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Effect of operating parameter on the anaerobic digestion oil palm mesocarp fibre with cattle manure for biogas production

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Abstract. Anaerobic digestion is a complex biological process resulting in the conversion of biodegradable organic matter into biogas and mineralized material. Anaerobic digestion involves the breakdown of biomass by a concerted action of a wide range of microorganisms in the absence of oxygen. The biological pre-treatment was used to reduce the lignocellulose content of substrate. Laboratory experiment was carried out in single stage 10 L bioreactors. The reactors were named R1, to R10 at different mixture conditions with organic loading of 1.62 and 2.11 g VS at HRT of 10 days. The result was stable at the initial stage, within the first 10 days was high and was attributed to the consumption of easily degradable COD. These indicate that there is stable COD removal efficiency for the anaerobic digestion of treated OPMF with CM and seeded with POME. The results showed the level of COD removal efficiency was observed and upon the steady state of the reaction. In this experiment, the results indicate that chemical oxygen demand (COD) reduction in reactor R1 shows the best result of the average removal efficiency value of 37.9 %. Although, ambient temperature was adopted, it still shows a high COD removal efficiency in R1 and may be associated to a more stable reaction. This indicated that pre-treated OPMF produced a better COD removal efficiency than the untreated OPMF. The removal efficiency started with 18 % and continued to increase to 38 %. The removal efficiency became relative stable until day 30 which give the highest percentage removal of 45 % which was achieved with a high OLR (2.11 kg VS L^{-1} d^{-1}). The reductions continued in the same trend until day 20 and remained stable till the end of the experiment. This indicates that the available microorganisms have been exulted by day 20 and this corresponds to a drop to the rate of biogas production. Operating parameters considered in this study have an influence on the rate of biogas produced during anaerobic digestion. The results show that COD, do influence the rate of biogas production.

1. Introduction

Anaerobic digestion is one of the best alternative systems used as a sustainable way of meeting energy demand in the world. Anaerobic digestion of bio waste is an effective method of treating different types of organic waste. Anaerobic digestion is the most widely studied technology for organic treatments for its efficiency in the waste reduction while producing renewable energy, reducing pathogen and organic waste [1]. Biogas is the bye-product of the process, which is more economically viable and environmentally-friendly renewable energy resources [2]. Biogas consist different gases; consisting of mainly 60% methane (CH_4), 35% carbon dioxide (CO_2), and 5% ammonia (NH_3) and other gases [3,4]. Biogas play a vital role in decreasing the concerns associated with the rapid increases in energy demands and on the other hand the resultant greenhouse gases (GHG) emissions and the downstream catastrophic consequences such as climate change and public health deterioration [5]. Since energy crisis and waste management are the major issues that the world is facing today due

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to population increase. Therefore, this system of anaerobic digestion is used to overcome these problems. Cattle manure has a complex structure hence longer retention time is required during treatment due to lignocellulose content and also high ammonia–nitrogen (NH_3–H) concentration which could presumably affect the treatment process [6]. Biogas is produced during anaerobic digestion (AD) of organic materials, carried out by a complex microbial community through multiple complicated biochemical reactions [7]. Biogas should be upgraded to biomethane prior to injection into the gas grid or use as a vehicle fuel [8]. Given the unique advantageous of this renewable energy carrier, there has been a renewed interest globally.

The COD content of substrate circulating throughout the system needs to determine, since COD content of the biogas produced by the digester could be determined by measuring the methane content. Therefore, the efficiency of anaerobic digestion can be greatly enhanced improving the rate of the operating parameters during the biodegradation process. The objective of this study was to evaluate the effects of the COD on the efficiency of anaerobic digestion process.

2. Materials and methods

2.1. Experimental set up

The experiment was carried out in a single stage laboratory scale reactor. The complete mix anaerobic reactor is made from stainless steel of 10 L capacity consisting of a top plate supporting a mixer, a mixer motor and equipped with sampling ports. The four reactors were run concurrently. Sludge was sampled from an outlet port located at the bottom side of the reactor as shown in Figure 1. Prior to daily feeds, an equivalent volume of the sludge was sampled for analytical analysis. The experiment was carried out at both batch and semi continuous digestion process under uncontrolled daily ambient temperature and uncontrolled pH. The reactors were named as in Table 1.

Table 1. Description of substrate mixture in reactors.

