Preliminary experimental results of Sewage Sludge (SS) Co-digestion with Palm Oil Mill Effluent (POME) for Enhanced Biogas Production in Laboratory Scale Anaerobic Digester

R Sivasankari, P Kumaran, Saifuddin Normanbhay and Abd Halim Shamsuddin
Centre for Renewable Energy, Universiti Tenaga Nasional (UNITEN)
43009 Kajang, Selangor, Malaysia
E-mail: sivasankari@uniten.edu.my

Abstract. An investigation on the feasibility of co-digesting Sewage Sludge with Palm Oil Mill Effluent for enhancing the biogas production and the corresponding effect of the co-digestion substrate ratio on the biogas production has been evaluated. Anaerobic co-digestion of POME with SS was performed at ratios of 100:0, 70:30, 60:40 and 0:100 to find the optimum blend required for enhanced waste digestion and biogas production. Single stage batch digestion was carried out for 12 days in a laboratory scale anaerobic digester. Co-digestion of sludge’s at the 70:30 proportion resulted in optimal COD and C: N ratio which subsequently recorded the highest performance with regards to biogas production at 28.1 L’s compared to the 1.98 L’s of biogas produced from digestion of SS alone. From the results obtained, it is evident that co-digestion of POME and SS is an attractive option to be explored for enhancement of biogas production in anaerobic digesters.

1. Introduction
Biogas is produced naturally when the environment is favourable for anaerobic fermentation or commonly known as anaerobic digestion of organic material [1]. It is generally comprised of 60 – 70% methane (CH₄), 30-40% carbon dioxide (CO₂) and low amount of other trace gases [2]. Sewage wastewater is filtered to separate the solids from the liquid in a modern state of art sewage treatment system. The collected solid sludge is then transferred into an anaerobic digester, to be treated and biogas produced is collected and flared[3]. POME is a thick brownish liquid that contains high amounts of total solids (40,500 mg/L), oil and grease (4,000 mg/L) and COD (50,000 mg/L) [4] [5] that is produced during the processing of Oil Palm. Literature studies have shown that, co-digestions of slurries are known to result in more efficient digestion of organic materials. Better NPK (Nitrogen: Phosphate: Potassium) ratio can also be obtained through co-digestion, which will aid in higher methane production [6]. Promisingly from previous literature reviews done, since both sewage sludge and POME are organic in origin, combined anaerobic digestion seemingly is an ideal solution. Also, improved sludge digestion due to synergistic effects of co-substrate and increased nutrients should result in improved degradation of organic matter. The aim of this work is to investigate the co-digestibility of Sewage sludge and Palm Oil Mill Effluent in laboratory scale single stage batch anaerobic digesters. In this work, the optimum ratio of the sludge for enhanced anaerobic biomethanation process is re-investigated and reported. This paper reports on the enhanced biogas production through anaerobic co-digestion of Sewage sludge and Palm oil mill effluent.
2. Experimental material and methods
The feed sewage sludge was collected from a Sewage Treatment Plant. Palm Oil Mill Effluent (POME) was collected from Seri Ulu Langat Palm Mill, Dengkil. The POME and SS samples were collected and sent for characterization studies upon arrival to the laboratory. The laboratory scale 10 L single stage batch anaerobic digesters were operated under mesophilic conditions at 29°C with a hydraulic retention time of 12 days. Each anaerobic digester was loaded with 5L’s of the substrate. Two control systems were fed with 100% POME and 100% SS and its operation is compared to the 2 experimental systems with 60:40 and 70:30 volume ratio of POME: SS. Sample 1 was fed with 60% POME and 40% SS while Sample 2 was fed with 70% POME and 30% SS. Sludge characteristics such as MLVSS, TS, TKN, COD and C: N ratio was measured using APHA 2005 standards at third party laboratory.

Biogas generated was collected in custom fabricated plastic canisters. The volume of gas produced daily is monitored by reading the amount of displaced water.

