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Treatment of sago mill effluent for methane production using anaerobic sequencing batch reactor (ASBR)

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Abstract: In this research, sago mill effluent was treated using anaerobic sequencing batch reactor (ASBR). Seven HRT from 10 to 1.5 days were tested to evaluate the methane production from sago mill effluent. The findings revealed the highest methane production rate was found at 1.288 L CH4/L reactor. d under HRT of 2 days The results showed that COD removals decreased from 70% to 47% as HRT was reduced from 10 to 2 days. The HRT 1.5 days was found critical for the studied system, which leads to decreased in methane production, yield and COD removal. Overall, ASBR was capable to treat sago mill effluent in producing methane by means of anaerobic digestion.

Key words: *Sago mill effluent, Anaerobic digestion, Methane*

INTRODUCTION

Sago palm is one of the most essential of few type species of palm that is useful for starch yield. It has been utilized in South East Asia region for no less than 700 years [1]. A palm of sago may produce between 150 to 300 kg of dry starch. At an average consumption of 1000 logs/day, a minimal of 400 tons of slurry effluent is generated for a typical sago factory [2]. Massive amounts of waste water, bark of sago trunk, and fibrous residue commonly called as *hampas* are produced during sago starch production [3]. As reported by Chew and Shim [4], about 5-11 tons of *hampas* is released daily from each mill in Sarawak.

Currently, these residues which are mixed together with wastewater are either washed off into nearby streams or deposited in the factory's compound. These circumstances, in time, may potentially lead to serious environmental problems.

Therefore, anaerobic digestion is suggested to be an effective way to treat wastewater from sago industry. It is a biological process whereby bacteria degrades organic waste such as food waste, municipal waste and other types of waste into biogas (mainly methane and carbon dioxide) in oxygen free environment. The purpose of this research was to study the performance of anaerobic digestion of sago mill effluent for methane production in an anaerobic sequencing batch reactor (ASBR

EXPERIMENTAL PROCEDURE

Substrate and inoculum

Sago mill effluent (SME) was used as substrate and prepared fresh in laboratory. Sago pith was liquefied in a heavy duty blender with addition of tap water at standard ratio of 1:4. The resulting liquid mixture was filtered with muslin cloth to settle the starch particles. The filtration and settling process was done thrice. The final supernatant was stored in bottles at 4°C and to be used within 3 days. The pH of sago mill effluent was adjusted to 7.50 and added with homogenous solution such as potassium dihydrogen phosphate, KH_2PO_4, potassium hydrogen phosphate, K_2HPO_4, cysteine, dextrose and ammonium hydrogen carbonate, NH_4HCO_3, sodium hydrogen carbonate, $NaHCO_3$. Enriched sago sludge was used as methanogenic inoculum.

ASBR operation

Experiment was performed at mesophilic condition (37°C) in 1 L ASBR reagent bottle with working volume of 800 mL. About 640 mL of SME was mixed with 160 mL of methanogenic inoculum. The bottle was capped and flushed with nitrogen gas for 10 mins to create oxygen free condition. Initially, the experiment was

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conducted in batch mode for 20 days to acclimatize the methanogenic inoculum to the substrate. Then, it was switched to ASBR mode started with an hydraulic retention time (HRT) of 10 days that is equal to organic loading rate (OLR) 1.39 kg COD/m^3.d. Then the HRT was decreased stepwise to 8, 6, 4, 3, 2 and 1.5 days. ASBR was fed once in 24 hrs consisted of 10 min feeding, 22.5 h reaction, 1 h settling and 10 min decanting.

Analytical methods

pH, COD, TS VS, TSS VSS were analyzed according to standard methods. The biogas volume produced was measured using water displacement method. 500 µL gas tight syringe (Hamilton, USA) was taken from the headspace of reactor. The composition of gas was measured using a gas chromatography (GC) (Hewlett Packard 5890) equipped with a thermal conductivity detector (TCD). The GC was fitted in series with a stainless steel molecular sieve column (10 ft 45/60) and Porapak Q packed column (9 ft 80/100). The injector, oven and detector temperatures were set at 90°C, 50°C and 200°C, respectively. Helium was used as the carrier gas with a flow rate of 18.7 mL/min.

For volatile fatty acids (VFA) and alcohol were analyzed using a gas chromatograph GC (Hewlett Packard 5890) equipped with flame ionization detector (FID). The column used was HP-FFAP (50 m length x 0.2 mm ID x 0.33 µm film thickness) with helium as carrier gas. Injector and detector temperature were maintained at 270°C and 200°C respectively. Oven temperature was set to run at 60°C, held for 4 min, then ramped at 6°C/min to 92°C followed by a 20°C/min ramping to 150°C, then ramped again at a slower rate of 6°C/min to 175°C before finally increasing the temperature to 210°C at a rate of 30°C/min to completely remove remaining compound in the column. The separation of the primary volatile fatty acids and related solvents were obtained within 19.57 min.

Fig 1 The sago palm (*Metroxylon sp*.)

