



Mechanical pretreatment effects on macroalgae-derived biogas production in co-digestion with sludge in Ireland



S. Tedesco*, K.Y. Benyounis, A.G. Olabi

Department of Mechanical and Manufacturing Engineering, Dublin City University, Glasnevin, Dublin 9, Ireland

ARTICLE INFO

Article history:

Received 15 November 2012

Received in revised form

14 January 2013

Accepted 29 January 2013

Available online 7 March 2013

Keywords:

Seaweeds

Anaerobic digestion

Biogas

Mechanical pretreatment

Optimisation

ABSTRACT

Cell walls and lignin component disruption treatments are needed to enhance the hydrolytic phase and the overall biodegradability of lignocellulosics during an anaerobic digestion process. Given their abundant availability in nature, low impact on food market prices and low lignin content, aquatic plants result in being particularly suitable for biofuel conversion.

A preliminary study on the effects of a Hollander beater mechanical pretreatment has been conducted in batch mode focusing on biogas yields from five different species of Irish seaweeds in co-digestion with sludge. A second experiment on *Laminaria Digitata* species has been carried out using a Response Surface Methodology (RSM) with treatment times (0–10 min), mesophilic range of temperatures (35–39 °C) and sludge amounts (100–300 ml). Results from biogas yields of treated macroalgae have been found to be up to 20% higher when compared to untreated ones. A mathematical model of the biogas volume behaviour has been developed and the ideal conditions identified.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Seaweeds as plants have much in common with their terrestrial relatives but their chemical composition differs greatly from lignocellulosic biomass. Besides being carbon neutral [1] like terrestrial plants, seaweed exploitation for bioenergy production has in particular two great advantages: aquaculture does not occupy land suitable for agriculture and growth rate is three-dimensional along height, breadth and length [2,3]. Algae have also been found to positively contribute to higher biogas yields in co-digestion with other organic wastes [4,5]. The anaerobic digestion (AD) of algal waste not only recycles the nutrients but also provides biomethane, a renewable energy source [6]. Many studies from different countries have been recently considering expanding their production of biofuels using indigenous resources in order to achieve lower greenhouse gas (GHG) emissions [7–9]. A pretreatment phase is generally necessary to break down the crystalline

structure of any type of plant biomass that, along with lignin, is an inhibitor and thus responsible for delaying the digestion of the cellulose and the hemicellulose [10–15]. In this respect macroalgae are better suited for the anaerobic digestion process to methane fermentation [16]. In fact, they not only have low lignin but also contain high levels of carbohydrates which make them a better feedstock for bioenergy production. Despite the low levels of lignin, macroalgal feedstock requires a mechanical pretreatment to be fully exploited [17], in order to improve and shorten the digestion cycle. In this study indigenous Irish seaweeds have been considered as substrate for pretreatment prior to anaerobic digestion.

In the literature many types of pretreatments have been performed on various substrates, while consequences to methane production were estimated [10,18–20]. The most used physical treatment on lignocellulosics is the *thermal* pretreatment, while the most used mechanical technique is *milling* [21]. Thermal pretreatment is very effective at enhancing both biogas yields and methane production, however due to its high temperature requirements it is expensive to maintain and, most importantly above certain levels of temperature, inhibiting phenomena may occur [22]. The extent of the inhibition depends on the type of substrate. Milling aims instead at reducing the particle sizes and leads to an increase of specific surface area available to microorganisms. Besides other advantages [18,23–26], milling results in a double benefit: it reduces the digestion time by 23–59% and it causes an increase in biogas yield by 5–25% of most lignocellulosics [10]. However, milling has high energy requirements which still limit its

Abbreviations: ADF, acid detergent fiber; ADL, acid detergent lignin; ANOVA, analysis of variance; BT, beating time; COD, chemical oxygen demand; HRT, hydraulic retention time; NDF, neutral detergent fiber; RSM, response surface methodology; SA, sludge amount; T, temperature; TS, total solids; VFA, volatile fatty acids; VS, volatile solids; WSC, water soluble carbohydrates.

* Corresponding author. Tel.: +353 1 700 7563.

E-mail addresses: silvia.tedesco84@gmail.com, silvia.tedesco3@mail.dcu.ie (S. Tedesco), khaled.benyounis2@mail.dcu.ie (K.Y. Benyounis), abdul.olabi@dcu.ie (A.G. Olabi).

exploitation as the continuous rise of energy prices is not counterbalanced by significant extra gas produced [27,28].

In our study digester sludge has been used to inoculate batch digesters with the necessary microorganisms. However, the sludge itself can be used as substrate for anaerobic digestion purposes and it currently constitutes the main organic waste for biogas production in wastewater treatment facilities. A variety of pretreatments can be applied on sludge singularly or in combination with others, with the goals of improving the methane yield and sludge's dewaterability, destroying the sludge's pathogens and reducing the odours associated with putrescible matter disposal [29]. Chemical and thermal treatments are mainly used for dewaterability improvements and pasteurization purposes, besides being associated with shorter retention times. Neyens et al. [30], for instance, show an improved sludge's dewaterability with a 30% reduction of the sludge volume via application of hydrogen peroxide treatment. An interesting review [31] shows the effect of thermal treatment temperature on different types of sludge, with ideal treatment temperature identified at 175 °C. Sludge's particles disintegration was efficiently achieved by Appels et al. [32] with 40% extra biogas obtained for low frequency ultrasound treatment at 37 °C.