Run	Reactor No	Substrate mixture	Mix Ratio (L)	Duration (days)
1	R1	Treated palm oil mesocarp fibre	3.5	30
		Cattle manure	3.5	
		Palm oil mill effluent	1	
	R2	Untreated palm oil mesocarp fibre	3.5	30
		Cattle manure	3.5	
		Palm oil mill effluent	1	
2	R3	Treated Palm oil mesocarp fibre	4	30
		Cattle manure	4	
	R4	Untreated Palm oil mesocarp fibre	4	30
		Cattle manure	4	
3	R5	Treated Palm oil mesocarp fibre	7	30
		Palm oil mill effluent	1	
	R6	Untreated Palm oil mesocarp fibre	7	30
		Palm oil mill effluent	1	
4	R7	Treated Palm oil mesocarp fibre	8	30
	R8	Untreated Palm oil mesocarp fibre	8	30
5	R9	Cattle manure	7	30
		Palm oil mill effluent	1	
	R10	Cattle manure	8	30

2.2. Chemical oxygen demand

Chemical oxygen demand (COD) was measured according to Standard Method [9] procedures as adapted by Hach Chemical Company (Hach, Loveland, CO). The DRB 200 reactor was turned on to preheat to 150 OC. 2 ml each of the diluted sample and distilled water were transferred into 2 'higSASh range' COD vials from HACH, and labeled "sample" and "blank" respectively. The vials were capped tightly and inverted several times to mix the content, and then placed in the reactor and heated at 150°C for 2 hours. The reactor heating stopped automatically as programmed, and the vials were allowed to cool to 120 °C before being removed from the reactor. The vials were finally allowed to cool to room temperature.

DR 5000 spectrophotometer was ready and the program for COD high range was selected. The vials were wiped with paper towel to remove fingerprints and then the blank was inserted into the adapter and covered, after which the ZERO button was pressed. The sample vial was also inserted and the READ button was pressed to display the COD reading for the diluted sample. The actual value of the COD was obtained by multiplying the displayed value by the dilution factor.

2.3. Total solids

Total solid (TS) represent the solid content of the sludge that remains after evaporation and drying at 105°C. 10 mL of the sludge was taken and placed on a previously weighed crucible. The crucible containing the sludge was weighed. It was oven dried for 24 hours at 105°C and the crucible was put in a desiccator to allow the sample to cool to a balanced temperature before being weighed [9]. Equation 1 was used to calculate the total solid in mg/L.

$$\text{Total solid mg/l} = \frac{(\boldsymbol{A}-\boldsymbol{B})}{\boldsymbol{sample\ volume}} \text{ X } 100 \quad (1)$$

A = weight of crucible and dried sample at 105°C
B = weight of empty crucible

2.4. Volatile solids

Volatile solid (VS) represents the quantity of organic matter in the sludge which is available for biodegradation. VS were determined as the portion of TS that volatilize upon heating at 550°C in a furnace for 20 min. The crucible was partially cooled in an air until the heat was dissipated, then transferred to a desiccator for cooling and weighed to a constant weight. The remaining ash is subtracted from TS to get the VS. The determined values were substituted into Equation 2 for the determining the volatile solid in mg/L.

$$\text{Volatile solids mg/L} = \frac{(\boldsymbol{A}-\boldsymbol{B})}{\boldsymbol{sample\ volume}} \times 100 \quad (2)$$

A = weight of crucible and dried sample 150°C
B = weight of crucible and ash dried sample at 550°C

2.5. Biogas Analyses

The daily biogas production for each anaerobic reactor was recorded using water displacement method and the corresponding cumulative biogas volume was calculated. The composition was analysed by using BW Gas Alert Micro 5 analyser to determine the percentage methane content in percentage from the biogas produced. The pump was connected to the end of teflon-lined Tygon tubing. Then, the tubing was inserted into the other end of the teflon lined Tygon tubing. The analyser was activated and inserted into the reactor for sampling process.

3. Results and discussion

The operating parameters considered were COD, TS and VS in the production of biogas were access to determine the effect on the biogas production at different mixture during period of the study. The following parameters were evaluated on the operating conditions of the anaerobic reactors. Figure 1 showed the profile of COD removal efficiency at different mixture of pre-treated OPMF. The COD concentration was monitored from day 5 which is the beginning of semi-continuous digestion. The initial concentration of COD in R1 decreased from 68,250 mg L^{-1} to 62,430 mg L^{-1} due to the influence COD and continued to decline until day 8. There was a slight increase between day 8 and day 13.

