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A COMPARATIVE STUDY OF THE PERFORMANCE OF ANAEROBIC DIGESTION OF SEAWEED (ASCOPHYLLUM NODOSUM) AT MESOPHILIC AND THERMOPHILIC TEMPERATURES

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Abstract

Global warming and other environmental issues associated with the consumption of fossil fuel have shifted attention to alternative energy such as renewable energy. At the forefront is biogas production from seaweed. The performance of the anaerobic digestion of brown seaweed (*Ascophyllum nodosum*) was conducted at mesophilic (37±2^{0}C) and thermophilic (55 ±2^{0}C) temperatures. Continuously fed single-stage reactors were analysed using seaweed substrate at different Organic loading rates in Hydraulic retention time of 20 days. The physico-chemical characteristics of the effluent such as pH and VFA were scrutinized. Biogas volume was measured using a water displacement system and its composition was monitored using gas analyser. There were accumulation of VFA and variation in pH value during the process, which was as a result of the increase in feeding rates. This accumulation of VFA affected the methanogens in the reactors. From the result, the thermophilic reactor produced higher biogas with less methane content while the mesophilic reactor produced low biogas with high methane content. For commercial use, the co-digestion process and the use of two stage reactors need to be considered.

Keywords: Anaerobic digestion; Biogas, Mesophilic, Thermophilic.

1. Introduction

The emissions of greenhouse gases such as methane, carbon dioxide, water vapour, ozone and nitrous oxide have resulted in global warming[1]. According to Intergovernmental panel on climate change[2], global warming, which is caused by anthropogenic activities, has a massive effect on temperature increase worldwide. Every aspect of life; environment, society and economy are affected by the fraction of temperature change. The awareness on global warming and the quest for sustainable development led to the need for alternative source of energy.

Amongst the renewable energy technologies, which include biomass, solar, wind, wave, hydroelectric power, tidal, and geothermal, Biomass is the biggest and most crucial type of renewable energy at present and can be used to generate energy in various forms such as heat and electricity[3]. It is distinctive because it is the only process using organic matter among all other sources of renewable energy[4]. It can be from terrestrial or marine sources. With the world population of about 7.0 billion today and an estimated growth of 9.5 billion in 2050[5], there is need to reduce to the barest minimum the use of terrestrial crops as a biomass for energy. The extensive use of terrestrial sources as biomass is likely to result to deforestation and the switch of energy crops to bio-fuel thereby leading to adverse food scarcity.

The most common source of marine biomass is macro algae (seaweeds)[6]. According to Vergara-Fernandez[7], researches carried out on seaweed have shown that they are valuable feed stocks because of their high polysaccharide content, low cellulose contents and low lignin contents. They are quite easily biodegradable with moisture contents of about 90%. The high moisture contents make anaerobic digestion the right process to release energy when compared to all "burning" process (pyrolysis).

Anaerobic digestion is the process whereby microorganisms degrade organic materials in the absence of air thereby producing biogas (60% of methane and 40% of carbon dioxide and traces of other gases) and a liquid fragment called digestate (rich in Nitrogen, Potassium and phosphorus)[8]. One of the regular factors that affect the biological processes of anaerobic digestion is temperature; increase in temperature also leads to increase in reaction rate[9].

Thermophilic temperature (45–60 ^{0}C) is described by Nayono[10] as a faster kinetics with great methane yield and elimination of pathogen, observed to be more productive when compared to mesophilic (20 – 40 ^{0}C) in the removal of volatile fatty acids. However, Matsui and Koike[11] opined that methane generation is high and efficient in mesophilic process compared to thermophilic.

The objectives of this study are to compare the performance of anaerobic digesters in treating brown seaweed at different temperatures and to determine the operational conditions of the anaerobic digestion of seaweed at different temperatures

2. Methodology

2.1 Sample collection and anaerobic inoculums

The substrate, brown Seaweed (*Ascophyllum nodosum*) was collected at Broughty Ferry beach in Dundee, Scotland, United Kingdom. It was dried and milled with FRITSCH rotor speed mill. The inoculums originated from a laboratory scale anaerobic digester which was in operation prior to the commencement of this study.

2.2 Experimental design and set-up

Brown seaweed was digested in a laboratory-scale stirred tank reactor under mesophilic (37 ± 2^0C) and thermophilic conditions (55 ± 2^0C) as shown in figure 1.

The type of anaerobic digestion process used was the wet process with a continuous feedstock supply at mesophilic and thermophilic temperature in single stage reactors. Intermittent stirring were used during the digestion process. Different organic loading rate were used and the system was fed 5 days a week with a hydraulic retention time (HRT) of 20 days. HRT is calculated[12]:

$$HRT = \frac{V\ (5.5)}{Q\ (0.275)}$$

Where:

V= Reactor volume, m^3

Q= Flow rate (quantity of liquid fed to the reactor each day), m^3/day

The sludge was removed before each feeding but after the gas composition had been noted. The same environmental and operational requirements such as hydraulic retention, mixing state etc were applied in both reactors.

2.3 Analytical method

Factors that affect anaerobic digestion like pH, Volatile Fatty Acids (VFA) and biogas composition were determined with pH meter, Hach Method No 8196/DR5000 spectrophotometer and Geotech GA 200 gas analyser respectively as they are prerequisite for anaerobic digestion process stability.

The VFA of the samples were evaluated twice in a week. 40ml of effluent from the reactors were centrifuged at a speed of 5200 rpm for a period of 30 minutes to get a supernatant. The procedure is as shown in table 1.

