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Anaerobic co-digestion for oily-biological sludge with sugarcane bagasse for biogas production under mesophilic condition

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Abstract. The oily-biological sludge is one of the toxic organic sludge generated from petroleum oil refineries wastewater treatment plants. However, its low Carbon/Nitrogen ratio (C/N) need a co-substrate material to meet the requirement of anaerobic digestion process C/N. The oily-biological sludge can act as a substrate and inoculum at the same time. Sugarcane bagasse is an organic waste and has high C/N ratio. Therefore, it is a proper material which can balance the batch C/N ratio. In this study, three mixing ratios for both materials with C/N ratios 20.0, 25.10 and 30.0 respectively. The temperature, mixing and digestion duration were 37 °C, 60 rpm and 33 days respectively. Both materials were pre-treated under thermo-chemical conditions to increase biogas yeild. The maximum biogas yield was for the maximum C/N and co-substrate/inoculum ratios with 9,268 mL.

1. Introduction

Human beings in the 21st century is facing a great challenge in environmental pollution and sustainable energy. Predictions on fossil fuels depletion during current century and emissions of greenhouse gases especially CO2 need an alternative sustainable resource to achieve every insecurity [1, 2]. Improper disposal of organic oily-biological sludge generated from oil refineries which is toxic and agricultural waste can contaminate water, soil and air [3].

Researchers had proven that anaerobic digestion process of organic matters considered an economic and effective treatment method for bioenergy recovery in biogas form [4, 5]. There are many factors affecting anaerobic co-digestion process such C/N, pH and temperature (thermophilic and mesophilic) and so on [6, 7]. Therefore, mono-digestion is not suitable and co-digestion method is required to achieve balance between the required factors to maintain proper environment for anaerobic bacteria to produce better biogas.

The objective of this study is to investigate the feasibility of anaerobic co-digestion between the oil-biological sludge and sugarcane bagasse. Also, to analyze the role of the key factors affect the biogas yield during anaerobic co-digestion technology which are C/N and co-substrate/inoculum ratios.

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2. Materials and methods

Wastewater treatment unit in the petroleum oil refinery was the source for collection the oily-biological sludge. The effluent treatment unit is an extended aeration activated sludge system. Then the sludge was stored at cooling room temperature ≤ 4°C to keep the originality of its characteristics. Prior anaerobic co-digestion process, thermo-chemical pre-treatment method for the oily-biological sludge was conducted using using sodium hydroxide.

Pasar Malam, Seri Iskandar, Malaysia was the source for collection the sugarcane bagasse. Prior co-digestion process, the sugarcane bagasse was purified using tapped water and stored in the cooling room for further process. The bagasse was treated through mechanical method to decrease the particles size meanwhile increasing the surface area to enhance bacteria activities. Also, bagasse was pre-treated through thermo-chemical method to decrease the lignin content and enhance the biogas production using sodium hydroxide.

2.1 Pre-treatment of raw materials

Pre-treatment method for oily biological sludge was thermo-chemical through magnetic stirrer using 1 g/L NaOH at 100 °C and 150 rpm. °C This method was used to increase pH value of the oily-biological sludge which has acidic nature to enhance the sludge stabilization and digestibility as well to provide proper environment for microorganism’s activities. Figure 1. shows the sludge during pre-treatment process.

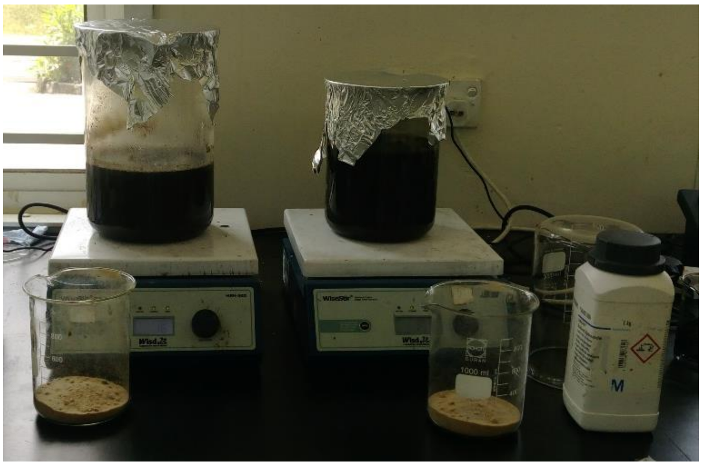

Figure 1. Oily-biological sludge thermo-chemical pre-treatment through magnetic stirrer.