However, the mixture started to stabilize at day 23 until the end of the experiment. COD is normally measured in term of organic content of the substrate and which shows a significance decrease at the beginning which was due to conversion of organic matter into biogas. The COD removal efficiency was observed and upon the steady state of the reaction. The removal efficiency started with 18 % and continued to increase to 38%. The removal efficiency became relative stable until day 30 which give the highest percentage removal of 45 % which was achieved with a high OLR (2.11 kg VS L^{-1} d^{-1}). The OPMF was not partially treated and contained high lignin and it can be limiting factor on the rate of COD removal efficiency and correspond to the amount of biogas produced. Although, ambient temperature was adopted, it still shows a high COD removal efficiency in R1 and may be associated to a more stable reaction.

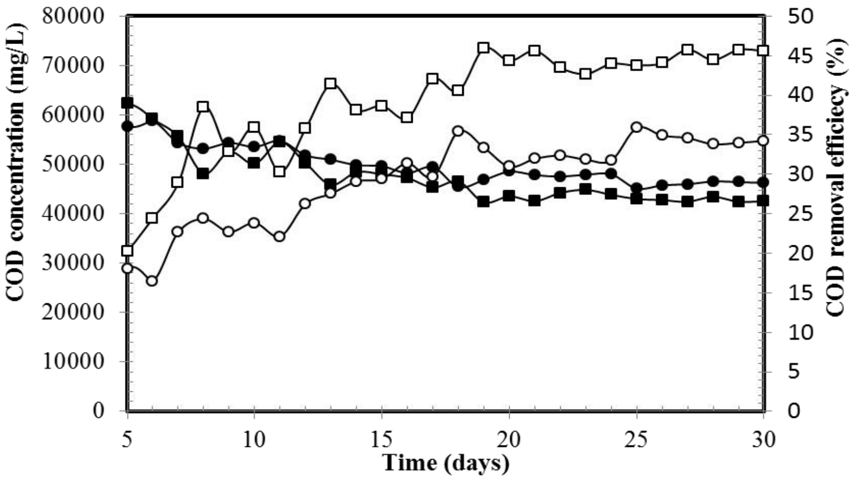

Figure 1. COD concentration and COD percentage reduction of the complete mix anaerobic reactor (■) R1 COD concentration of pre-treated OPMF + CM + POME; (□) R1 COD removal efficiency; (●) R2 COD Untreated OPMF + CM + POME (o) COD removal efficiency.

R3 started to decrease at the beginning of semi-continue operation and fluctuated till the end of the experiment. The initial concentration of 50,150 mg L^{-1} decreased to 40,650 mg L^{-1} this was due to high level of degradation in R3. R3 showed a good COD removal towards the end of the digestion and fluctuated between 40 – 43%. The COD removal efficiency increased and became stable. The removal efficiency in R4 showed an increased at the beginning and became stable between 35 to 36% less than the pre-treated OPMF which indicated the unstable nature of mixture in R4 as shown in Figure 2.

The profile Figure 3 shows the concentration of COD in R5. There was decrease for the first 4 days of semi-continuous digestion. This was due to reduction of the suspended organic material and also due to initial lag period where hydrolytic activity was low. R5 showed a decrease from day 7 until day 16. The reduction in concentration was due to more biodegradable substrate in reactor R5 since the OPMF was partially pre-treated using oyster mushroom. Thus, the mixture in R5 make microbial activity more efficient with the inoculum (POME) used. The COD removal efficiency in reactor R6 show a lower percentage reduction than that of reactor R5. The removal efficiency in R6 increased from day 5 until day 19 and remained stable between 34 to 35%. The high removal efficiency in R5 indicated that pre-treated OPMF has an influence on the rate of microbial activity during anaerobic digestion process.

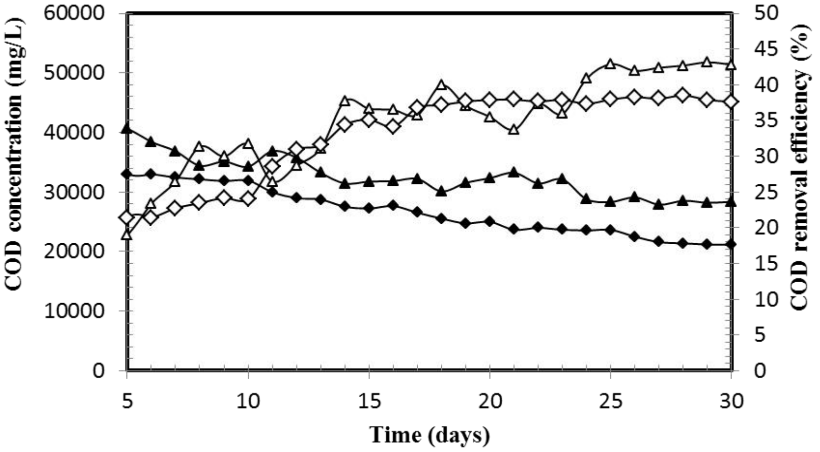

Figure 2. COD concentration and COD percentage reduction of the complete mix anaerobic reactor (▲) R3 COD concentration of pre-treated OPMF + CM; (Δ) R3 COD removal efficiency; (●) R4 COD concentration of untreated OPMF + CM; (○) R4 COD removal efficiency

