

Acclimatization and Performance Study of Acidogenesis Anaerobic Degradation Process for Palm Oil Mill Effluent

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Abstract. The acclimatization and performance study of palm oil mill effluent (POME) are carried out in closed anaerobic digester at mesophilic temperature of 35°C. Several of hydraulic retention time (HRT) is conducted at the 12, 10, 8, 6, 4, and 2 days of HRT, which correspond to the feed flow-rates as 0.375, 0.450, 0.563, 0.750, 1.125 and 2.250 liters of raw POME per day. The performance study showed that the Chemical Oxygen Demand (COD) removal efficiency is 87.08% for 12 days of HRT. While shorter the HRT, the COD removal efficiency was reduced within the range of 63.87% and 38.20% between 10 days and 2 days of HRT. Besides, the biomass concentrations are in the range of 20958 mg MLVSS/l for 12 days of HRT and increased to 43228 mg MLVSS/l for 2 days of HRT. Moreover, the total alkalinity increased from 5902 until 7716 mg CaCO₃/l, respectively from the HRT of 12 days until 2 days.

Keyword: Palm oil mill effluent; closed anaerobic digester; hydraulic retention time; chemical oxygen demand.

1. Introduction

Malaysia is one of the largest producers and exporters of palm oil in the world, accounting for 11% of the world's oils & fats production and 27% of export trade of oils & fats [1]. POME is highly polluting wastewater which is organic in nature and contains oil and carotenes. POME is a thick, brownish in color liquid with a discharged temperature of between 80 and 90 °C, being fairly acidic in the range of 4.0 – 5.0 [2]. It generated through oil extraction processes has a great impact to the industry [3]. In the process of palm oil milling, POME is generated through sterilization of fresh oil palm fruit bunches, clarification of palm oil and effluent from hydro cyclone operations [4]. During palm oil extraction, about 1.5 tones of POME is produced per tone of fresh fruit bunch (FFB) processed by the mill [5]. It is a colloidal suspension containing 95-96% water, 0.6-0.7% of oil and grease, and 4-5%of the total solids. Since the POME is considered as polluting contaminants due to its high organic load, POME has to be treated before being released into the environment [6].

In terms of energy requirement for POME treatment operation, anaerobic digestion has a stronger advantage over the other alternative methods as it does not require energy for aeration, where dissolve the oxygen into the system, as low energy requirement [7] involved, and involved the process of hydrolysis, acidogenesis, and methanogenesis to convert the complex molecules into simpler end products, and produce biogas. The utilization of methane gas as a renewable energy from the anaerobic digestion can be used to obtain certified emission reduction (CER) credit by clean development mechanism (CDM) under the Kyoto protocol [8]. Besides helping to reduce carbon emission to the environmental, CDM has the advantage to offer developing countries such as Malaysia to attract foreign investments to sustain renewable energy

projects [9]. Methane gases as a final product from the anaerobic digestion which can be used to generate the electricity [10].

2. Material and Method

The suspended closed anaerobic reactor is shown in **Figure 1**. The reactor comprises of the electronic heat sensor, pH probe, and electronic stirrer. The reactor was maintained at constant desired temperature of 35 °C using controller heat sensor. HRT was adjusted volumetrically through controlling the flow rate of the influent feed. Mixed and effluent samples were taken from the reactor tank after 24 hours for analysis at each batch of HRT with the manual pump. The samples were subjected to the analysis of the following parameters such as COD, pH, alkalinity, suspended solids and volatile suspended solids based on the American Public Health and Association (APHA) standard methods for water and wastewater analysis (APHA 2005). The anaerobic reactor was monitored constantly to ensure the smooth operation. The start-up of the SCAR involved step increasing in influent organic volumetric loading rates from higher retention time to lower retention time of 12 to 10, 8, 6, 4, and 2 days, which correspond to the feed flow-rates as 0.375, 0.450, 0.563, 0.750, 1.125 and 2.250 liters of raw POME per day. The acclimatization phase was used the feed flow-rate of 0.375 liters which correspond to the HRT of 12 days for about 27 days to allow all the microorganisms present in the mixed liquor perfectly acclimatized to the new environmental.

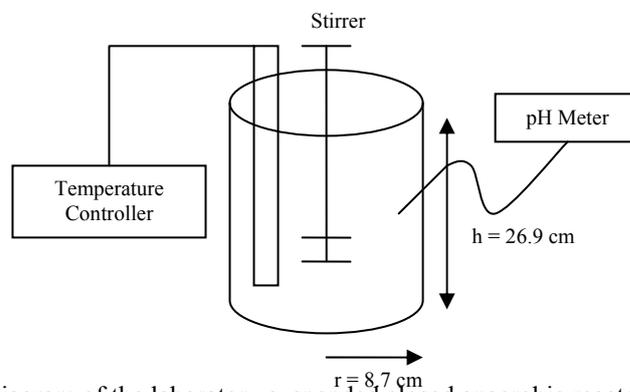


Figure 1: Schematic diagram of the laboratory suspended closed anaerobic reactor (SCAR) - Anaerobic digestion reactor tank.