The sugarcane bagasse mechanical pre-treatment was conducted by cutting the bagasse to 15 cm pieces manually. Then the bagasse grinded by using mechanical granulator and miller as shown in Figure 2. to < 0.5 mm to enhance digestibility by anaerobic bacteria due to increment of the material surface area [8].

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Figure 2. Sugarcane bagasse before and after mechanical pre-treatmnet.

The bagasse then treated through thermo-chemical method by using sodium hydroxide 1% (w/v) and solid liquid ration 1:10. The temperature at 100°C and 150 rpm for 1 hour to reduce lignin content which is reluctant to hydrolysis process as much as possible [9]. The ratios of thermo-chemical pre-treatment are shown in Table 1.0. Figure 3. shows the thermo-chemical pre-treatment through magnetic stirrer.

Figure 3. Thermo-chemical pre-treatment of bagasse using magnetic stirrer.

2.2 Analytical methods

Proximate analysis and pH for the sludge were conducted according to APHA, 1998 methods. The ultimate analysis including Carbon, Nitrogen, Hydrogen and Sulphur were determined by using CHNS analyzer. Sugarcane bagasse proximate analysis including moisture content, volatile matter, fixed carbon was conducted according to ASTM D3172-89 standard. The sugarcane bagasse pH was determined according to Hach Method. The ultimate analysis including Carbon, Hydrogen, Nitrogen and Sulphur were determined according to ASTM D5373 standard.

2.3 Experimental design

Three mixing ratios of the treated materials were designed mainly based on C/N ratio. The design of the experiments was conducted to obtain the C/N ratio subsequently co-substrate/inoculum between 20-30, and 0.06-0.18 respectively [6,7]. Equation (1) was used to calculate C/N ration for composite materials:

$$R = \frac{Q_1(C_1*(100-M_1)+Q_2(C_2*(100-M_2)}{Q_1(N_1*(100-M_1)+Q_2(N_2*(100-M_2)} \quad (1)$$

Where:
R = C/N ratio;
Qn = Mass of material “as is” or wet weight;
Cn = Carbon (%);
Nn = Nitrogen (%) ;
Mn = Moisture content of material

Figure 4. shows the SOLTEQ TR37 sludge anaerobic digester which used to carry out the experiment. the digester includes six reactors 2.5 Liters size. Working volume of the reactors is 2.0 Liters. To provide anaerobic environment, after placing the samples in the reactors they were purged by Nitrogen gas to remove oxygen. The operational conditions of the experiments were; temperature 37.0± 0.5 °C, Mixing = 60 rpm for 33 days.

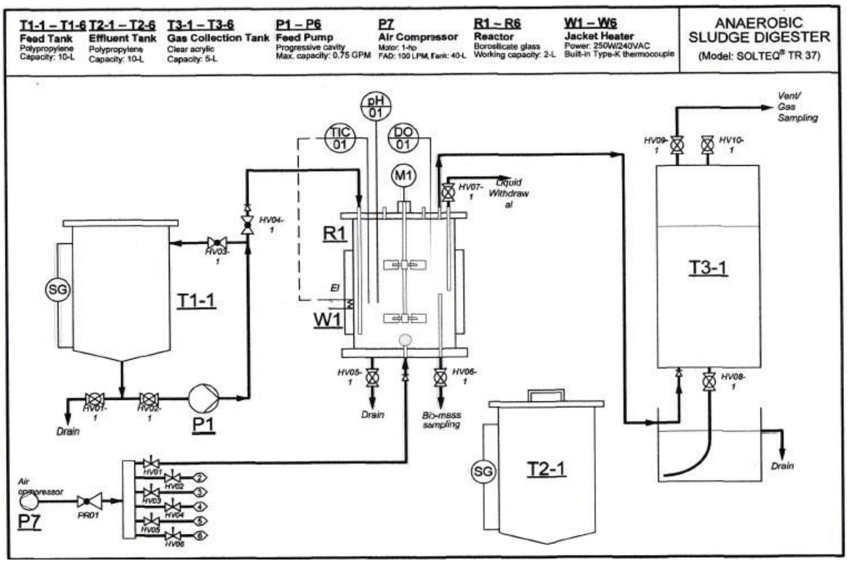

Figure 4. SOLTEQ TR37 sludge anaerobic digester.