Table 1: VFA procedure

Steps	**Quantity**	**Instruction**
Distilled water	0.5	Blank
Pipette sample	0.5	Prepared
Ethylene Glycol	1.5	Twirl to mix
Sulphuric Acid Std	0.2	Twirl to mix
Boil for 3 Minutes and cool		
Hydroxylamine Hydrochloride	0.5	Twirl to mix
Sodium Hydroxide Std	2.0	Twirl to mix
Ferric Chloride Sulphuric Acid	10.0	Twirl to mix
Distilled water	10.0	Invert to mix
Transfer 10ml of each sample to square sample cells and wait for 3 minutes before using the Spectrometer.		

3. Results and Discussions

3.1.1 pH

In the mesophilic reactor (reactor 3), the pH range is between 7.20 and 7.50 while for thermophilic reactor (reactor 2), it is between 7.39 and 7.75 as illustrated in figure 1. The pH was not stable at the beginning of the experiment for both reactors because the microorganisms were yet to adapt to the new feeding rate. The pH values were fairly stable after the microorganism had adapted. A decrease was observed in the thermophilc reactor from the 30^{th} day and from the 50^{th} day for the mesophilic reactor.

Figure 1: PH variations of anaerobic digestion of *A. nodosum* for thermophilic (R2) and mesophilic (R3) reactors.

3.1.2 VFA

Accumulation of VFA is as a result of the microorganisms not being able to degrade the substrates. The bar chart is used to illustrate this because the measurement was not carried out everyday like other parameters. The VFA values as shown in figure 2 are in the range of 1014 and 105 mg/L for the thermophilic reactor and range of 206.5 and 23 mg/L for the mesophilic reactor. The VFA values decreased to a limit acceptable for stable anaerobic digestion process on the 21st day and then increased again. In the mesophilic reactor, the VFA value was in acceptable limit till the 42nd day when it increased.

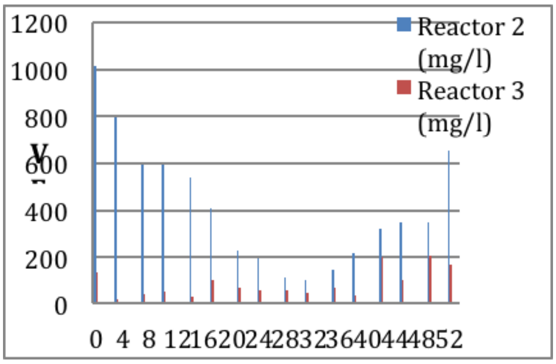

Figure 2: VFA concentration change during anaerobic digestion of *A. nodosum* at mesophilic (R3) and thermophilic (R2) temperatures.

3.1.3 Biogas

The thermophilic reactor had 2500ml as the highest yield of biogas in day 46 while mesophilic reactor had 234ml as the highest yield of biogas that same day. The decrease in biogas yield was detected because of VFA accumulation. Further analysis were carried out to ascertain the proportion of the methane in the biogas yield of both reactors. In day 1 of the experiment in thermophilic reactor (Figure 3), when the biogas yield was 1150ml, 57.74% was methane and on the 46th day when the highest biogas yield of 2500ml was measured, the methane yield was 16.53%.

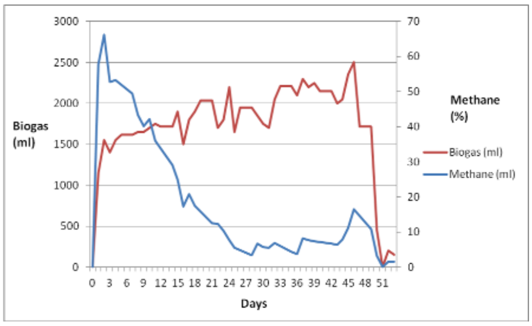

Figure 3: Methane and Biogas composition in anaerobic digestion of *A. nodosum* for thermophilic reactor.

In the mesophilic reactor (Figure 4), there was no measurement on the first three days of the experiment because the microorganisms had not adapted to the environment and as a result did not generate gas. In day 4 of the experiment, the biogas yield was 193ml, 22.57% was methane and on the 46th day when the highest biogas yield of 234ml was measured, the methane yield was 40.02%.

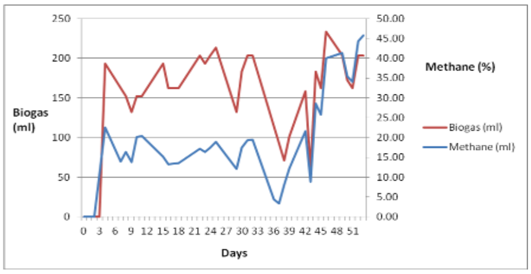

Figure 4: Methane and Biogas composition in anaerobic digestion of *A. nodosum* for mesophilic reactor.

3.2 Discussion

From the result, the performance at mesophilic temperature is more efficient than the thermophilic temperature. Although the thermophilic reactor produced more biogas, the methane yield is quite low pointing to the fact that other gases were likely to have been produced. The mesophilic reactor produced biogas with more of methane yield than other gases.

It is recommended for two-stage reactor to be used instead of the one-stage reactor where the microorganisms share the same environment thus resulting in low pH and build up of VFA. Also recommended is the use of co-digestion, which is a process of combining any other substrate to decrease toxic level of seaweed and increase in methane yield.

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