3. Result and Discussion

3.1. Acclimatization Study of SCAR

Acclimatization process of the SCAR is done with the feed rate as 0.375 liters/day which corresponds to HRT of 12 days to allow the anaerobic bacteria which present in the mixed liquor entirely will acclimatize to the new environmental in the reactor. The acclimatization phases of each parameter are achieved with the steady state as shown in Figure 2 and 3. The pH of the reactor is decrease gradually from 6.95 to 5.09 on operation days between 0 days and 14 days as shown in Figure 2. This is due to bacteria in the SCAR break down the sugar, fatty acids and amino acids from the feed materials into organic acids which mainly consist of acetic acid together with hydrogen and carbon dioxide [10]. It indicates that the acidogenesis phase had occurred in the SCAR during operation process. On the operation day of 15th to 19th, the pH reading showed fluctuation between value of 5.11 and 5.17. For the next 8 days, the reading of the pH starts increasing slightly from 5.21 to 5.32 until the day of 27th. The pH slightly increased about 0.11 to 5.32 in these 8 days of operation was indicated that the SCAR had already reached the stability of the anaerobic digestion process. The initial concentration of MLVSS is 34190 mg/l as shown in Figure 2. The concentration of MLVSS decreases to 8940 mg/l respectively for the next 7 days of operation. In this stage, it is believe that the reducing concentrations of the biomass growth is related to the bacteria which are still trying to adapt the new environmental in the SCAR reactor in the beginning. Hence, the anaerobic digestion process is time consuming as bacterial consortia responsible for the degradation process requires time to adapt to the new environmental before start to consume on organic matters to grow [11]. On the 8th operation day, the concentration for MLVSS is 10140 mg/l and then gradually increases to 19870 mg/l for the next 12 day. In

this stage, the increase concentration of bacteria is due to the bacterial had already adapt the new environmental and can effectively consume on organic matters to grow. On the 21st day of operation, the concentration of the MLVSS remains constant for the next 6 operation days, with on the range between 20680mg/l and 21000 mg/l. The stationary phase of MLVSS concentration is reached in this time periods. This demonstrated that SCAR is capable to holding high organic strength of POME wastewater. The initial concentration of alkalinity is 5480 mg CaCO₃/l as shown in Figure 2. The alkalinity are greatly reduces to 3330 mg CaCO₃/l on the 1st day of operation, and increase gradually to 4280 mg CaCO₃/l for the 9th days of operation. The acidogenesis phase occurred in the SCAR with the reduced of pH as shown in Figure 2 due to accumulation proving an optimal environmental for the acidogenesis bacteria [12]. For the next 8 days of operation, the concentration of alkalinity gradually increased from 4890 to 5910 mg CaCO₃/l. The increase of concentration alkalinity is due to increasing concentrations of ion calcium from CaCO₃ significantly improved the bacteria growth under acidogenesis conditions. The system regained the stability state for the remaining 8 days, until 27th day of operation with the concentration of alkalinity fluctuated between 5870 to 5950 mg CaCO₃/l. The initial COD effluent concentration is 12475 mg/l and the percentage removal efficiency is 84.93% as shown in Figure 3 until 10th day of operation, with 26250 mg/l as a peak concentration. Meanwhile, the removal efficiency is decrease to 68.93% on the 10th day of operation. This is because the bacteria are tried to adapt the new environmental, concurrently the pH of SCAR reduced at initial stage start from pH 6.95 to pH 5.11. This due the acid-producing bacteria grow faster than the methane forming bacteria, the excess acid which formed because the pH drops, thus affect the performance of the bacteria inside the reactor [13]. The COD effluent concentration is decreasing to 12250 mg/l for the 20th day of operation. Meanwhile, the removal efficiency is increased up to 86% on the 20th day. The decreasing of concentration of COD effluent and increase of the percentage removal efficiency is due the bacteria already acclimatize oneself to the new environmental and increase the biomass in the SCAR reactor, with sufficient to removal the concentration of COD during the process. Since from Figure 2, the biomass MLVSS are keep increasing and remain constant in the operation days from 21st to 27th can be said already achieve the optimum condition in anaerobic biomass in this acclimation process, as a results the effluent COD will decrease and the removal efficiency will increase until each achieve a maximum condition. Therefore the effluent COD fluctuated between 11550 mg/l and 11350 mg/l while the removal efficiency also fluctuated at 86.78% to 87.19% for the remaining 7 days of the operations. The acclimatization periods of SCAR is already completed in these 7 operation days.