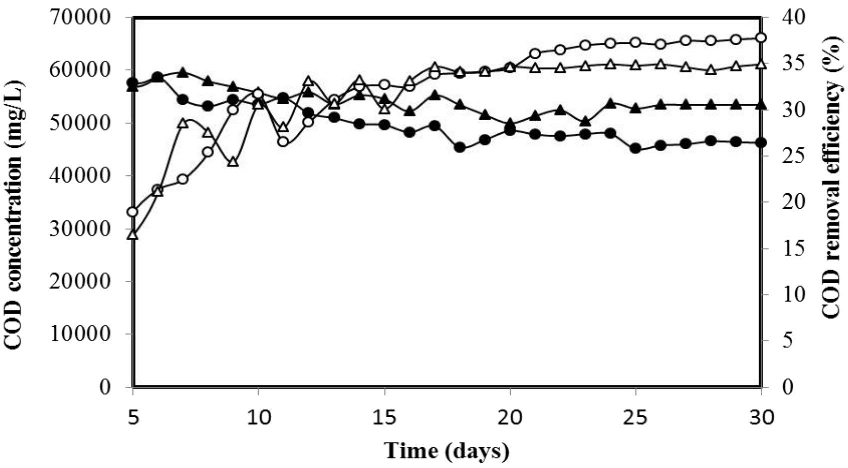

Figure 3. COD concentration and COD percentage reduction of the complete mix anaerobic reactor (●) R5 COD concentration of pre-treated OPMF + POME; (○) R5 COD removal efficiency; (▲) R6 COD concentration of untreated OPMF + POME; (Δ) R4 COD removal efficiency.

However, in Figure 4, removal efficiency was higher in reactor R7, because the OPMF was a biologically pre-treated substrate as compared to that of reactor R8 which contained untreated OPMF having a high lignocelluloses material. Though the COD removal was low at the beginning in R7 which started 12% and progressed significantly and the high removal with 33% as archived at the end of the operation compared to R8 which showed a lower COD removal efficiency of 26%. This indicated that pre-treated OPMF produced a better COD removal efficiency than the untreated OPMF.

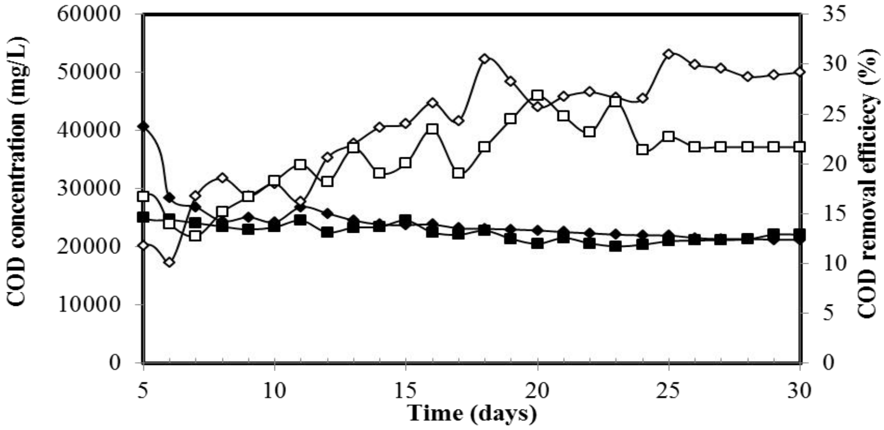

Figure 4. COD concentration and COD removal efficiency of the complete mix anaerobic reactor (♦) R7 COD concentration of pre-treated OPMF; (◊) R7 COD removal efficiency; (■) R8 COD concentration of untreated OPMF; (□) R8 COD removal efficiency.

Figure 5 shows the COD concentration and the COD removal in reactor R9 and R10. The higher COD concentrations in R9 which contain CM with POME as inoculum, this is due to addition of POME as inoculum. It decreases as the operation progress which is an evidence of microbial activity in the reactor. The COD in R1 was gradually declined and stabilizing and fluctuates until the end of the operation. R10 concentration slightly decrease remains constant at about 20,000 mg L^{-1} COD concentration until the end of the experimental period. Higher methane content in R9 indicated a substantial rate of biogas produced which reflects the efficiency in reaction between the CM and POME in the reactor.

