Bioresource Technology 217 (2016) 21–27

Contents lists available at ScienceDirect

Bioresource Technology

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

Improving the biogas production performance of municipal waste activated sludge via disperser induced microwave disintegration

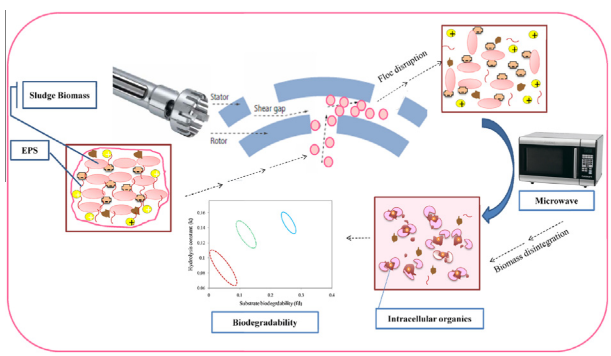
S. Kavitha [a,1], J. Rajesh Banu [a,*], J. Vinoth Kumar [a,1], M. Rajkumar [b]

[a] Department of Civil Engineering, Regional Centre of Anna University, Tirunelveli, India
[b] Department of Life Sciences, Central University of Tamil Nadu, Thiruvarur, India

HIGHLIGHTS

- Disperser induced microwave pretreatment is a novel sludge disintegration process.
- This efficient process solubilize organics at 18,000 kJ/kg TS of specific energy.
- This pretreatment enhances the disintegration rate efficiently upto 18,000 kJ/kg TS.
- The novel process improves VFA production (770 mg/L) efficiently at fermentation.
- A positive net profit of 104.8 USD/ton of sludge was obtained by this process.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 22 December 2015
Received in revised form 8 February 2016
Accepted 9 February 2016
Available online 12 February 2016

Keywords:
Sludge
Disperser
Microwave
Disintegration
Methane

ABSTRACT

In this study, the influence of disperser induced microwave pretreatment was investigated to analyze the proficiency of floc disruption on subsequent disintegration and biodegradability process. Initially, the flocs in the sludge was disrupted through disperser at a specific energy input of 25.3 kJ/kg TS. The upshot of the microwave disintegration presents that the solids reduction and solubilization of floc disrupted (disperser induced microwave pretreated) sludge was found to be 17.33% and 22% relatively greater than that achieved in microwave pretreated (9.3% and 16%) sludge alone. The biodegradability analysis, affords an evaluation of parameter confidence and correlation determination. The eventual biodegradability of microwave pretreated, and floc disrupted sludges were computed to be 0.15 (g COD/g COD) and 0.28 (g COD/g COD), respectively. An economic assessment of this study offers a positive net profit of about 104.8 USD/ton of sludge in floc disrupted sample.

1. Introduction

Activated sludge process is the extensively employed technique in waste water treatment (particularly in municipal waste water treatment) plants, which foments colossal quantity of waste activated sludge (WAS) (Appels et al., 2013). The WAS mostly contains a hefty amount of biomass, primarily protein carbohydrate and lipids in particulate forms (Saha et al., 2011). Therefore prior to disposal, the sludge must be treated because of its high organic load. Anaerobic degradation (AD) is the most competent treatment for waste activated sludge from the perspective of energy recovery (Kandel et al., 2013). In AD process, solubilization (hydrolysis) is believed to be the rate restriction step (Yang

* Corresponding author at: Department of Civil Engineering, Regional Centre of Anna University, Tirunelveli 627007, India. Tel.: +91 9444215544.
E-mail address: rajeshces@gmail.com (J. Rajesh Banu).
[1] These two authors have contributed equally in this work.

http://dx.doi.org/10.1016/j.biortech.2016.02.034
0960-8524/

et al., 2013). Hence to appease solubilization of particulate organics to biodegradation, different disintegration methods such as thermal (Neyens and Baeyens, 2003), chemical (Chen et al., 2013), mechanical (Poornima et al., 2014), biological (Kavitha et al., 2015a) methods or combination of any of these methods are effectuated prior to AD process. Amidst the above disintegration methods, thermal disintegration has been evaluated as a promising technique (Jang and Ahn, 2013). Conventional low-temperature thermal disintegration requires prolonged treatment time in lieu to high temperature treatment (Neyens and Baeyens, 2003). Corrosion problems and narrow knowledge gap put off this technique from attaining its higher potential ability for disintegration. As a result, an effectual disintegration process is still essential. One potential approach is to employ microwave (MW) irradiation for disintegration. The appliance of MW can cause polar side-chains of larger molecules to ally with the path of the electric field, probably causing the breakage of hydrogen bonds and modification of the hydration zone. The prime features of MW irradiation leverages dielectric parameters such as temperature, radiation time, and penetration depth which dexterously disintegrate the cells. However, the major disadvantage of this method is high energy consumption and costs. Accordingly the higher energy requirement and costs of microwave can be downsized by combining with other disintegration methods. Nevertheless increase in the cell disintegration does not expedite higher energy recovery (Ebenezer et al., 2015). Therefore to reduce the energy consumption and to increase the energy recovery from the sludge, in the present study, it is planned to deflocculate the sludge with disperser, an effective mechanical method to disrupt the flocs, known for its proficient function such as pressure gradient, cavitation, impingement, shear stresses and extensional shear (Poornima et al., 2014).