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Fig 2 ASBR reactor

CALCULATION

COD removal is the amount of chemical oxygen demand loading to be degraded from the system. COD removal efficiency is calculated based on Equation 1:

$$\text{COD removal} = \frac{\text{COD inf-COD eff}}{\text{COD inf}} \times 100 \qquad (1)$$

Where: COD eff = effluent COD (mg/L)
COD inf = influent COD (mg/L)

Hydraulic retention time (HRT) is HRT expressed in day or hour and calculated by Equation 2 in a ASBR system

$$\text{HRT} = \frac{\text{Vr}}{\text{Q}}$$

Vr = Effective volume of the reactor, L
Q = Influent flow rate, L/d

RESULT AND DISCUSSION

Methane and biogas volume

Single stage process was performed by utilizing sago mill effluent as influent for methane production. Seven experimental runs of different HRTs (10, 8, 6, 4, 3, 2 and 1.5 days) were tested. Table 1 summarizes the steady state results obtained during the course of experiment. The biogas volume was found to increase from 325 to 1828 ml as HRT was decreased from 10 to 2 days. As reported by Ndegwa, Hamilton, Lalman and Cumba [5], the increment in biogas was predicted as HRT is reduced due to the increase in loading rate and thus further supply of degradable substrate. When, HRT is progressed further to 1.5 days, a decline trend in biogas volume was observed.

Methane production plays a vital part in anaerobic digestion that defines the efficiency of anaerobic digestion. At the beginning of the experiment, methane volume was low because of low OLR and the evolved methane increase with the increment of OLR or short HRT. As can be seen from Table 2, the volume of methane increased from 145 ml to 1043 ml as a result of less HRT was applied. Generally, methane content was found to be within the range of 33% to 46%. The same trend as biogas volume was observed in methane volume as HRT going down to 1.5 days.

Methane production rate and Methane yield

The methane production rate (MPR) and methane yield (MY) was found to increase steadily from initial experiment start-up to approximately 0.344 L CH_4/L_{ww} and 0.1867 L CH_4/g COD $_{removed}$ until day 56 of fermentation, respectively. After HRT were reduced from 8 to 6 d at day 47, the MPR and MY was found to decreased until day 82 of fermentation possibly due to the variation of sago mill effluent being used. Then, MPR and MY started to increase gradually at day 83 when HRT was further decreased from 4 d to 3 d. At HRT 2 d, the MPR and MY continuously increase to 1.288 L/L CH_4.d and 0.2569 L CH_4/g COD $_{removed}$, respectively. Meanwhile at HRT of 1.5 days, MPR decreased to 0.939 L CH_4/L_{ww}. d though the MY keep continue to rise to 0.3377 L CH_4/g COD $_{removed}$. Thus, it can be concluded that an HRT of 1.5 days was too short to allow substantial methane production in this system.

pH, VS and COD removal

In general, COD removal showed a decreasing trend from 70% to 47% as HRT is reduced from 10 to 2 days. This could be attributed to biomass loss as HRT is reduced thus contributing to the decreased in substrate removals [6]. Although the biogas and methane volume were increased, it takes time for the reactor to stabilize as the COD removal started to decrease which then followed by the increase in COD concentration of the effluent which eventually would affect the performance of COD removal in the reactor.

The pH range in the effluent was all above 7.0 which are optimal for production of methane. VS and VSS are crucial criteria when loading anaerobic reactor as both represents solid material suspended and the population size of bacteria within the activated sludge process respectively. As illustrated in Figure 7, it can be seen that the concentration of solid biomass was increasing. This behavior can be explained when HRT is declined, the organic loading increases accordingly and biomass synthesis is greater [6]. It can be observed the ASBR was capable to hold up to 23000 mg/liter of biomass concentration. The high MLVSS of the reactors proves that the ASBR system has the ability to support high solids in the system and allowing efficient treatment of low-strength wastewater [7].

