Bioresource Technology 238 (2017) 733–737

Contents lists available at ScienceDirect

Bioresource Technology

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

Short Communication

Electrohydrolysis pretreatment of water hyacinth for enhanced hydrolysis

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HIGHLIGHTS

- Growth of water hyacinth and decline in fossil fuel is a dilemma worldwide.
- Water hyacinth can be utilized for the production of renewable biogas.
- Hydrolysis of water hyacinth is tedious due to the presence of lignin.
- Electrohydrolysis pretreatment was studied to cut short the hydrolysis period.
- Electrohydrolysis pretreatment enhanced the hydrolysis of water hyacinth.

ARTICLE INFO

Article history:
Received 10 February 2017
Received in revised form 4 April 2017
Accepted 5 April 2017
Available online 8 April 2017

Keywords:
Water hyacinth
Electrohydrolysis pretreatment
Lignocellulose
Hydrolysis

ABSTRACT

This study investigates the use of electrohydrolysis pretreatment on water hyacinth to cut short the hydrolysis step and increase biogas production at the same time. Electrohydrolysis pretreatment of water hyacinth at 20 V for 60 min exhibited improved solubilisation (42.9%). Therefore, bio-chemical methane potential (BMP) test was carried out between water hyacinth pretreated at 20 V for 60 min and untreated water hyacinth. By the end of 30 days, cumulative methane production of 2455 ± 17 mL CH_4/g VS for electrohydrolysis pretreated substrate and 1936 ± 27 mL CH_4/g VS for the untreated substrate was achieved. Compositional analysis and characterization study revealed the efficiency of electrohydrolysis pretreatment in melting the lignin and lowering the cellulose crystallinity of water hyacinth.

1. Introduction

Incessant reproduction potential of water hyacinth and burning of fossil fuel is a universal problem. Burning of fossil fuel generates green house gases which pollutes the environment and regular usage of fossil fuel has led to its scarcity thus increasing its price. Water hyacinth mats on the other hand, hinders the aquatic ecosystem and the livelihood and recreational activities of people. Hence, anaerobic digestion seems to be a good alternative for managing water hyacinth and tackling environmental pollution, energy crisis. During the phase of stress, the quiescent seeds at the floor of the aquatic body initiates the growth cycle of this pest (Malik, 2007). However, water hyacinth biodegradability is lessened due to the occurrence of lignin, elevated cellulose crystallinity and confined available surface area. Consequently, making hydrolysis a cumbersome step and restraining the production of biogas (Barua and Kalamdhad, 2016). Thus, to accelerate the hydrolysis step and enhance the biogas production, electrohydrolysis pretreatment was investigated. The principle of electrohydrolysis pretreatment depends on ohmic heating, electrophoresis and electro-osmosis thereby unlocking the lignocellulosic complex i.e., making hydrolysis easier and faster (Mahmoud et al., 2010; Zhen et al., 2014).The method of generating thermal energy from organic substances by the passage of electric current is known as ohmic heating (Knirsch et al., 2010). The organic substrate acts as an electrical resistor. Electrical resistance aids uniform and rapid heating of mixture with high solid fraction (Varghese et al., 2014). The shifting of ions relative to a static phase is known as electrophoresis (Mahmoud et al., 2010). In electrophoresis, when electric current is passed through the substrate, the molecules in the mixture, passes through the medium at altered rate, depending on its electrical charge and molecular size. The motion of solid particles suspended in a liquid, under the influence of an electrical

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http://dx.doi.org/10.1016/j.biortech.2017.04.016
0960-8524/

field is known as electro-osmosis (Mahmoud et al., 2010). Direct current (DC) is used for electrohydrolysis pretreatment of water hyacinth because in electrolysis the ionisation of the electrolyte occurs i.e., the cation and anion travels towards the opposite electrodes (Nandi, 2013). The polarity of the electrodes keeps switching places on the application of alternating current (AC), resulting in no ionisation i.e., the ions will not be attracted towards any of the electrode.

In this study, the effect of the electrohydrolysis pretreatment on the hydrolysis of water hyacinth was investigated. This is a novel work, as to the best of knowledge nobody has ever investigated the effect of electrohydrolysis pretreatment on freshly ground water hyacinth whole plant followed by bio-chemical methane potential (BMP) test.

2. Materials and methods

Fresh water hyacinth whole plant was gathered from the Amingaon industrial area and cow dung from Amingaon village, situated near the campus of Indian Institute of Technology Guwahati (IITG), India. Initial study, revealed the ratio of leaves, stem and roots of a grown fresh water hyacinth plant to be 13:69:45. Accordingly, equivalent ratio of leaves, stem and root of water hyacinth was chopped and then ground to be used in every trial.

2.1. Electrohydrolysis set up

The electrohydrolysis set up comprised of a 2 L plastic feed tank, DC power supplier, two graphite electrodes, flash mixer, ammeter, multimeter and tachometer. The feed tank was half filled with ground water hyacinth. DC was passed through the sample with the help of the electrodes which were half immersed in the substrate. The graphite electrodes, set 10 cm apart, acted as both anode and cathode. Insulated flash mixer kept the substrate in suspension, by continuously stirring at 300 rpm. Tachometer maintained the speed of the flash mixer. Ammeter assessed the current while multimeter checked the voltage in the circuit.