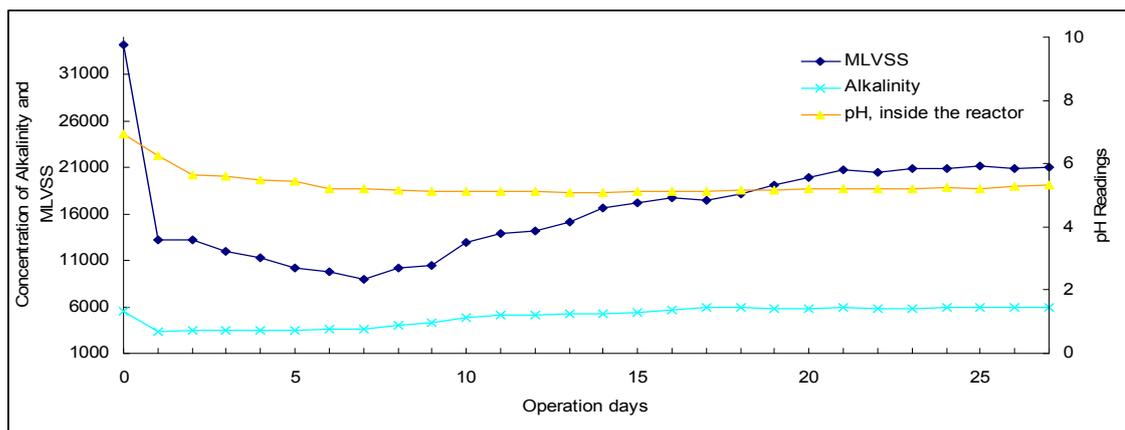


Figure 2: MLVSS, Alkalinity and pH variation of SCAR during acclimation process

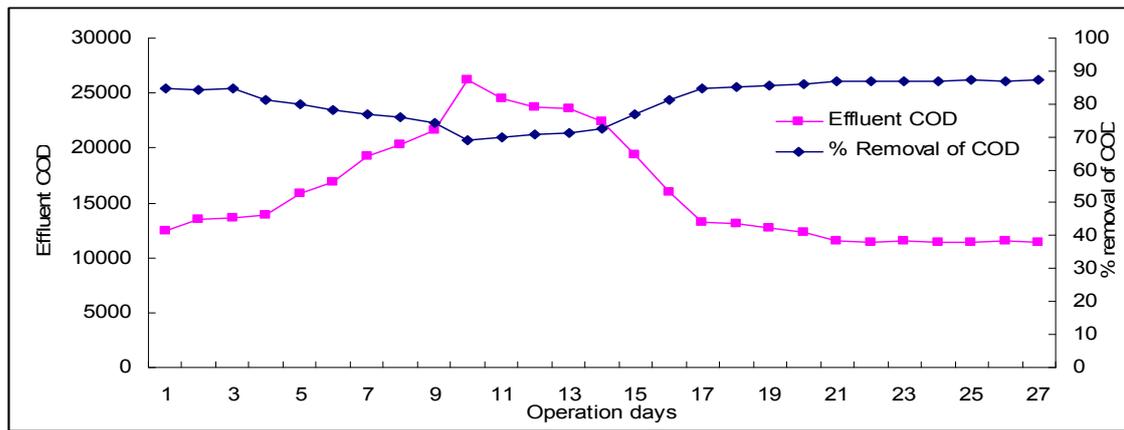


Figure 3: Effluent COD and % removal COD variation of SCAR during acclimation process

3.2. Performance Study of SCAR at various HRT

Table 1 summarized the steady state performance of SCAR at six different HRT of 12, 10, 8, 6, 4, and 2 days. The variations of the percentage of COD removal efficiency increased from 2 until 12 days. Hence the COD removal efficiency was in the range of 38.20 % until 87.08%. The higher COD removal efficiency for the SCAR is 87.08% for 12 days of HRT. The COD removal efficiency becomes poorer at the shorter HRT. This was largely due to the wash-out phase of the reactor since the concentration of biomass increased in the system reactor as shown in Table 1. The pH inside the reactor show that the acidogenesis phase occurs in the system. The alkalinity concentration of SCAR decreased from 7716 until 5902 mg CaCO₃/l by the HRT of 2 until 12 days. The increased of the concentration of alkalinity is due to increase of organic loading rate since increase of the biomass in the system from 12 day to 2 day of HRT, thus alkalinity produced to reduce the accumulation of VFA. The higher alkalinity level indicates that the bacterial groups were in equilibrium. As results, the performance of SCAR could maintain active in acidogenesis activity.