This is in agreement with previous research demonstrating rate of biodegradation and methane content produced with addition of inoculum [10]. Despite constant COD concentrations in R10, the COD percentage reduction was 36%. R10 demonstrates lower COD concentrations as expected as it was operated without POME supplementation as inoculum. The fluctuation in bioreactor R9 indicates the unstable nature of the microorganism due to ambient temperature adopted, but it still has high COD removal efficiencies compared to R10 and may be associated to an increase in pH fluctuation since it was uncontrolled during the operation [11]. The COD average percentage reduction efficiency in R9 was 40% compared to that of R10.

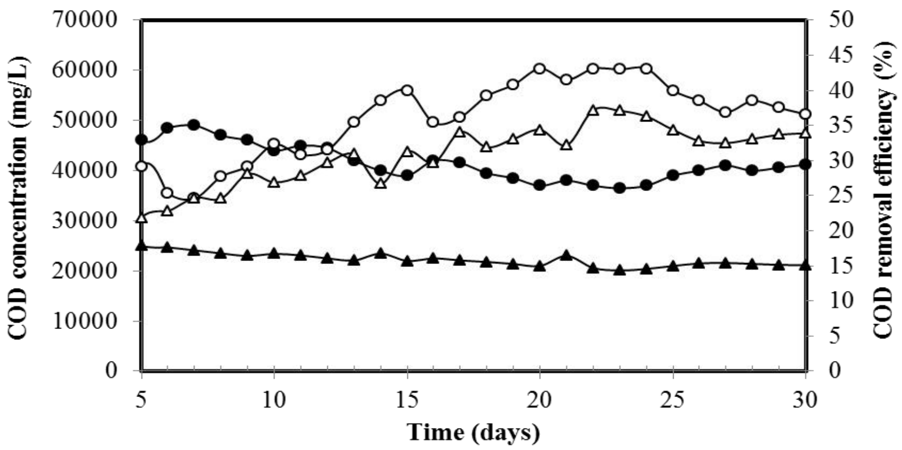

Figure 5. COD concentration and COD removal efficiency of the complete mix anaerobic reactor (●) R9 COD concentration of CM + POME; (○) R9 COD removal efficiency; (▲) R10 COD concentration of CM; (Δ) R10 COD removal efficiency.

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Operating parameters considered in this study have an influence on the rate of biogas produced during anaerobic digestion. In this experiment, the results indicate that chemical oxygen demand (COD) reduction in reactor R1 shows in figure the best result of the average removal efficiency value of 37.9% as shown. This has proven that the substrate conversion from particulate matter to soluble compound suggested that the hydrolysis has occurred.

4. Conclusion

From the results, it can be concluded that COD do influence the rate of biogas production. This indicated that pre-treated OPMF produced a higher COD removal than the untreated OPMF due to less lignocellulose content in the substrate.

References

[1] Saidu M Yuzir A Salim M R Salmiati S Azman S Abdullah N 2013 *Bioresource Technology* **141** 174-176
[2] Deublein D Steinhauser A 2011 (John Wiley & Sons)
[3] Khanal S K 2008 (New York: John Wiley & Sons)
[4] Valijanian E Tabatabaei M Aghbashlo M Sulaiman A Chisti Y 2018 (Springer) 95-116
[5] Aghbashlo M Mandegari M Tabatabaei M Farzad S Mojarab S Soufiyan J Görgens F 2018 *Energy* **149** 623-638
[6] Zeeman G Wiegant W M Koster-Treffer M E and Lettinga G 1985 *Agric. Wastes* 14 19–35
[7] Rajaeifar H Ghanavati B Dashti B Heijungs R Aghbashlo M and Tabatabaei M 2017 *Energy Reviews* 79 414- 439
[8] Sahota S Shah G Ghosh P Kapoor R Sengupta S Singh P Vijay V Sahay A Vijay V K and Thakur I S 2018 *Bioresource Technology Reports* 1 79-88
[9] American Public Health Association (APHA) 2005 (Washington DC: American Public Health Association) 21st ed 1220
[10] Forster-Carneiro T Pérez M and Romero L I 2008 *Bioresource Technology* 99 6994-7002
[11] McHugh S Collins G O'Flaherty V 2006 *Bioresource Technology* **97** 1669-1678