The quantity of biogas produced from each reactor and collected by gas collection tank was measured every day using liquid replacement method using gas collection as shown in Figure 4.

3. Results and discussion

From Table 1. the analysis of the treated raw materials shows that the C/N ratio for oily-biological sludge is very low which is 14.42, on the other hand the C/N ratio of the sugarcane bagasse is very high which is 132.69. Therefore, this diversity in C/N ratios for both organic wastes will provide a compromising balance for the batch mixture C/N ratio during co-digestion process.

Table 1. Ultimate and proximate analysis for the pre-treated materials [10].

Parameter	Unit	Oily-biological sludge	Unit	Dry sugarcane bagasse
Moisture content	%	94.20	%	0
pH	N/A	8.70	N/A	7.21
TS	g/L	58.00	%	100
VS	g/L	50.46	%	87.80
C	% of TS	4.31	%	34.70
N	% of TS	0.30	%	0.26
C/N	N/A	14.42	N/A	132.69

From Figures 5 & 6., the biogas yield was increasing with duration especially with 25.1 and 30.0 C/N ratios. However, the 20 C/N ratio the biogas increased until day 11 then started to decrease. The increasing of the C/N ratio meets increasing of the sugarcane bagasse content in the batch. Therefore, the increasing of biogas yield could be due to the increasing of the volatile solids content in the batch.