Table 1: Experimental results obtained under steady state condition at six different HRT

Parameter	Average concentration for HRT (day) of					
	12	10	8	6	4	2
pH in SCAR	5.26	5.36	5.54	5.53	5.34	5.20
Effluent COD (mg/l)	11420	27590	29370	34340	35370	40230
COD removal efficiency (%)	87.08	63.87	58.10	54.30	48.18	38.20
MLVSS in SCAR (mg/l)	20958	30368	31246	30012	35144	43226
Alkalinity in SCAR (mg CaCO ₃ /l)	5902	6620	6706	7098	7492	7716

4. Conclusion

As a conclusion, when shorter the HRT, organic loading rate will increased, thus will increase the bacteria growth in the reactor. As a results, this will cause the concentration of the COD effluent increased with reduced the removal efficiency of the COD. The system stressed to obtain a maximum COD loading rate in a short period of time [14]. At the same time, it will increase the total alkalinity since increase of the acidogenesis bacteria growth rise the VFA in the system, thus more alkalinity needed to buffering the capacity of anaerobic degradation system. Throughout this research study, it can be concluded that the suspended closed anaerobic reactor (SCAR) effective to treating the high strength wastewater of POME at different HRT. The optimum performance HRT of the COD removal efficiency is 12 days with removal efficiency of 87.08%, respectively.

5. References

- [1] Malaysian Palm Oil Council (MPOC) (2009), <http://www.mpoc.org.my> (accessed 02 January 2010)
- [2] Poh, P.E., Chong, M.F. (2008). Development of Anaerobic Digestion Methods for Palm Oil Mill Effluent (POME) Treatment. *Bioresource Technology*, 100, pp. 1-9.
- [3] Yacob, S., Hassan, M.A., Shirai, Y., Wakisaka, M., Subash, S. (2006). Start-Up Operation of Semi-Commercial Closed Anaerobic Digester for Palm Oil Mill Effluent Treatment. *Process Biochemistry Journal*, 41, pp. 962–964.
- [4] Borja, R., Banks, C.J., Sánchez, E. (1996). Anaerobic Treatment of Palm Oil Mill Effluent in a Two-Stage Up-Flow Anaerobic Sludge Blanket (UASB) Reactor. *Journal of Biotechnology*, 45, pp. 125–135.
- [5] Ahmad, A. L., Ismail, S., Bhatia (2003). Water Recycling from Palm Oil Mill Effluent (POME) Using Membrane Technology. *Desalination*, 157(1-3), pp. 87-95.
- [6] Environmental Quality Act 1974 (ACT 127) and Subsidiary Legislation, Environmental Quality (Sewage and Industrial Effluents) Regulation 1979.
- [7] Metcalf, Eddy, (2003). *Wastewater Engineering: Treatment and Reuse*. 4th Ed., New York: McGraw Hill, pp. 96–97.
- [8] Tong, S.L., Jaafar, A.B. (2006). POME Biogas Capture, Upgrading and Utilization. *Palm Oil Engineering Bulletin*, 78, pp. 11–17.
- [9] Menon, R. (2002). Carbon Credits and Clean Development Mechanism. *Palm Oil Engineering Bulletin*, 65, pp. 11–14.
- [10] Gerardi, M.H. (2003). *The Microbiology of Anaerobic Digesters*. Wiley-Interscience, New Jersey. pp. 51-57.
- [11] Wong, P.W., Sulaiman, N.M., Nachiappan, M., and Varadaraj, B. (2002). Pre-Treatment and Membrane Ultrafiltration using Treated Palm Oil Mill Effluent (POME). *Membrane Science & Technology*, 24, pp. 891-898.
- [12] Azbar, N., Ursillo, P., and Speece Richard, E. (2000). Effect of process configuration and substrate complexity on the performance of anaerobic processes. *Water Resource Journal*, 35, pp. 817-829.
- [13] Wong, Y.S., Omar A.B. Kadir, M., Teng, T.T. (2009). Biological Kinetics Evaluation of Anaerobic Stabilization Pond Treatment of Palm Oil Effluent. *Bioresource Technology*, 100, pp. 4949-4975.
- [14] Angenent, L.T., Sung, S.W. (2000). Development of anaerobic migrating blanket reactor (AMBR), a novel anaerobic treatment system. *Water Resource*, 35(7), pp. 1739-1747.