2.1.1. Voltage and time study

For voltage study, each sample was exposed to different voltage. The voltage considered for this study are 10, 15, 20, 25 and 30 V (Yuan et al., 2011; Gharibi et al., 2013; Zhen et al., 2014). A sample was kept as control without providing electrohydrolysis pretreatment. All samples were exposed to a time period of 30 min. The water hyacinth sample pretreated at 30 V was discarded due to excessive foaming. For time study, each sample was exposed to different time interval (20, 40, 60, 80 and 100 min) at the optimised voltage (Yuan et al., 2011; Gharibi et al., 2013). The sample pretreated at 100 min was discarded due to excessive foam formation. A sample was kept as control without giving any treatment. Optimum voltage and time exposure was selected based on soluble chemical oxygen demand (sCOD) (APHA, 2005) and volatile fatty acids (VFA) (DiLallo and Albertson, 1961).

2.1.2. Compositional analysis and instrumental characterization

To determine the composition of lignin and cellulose, national renewable energy laboratory (NREL) procedure (Ehrman, 1996); Updegraff (1969) method was useful. Goering and Van (1975) method assisted in analysing the changes in hemicellulose. HPLC (Perkin Elmer Series200, Switzerland) equipped with a column (Agilent Hi-PlexH) was used to estimate glucose and xylose content. FESEM (Zeiss, Sigma) was used to study the morphology of water hyacinth before and after pretreatment. FTIR (PerkinElmer Spectrum 2) spectra was obtained for the substrate before and after electrohydrolysis pretreatment using KBr discs. XRD diffractometer (Bruker, D-8 Advance) recorded the X-ray diffractograms from 5 °C to 35 °C of diffraction angle (2θ) at a scanning speed of 5°/min.

2.2. Anaerobic biodegradability test

BMP test was performed between untreated and electrohydrolysis pretreated water hyacinth for a food to microorganism ratio of 1.5:1 calculated on the basis of volatile solids content. Triplicate bottles (1L) were fed with freshly ground water hyacinth, cow dung and with essential macro and micro nutrients. A control was kept only with water hyacinth. Distilled water was used for maintaining the volume at 700 mL. Nitrogen was purged, fastened and connected to aspirator bottles filled with 1.5 N NaOH (Elliott and Mahmood, 2007). The experiment was conducted till the cumulative biogas curve stabilised.

3. Results and discussion

3.1. Electrohydrolysis pretreatment

3.1.1. Variation of current and resistance with time at different applied voltages

It was observed that at the constant applied voltage, current increases (Fig. 1a) and resistance decreases (Fig. 1b) gradually with the increase in time of exposure. During electrohydrolysis pretreatment, carbohydrates and proteins are broken down into glucose and amino acids respectively. Amino acids get ionised in aqueous solution but glucose does not. As water hyacinth mainly contains carbohydrate, therefore not much increase in current can be witnessed although sCOD is increased (Fig. 2). The slight increase in current can be attributed to the low protein content in water hyacinth getting converted to amino acids. Thus, increase in conductivity during electrohydrolysis is minimal. The decrease in sCOD at 25 V is due to vaporisation of volatile compounds.

With the rise in applied voltage, the slope of the current versus time rose and the slope of the resistance versus time fell. When the sample pretreated at 10 V depicted a rise of just 0.091 amp and a

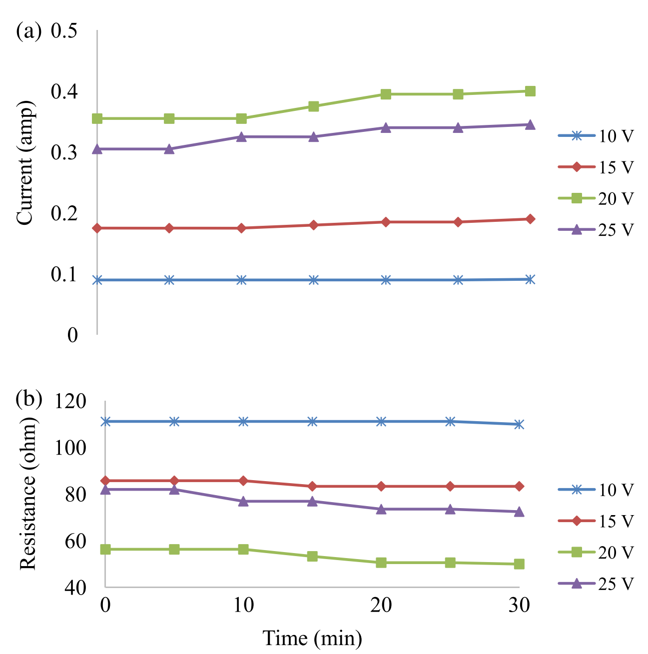

Fig. 1. Variation of (a) current and (b) resistance of with time at different applied voltage (V).