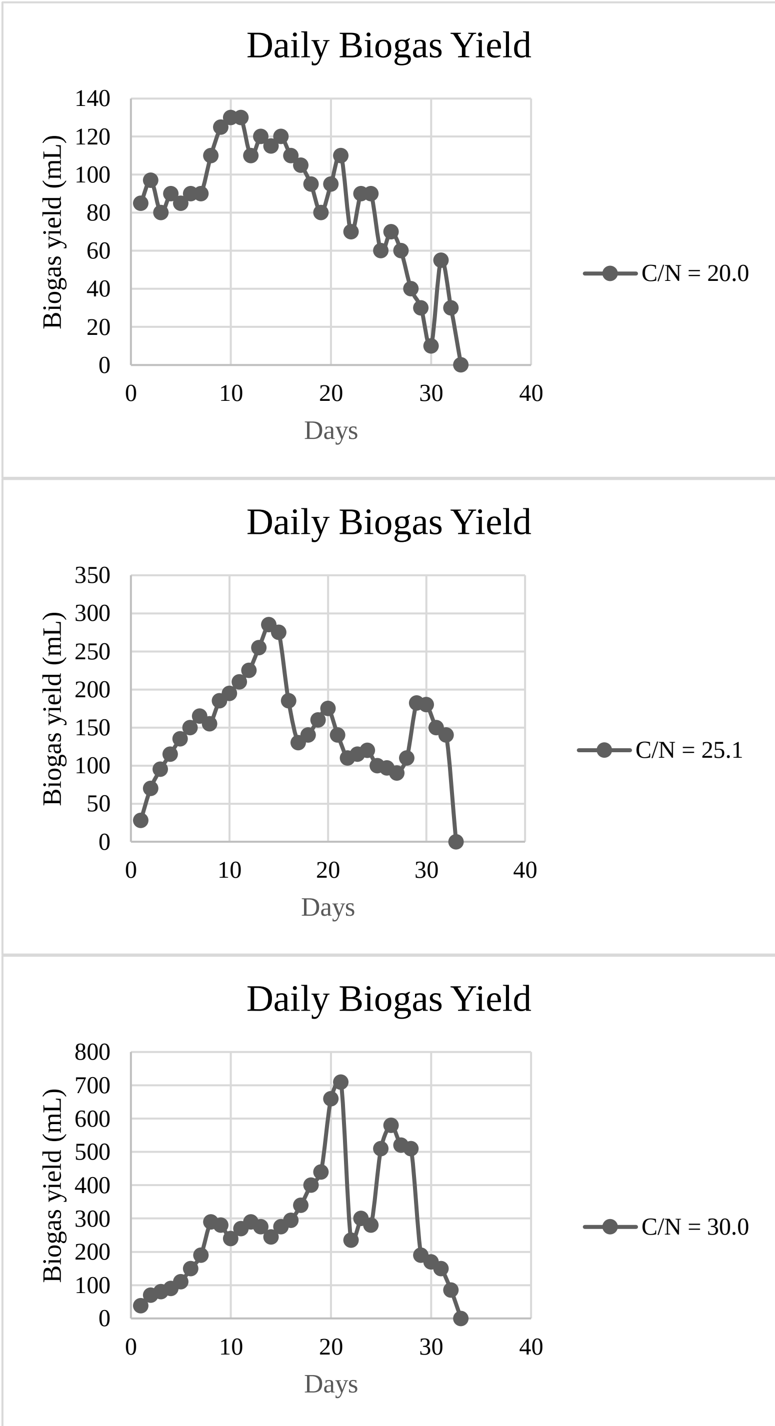

Figure 5. Daily biogas yield from the three reactors during 33 days.

From Table 2. The biogas yield was increased with C/N ratio and co-substrate/inoculum increment. Meanwhile, the main factor for increasing C/N ratio and co-substrate/inoculum was sugarcane bagasse content because it has high C/N ratio as well high volatile matter content. was the main factor to increase. The methane content in the biogas yield, pH effect and other C/N ratios need to be investigated in the future works. The methane content for the same mixtures were discussed and analyzed by Ghaleb, refer to [10].

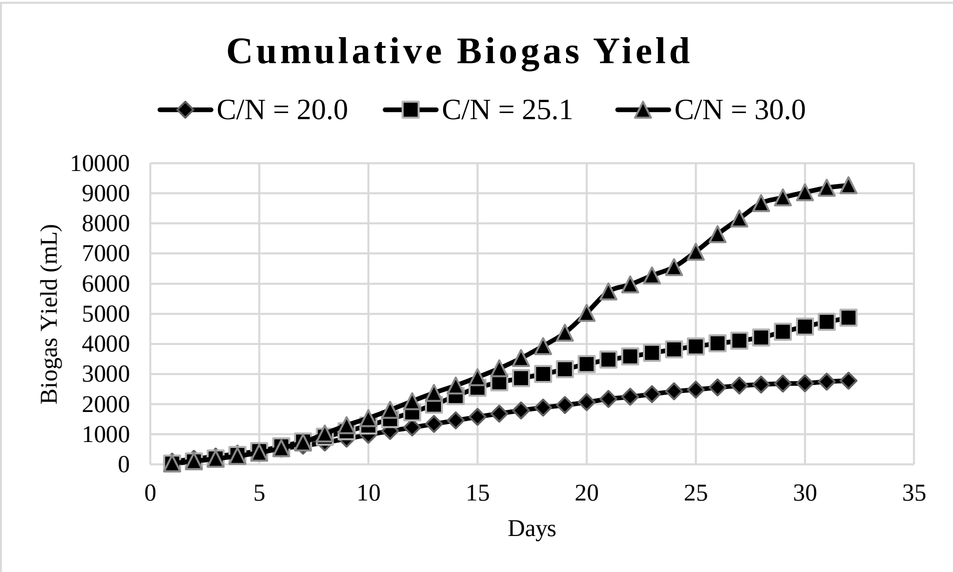

Figure 6. Cumulative biogas yield from the three reactors during 33 days.

Table 2. Biogas yield during batch anaerobic co-digestion process.

C/N ratio	Sugarcane (g): Oily-biological sludge (g)	Co-substrate/Inoculum (Volatle matter)	Biogas yield (mL)
20.0	1.0 : 294.0	0.06	2,777
25.1	2.0 : 294.0	0.12	4,867
30.0	2.0 : 193.0	0.18	9,268

4. Conclusion

The biogas yield from anaerobic co-digestion of oily-biological sludge with sugarcane bagasse was increased together with C/N ratio increment. The increasing of C/N ratio was by increasing the sugarcane bagasse content in the batch. During the increasing of sugarcane bagasse content, the co-substrate/inoculum ratio was increased as well. Therefore, biogas production increasing could be due to the increasing of volatile solids content in the batch. The maximum biogas yield was 9,268 mL found at maximum mixing ratios.

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