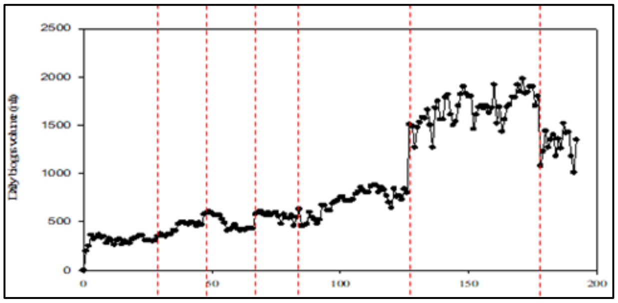

Figure 3 Daily biogas volumes

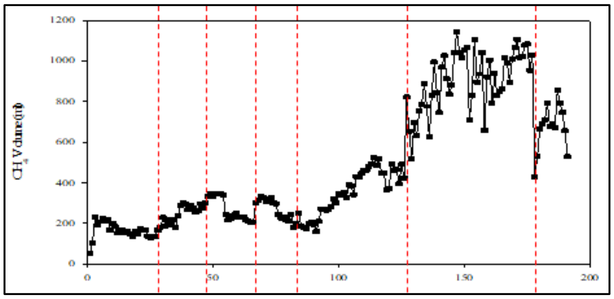

Figure 4 Methane volume

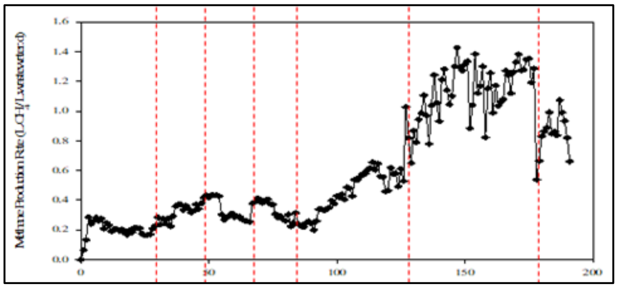

Figure 5 Methane production rate

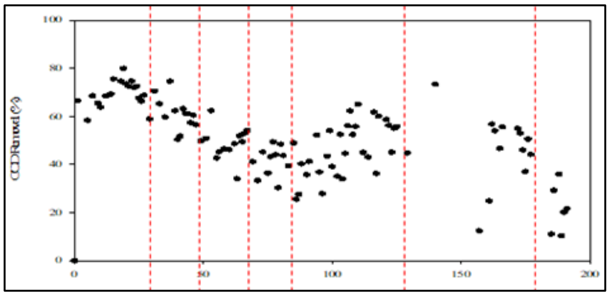

Figure 6 COD removal

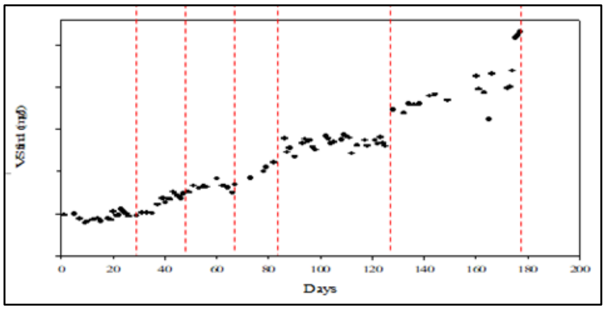

Figure 7 Volatile solids concentration

Volatile fatty acid (VFA)

At any given HRT, ethanol was the most abundant alcohols in the influent of ASBR. Unlike other studies, ethanol production was relatively high in this experiment, possibly due to the properties of sago mill effluent itself. The highest VFA reduction was 72% at HRT 8 days, and the lowest was 43% at HRT 3 days. All VFAs were degraded by microbes to acetic acid before converting to CH_4 according to sequence acetic acid > ethanol > butyric acid > propionic acid [8] . Meanwhile, propionic acid was least detected in the reactor.

CONCLUSION

The Anaerobic Sequencing Batch Reactor (ASBR) has been shown to effectively treat sago mill effluent. High organic matter removal efficiencies (up to 70% COD removal) can be achieved in single stage digestion. Methane gas was produced in the range of 145 mL to 1043 mL. The highest methane production rate obtained was at 1.288 L CH_4/L $_{reactor}$. d under HRT of 2 days.

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Table 1 Average steady state data in single stage experiment

	Unit							
HRT	days	10	8	6	4	3	2	1.5
OLR	kg COD/m^3.d	1.39 ± 0.04	2.21 ± 0.07	2.21 ± 0.29	3.26 ± 0.13	3.69 ± 0.16	7.61 ± 0.42	11.23 ± 1.46
Effluent pH	-	7.84 ± 0.10	7.44 ± 0.05	7.42 ± 0.12	7.00 ± 0.10	7.11 ± 0.02	6.97 ± 0.02	7.26 ± 0.42
Biogas volume	mL/d	325 ± 27.57	481 ± 15.24	429 ± 9.17	528 ± 48.34	790 ± 45.87	1828 ± 74.41	1362 ± 123.68
Methane volume	mL	145.83 ± 18.13	275.24 ± 16.69	216.97 ± 12.49	218.05 ± 22.31	454.07 ± 39.09	1043.00 ± 76.10	735.00 ± 79.22
Methane content	%	35.80 ±1.70	45.80 ± 2.82	41.10 ± 3.14	33.10 ± 2.55	45.90 ± 2.59	45.10 ± 0.56	43.20 ± 1.84
Methane production rate	L CH$_4$/L$_{ww}$. d	0.182 ± 0.02	0.344 ± 0.02	0.271 ± 0.02	0.273 ± 0.03	0.568 ± 0.05	1.288± 0.06	0.939 ± 0.10
COD removal	%	70.42 ± 3.23	59.25 ± 4.08	47.49 ± 7.68	43.26 ± 7.62	54.24 ± 5.25	47.68 ± 6.60	21.39 ± 11.23
Methane yield	L CH$_4$/g COD $_{removed}$	0.1307 ± 0.01	0.1867 ± 0.03	0.1872 ± 0.05	0.1450 ± 0.03	0.2054 ± 0.04	0.2569 ± 0.05	0.3377 ± 0.20