna Instruments Turbidimeter and a Crison 506 pH-meter, respectively) were determined from fresh HRAP mixed liquor at the beginning of the experiments and from the supernatant liquid after the jar tests. Then, biomass recovery (RE) was calculated based on initial (Ti) and final (Tf) turbidity measurements (Eq. (1)). Recovery values of the five jar tests were then averaged.

$$RE\,(\%) = (Ti - Tf)/Ti * 100 \qquad (1)$$

2.4. Elutriation test

Elutriation is a water-current separation technique in which particles are washed out according to their weight, volume or form. This test can be used to assess the feasibility of separation treatment by settling (Krishnappan et al., 2004).

The water elutriation apparatus used in the present study was a modified version of a system proposed by Walling and Woodward (1993). The system (Fig. 1) consisted of 3 cylindrical settling columns of different diameter (corresponding to different settling velocities) interconnected in series by glass and PVC tubing. The diameters of the columns were: 50 mm in the first column, 100 mm in the second and 200 mm in the third one. The sample entered the columns near the bottom and exited near the top, allowing the sediment flocs that had settling velocities higher than the upward suspension velocity to settle in the respective columns. Considering a flow rate of 0.21 L/min, the upward velocities generated in the three settling columns were 6.5 m/h, 1.6 m/h and 0.4 m/h, respectively. Thus, the first column collected biomass with settling velocities >6.5 m/h, second column collected biomass with settling velocities between 6.5 and 1.6 m/h, and the third column collected the biomass with settling velocities between 1.6 and 0.4 m/h. The outlet suspension contained the biomass fraction

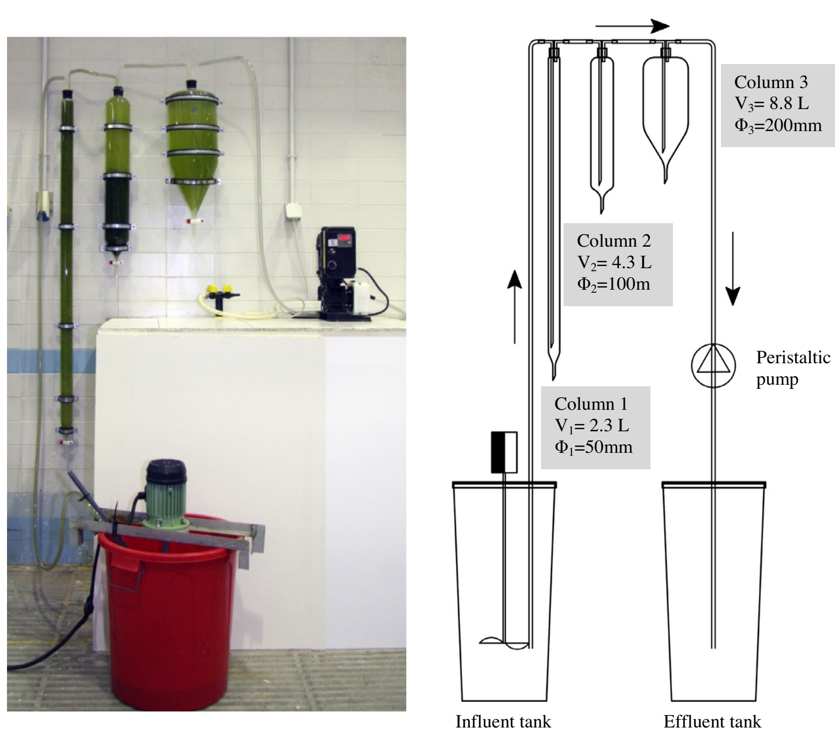

Fig. 1. Image and schematic view of the experimental elutriation apparatus used for testing the settleability of microalgal biomass.