This paper investigates the improvements provided by a Hollander beater pretreatment. This technique is based on the same 'comminution' concept proposed by all other mechanical treatments and increases biogas production. Due to the multiple benefits of exploiting the co-digestion technique [4,5], a co-digestion with sludge will provide the necessary bacteria in the digesting reactors. The Hollander beater has never been used as mechanical pretreatment machine on seaweed biomass. Seeing that this proposed pretreatment has already proved its effectiveness when applied to maize silage [33] gaining up to 29% extra biogas volume, in this study it has been applied to seaweed biomass in batch mode. The energy balance assessment at laboratory scale has been carried out and discussed in the results section.

2. Materials and methods

2.1. Pretreatment machine characteristics

The pre-treatment machine consists of a modified Hollander beater, model Reina in Fig. 1. The machine is made of an elliptic water raceway equipped with a bladed drum spinning at 580 RPM. The energy requirement of the machine's engine is 1 hp. A bed-plate with sharp grooves is located under the rotating wheel with dual functionality for cutting the material and decreasing the gap between blades and bed-plate. When the power is activated, blades

and grooves exercise a cutting action while the high pressure and speed reached under the drum beat the mixture.

2.2. Feedstock composition

Algal biomass has been collected on-shore in Howth (Dublin, Ireland) in mid-January 2012 for the preliminary experiment and mid-February 2012 for the second experiment and treated the same day. The species under investigation are *Pelvetia Caniculata*, *Fucus Serratus*, *Gracilaria Gracilis*, *Fucus Vesiculosus Linnaeus* and *Laminaria Digitata*. The biological composition of each collected species has been provided by the Lyons Research Farm of University College Dublin and is shown in Table 1. Analysing Table 1 some observations were made: *L. Digitata* species has the highest amount of water soluble carbohydrates (WSC) which is expected to speed up the digestion at least at an initial stage [34,35]. *Gracilaria Gracilis* species holds the highest neutral detergent fiber content (NDF), which means more cellulose, hemicellulose and lignin but on the other hand it also contains the highest acid detergent lignin (ADL) value. *Pelvetia Caniculata* species has a reasonable %NDF and %WSC and the lowest lignin content, making it well balanced for biogas production.

2.3. Inoculum

Digester sludge was used as inoculum and it was collected from the anaerobic sludge vessels of the wastewater treatment plant of Celtic Anglian Water Ltd., Ringsend, Dublin. A 25 L tank of sludge was collected the same day of the experiment and used immediately. Total solids of sludge (%TS (Total Solids)) are very low while ammonia is high without reaching inhibitory values [36]. The sludge characterization is illustrated in Table 2.

2.4. Bioreactors preparation

The bioreactor system consists of flasks of 500 ml in capacity. The equipment is constituted of: 2-way and 3-way valves, quick release tubing connectors, plastic pipes and airtight plastic bags (for biogas collection), see Fig. 2. To preserve anaerobic conditions, nitrogen has been flushed for 2 min into the reactors to clear up any residual trace of oxygen from within the flasks and pipes, according to [37]. Water-baths were used to keep the reactors at a fixed mesophilic temperature. A biogas analyser, model Dräger X-Am 3000, was used to verify anaerobic conditions were created correctly when preparing the reactors and to analyse the biogas

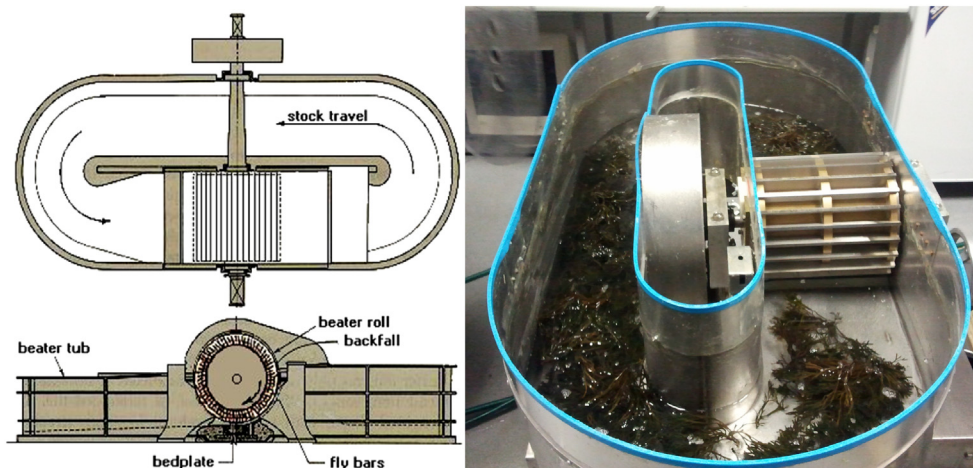


Fig. 1. Hollander beater's working scheme [46] and machine used in the experiment.

Download English Version:

<https://daneshyari.com/en/article/8079037>

Download Persian Version:

<https://daneshyari.com/article/8079037>

[Daneshyari.com](https://daneshyari.com)