Extracellular Polymeric Substances (EPS) are microbial secretion positioned on or exterior to the cell and embodies multifaceted combination of proteins, carbohydrates, lipids, DNA, and humic acid substances (Liang et al., 2010). These EPS provides structural stability to the flocs. Therefore by disrupting the flocs through the release of EPS could enhance the disintegration efficiency of subsequent microwave pretreatment. Hence the present study aims to disrupt the flocs with disperser and disintegrates the sludge biomass through subsequent microwave pretreatment. As to our knowledge, studies about the influence of disperser on floc disruption followed by subsequent microwave disintegration have been seldom reported. The key objectives of the present work is (1) to disrupts the flocs at lower specific energy input; (2) to evaluate the influence of disperser induced microwave pretreatment on disintegration; (3) to explore kinetic determination of disintegration rate; (4) to study the effect of this novel approach in fermentation studies; (5) to assess the proficiency of disperser induced microwave disintegration on biodegradability through parameter estimation (non linear regression modeling).

2. Methods

2.1. Sludge sampling and characterization

The waste activated sludge (WAS) was obtained from a return line of secondary sedimentation of wastewater treatment plant at Karakonam in Kerala (India). The characteristics of sludge samples were as follows: pH was 7.65, Soluble COD (SCOD) was 200 mg/L, Total COD (TCOD) was 10,200 mg/L, Total Solids (TSs) content was 11,520 mg/L, Volatile Solids (VSs) content was 4000 mg/L, and Suspended Solids (SS) content was 7500 mg/L.

2.2. Floc disruption experiment

Sludge floc disruption was performed using a disperser (IKA T25 Ultra Turrax Digital disperser). The experiment was done with 500 mL of sludge taken in 1000 mL conical flask. A sequence of experimentation was carried out with different specific energy input ranges from (0 kJ/kg TS to 50 kJ/kg TS) for effective removal of EPS. In addition, the floc disruption experiment depends on reaction time, and it was assessed by collecting samples at various time intervals (5 s–30 min).

2.3. Microwave pretreatment

Pretreatment experiment was performed as batch process with 250 mL of sludge in a microwave oven (2450 MHz frequency, 900 W). The experiments was carried out in Polytetrafluoroethylene (PTFE) vessels for effective microwave diffusion and a cover was employed to evade sludge losses caused by hot spot formation during the disintegration process. The tests were performed at different treatment times ranges from 0 min to 45 min. The specific energy was performed by following the method of Yang et al. (2013).

2.4. Fermentation studies

Fermentation experiments were performed in 300 mL glass bottles. The substrate and inoculum were employed in the ratio of 9:1. The samples were heated at 102 °C for 30 min and added with 50 mM BESA (2-bromoethane sulfonic acid) to get rid of methanogens. Subsequently, the bottles were purged with nitrogen and placed in a shaker at 120 rpm for 72 h at 35 °C.

2.5. Biodegradability studies

Biodegradability assay was performed according to the method adopted in the previous work (Kavitha et al., 2014a–c). The inoculum (bovine rumen fluid) and substrates (control (raw), microwave pretreated alone, and disperser induced microwave pretreated samples) were employed in a ratio of 3:1. The first order kinetic model was executed to assess the methane generation as follows:

$$M(t) = M(fd) * \left(1 - e^{kt}\right)$$

where $M(t)$ is the cumulative methane yielded at digestion time t days (g COD/g COD added), $M(fd)$ is methane potential of the substrate (fraction of the degradable substrate that can be converted to methane) (g COD/g COD added), k is the first order disintegration rate constant (day^{-1}), and t is the time (days). The model was executed in a Mat lab 2012a Version. The parameter assessment, and uncertainty with 95% confidence region, was computed according to the work of (Batstone et al., 2009).

2.6. Analytical methods

SS, TCOD, SCOD, Volatile Fatty Acids (VFA) and Turbidity were estimated as per standard methods (APHA, 2005). The extracellular polymers (proteins and carbohydrates), DNA were quantified according to the method adopted by Kavitha et al. (2015b,c).

2.7. Statistical analysis

All analyses were performed in triplicate and the outcomes were articulated as an average of triplicate. A Standard T test was done to test the significance of results where $P < 0.05$ was calculated to be statistically significant.