3. Results and discussion
The results of compositions of the samples are as described in Table 2. It was found that Sample 2 with composition of 70% POME and 30% SS had produced highest quantity of biogas. This was followed by Control 1 (100% POME), Sample 1 (60% POME and 40% SS) and lastly, Control 2 (100% SS). Cumulative production of biogas for all the samples is as detailed in Figure 2.

| Parameter  | Control 1 (POME) | Control 2 (SS) | Sample 1 60:40 | Sample 2 70:30 |
|------------|------------------|----------------|----------------|----------------|
| MLVSS (mg/L) | 33,000           | 8,420          | 22,900         | 3,000          |
| TS (mg/L)   | 45,300           | 63,600         | 30,900         | 15,400         |
| COD (mg/L)  | 103,000          | 22,800         | 29,000         | 50,600         |
| TKN (mg/L)  | 1,260            | 1,160          | 1,200          | 1,350          |
| C:N Ratio   | 50.0             | 2.07           | 23.3           | 20.0           |

The amounts of biogas produced in the respective samples as in figure 2 were 28.1 L’s, 11.98 L’s, 9.9 L’s and 1.98 L’s. Control 2 (100% SS) has produced the least amount of biogas as compared to the rest of the test subjects. This finding is concurrent with previous works done, which proved that
sewage sludge in combination with high organic content material aids in decomposition of waste and enhanced methane formation [7].

The efficiency of anaerobic digestion for methane production depends on the organic strength of sludge present in the waste. The most important parameters for characterizing these slurries are total solids content (TS) and volatile solids content (VS). Anaerobic digestion typically results in a 50% reduction of organic matter (volatile solids). According to previous works reported, it is derivable that anaerobic digestion of SS as a single substrate is possible, but the amount of biogas produced from this process will be lower than that compared to SS co-digested with other high organic material sludge. The results obtained as in Figure 2 seem to comply with Schmidell’s studies which show that a substrate digested individually will produce lesser biogas compared to mixed sludge’s [8].

The biogas production rates for the four experimental samples are shown in Figure 3 and Figure 4. From the Figure 4 it can be seen that Control 2, had produced the least amount of biogas, meanwhile Sample 2, a co-digestion mixture of 70% POME and 30% SS had produced the highest amount of biogas. This can be traced back to the C: N ratio of the sludge. The optimum C: N ratio required for anaerobic digestion is between 20 – 30 [9]. Sewage sludge, suggests very low C: N ratio, and on the other hand, the C: N ratio of POME is much higher and through co-digesting the sewage sludge and POME, a relatively optimal C: N ratio is achieved, thereby improving the digestion process and correspondingly the by-product methane generation enhancement.

The Chemical Oxygen Demand (COD) is another important parameter which affects the biogas production process. COD value indicates the value of organic compounds present in the water. Recent experimental works has proven that substrates with higher COD value led to better performance in terms of methane production and COD reduction. As visible in Table 2, the COD value of POME is at 103,000 mg/L and COD value of Sewage sludge is a mere 22,800 mg/L. When combined at the ratio
of 70:30 (Sample 2) for co-digestion, and optimal rate of 50,600 was achieved. The increased biogas production can be attributed to this particular character of the sludge [10].

Based on the results collected as seen in Figure 4, it can be stated the co-digestion of Sewage Sludge of low organic content with Palm Oil Mill Effluent, which has a higher organic content at the ratio of 30:70 produces increased amount of biogas as compared to its control systems.

4. Conclusion
The objective of this study was to assess the feasibility of co-digesting Sewage Sludge with Palm Oil Mill Effluents. Preliminary findings have concluded that co-digestion on the optimum sludge ratio of 70:30 (POME: SS) has shown increase in biogas production 5 times higher than the samples which were not co-digested. Hence, it can be deduced that mixing SS with POME enhances the decomposition of organic materials leading to higher biogas production. Further research is recommended to evaluate the quality of biogas that is generated from the experiment.

Acknowledgement
We would like to thank AAIBE for funding this research, Indah Water Konsortium (IWK) for providing us sewage sludge samples for this experiment, also thanks to the participation of undergraduate students, Ms. Hephzibah David and Mr. Kuhan Sundrarajoo in assisting with starting up the research process.

References

[1] NNFCC and The Andersons Centre 2011 NNFCC Renewable Fuels and Energy Factsheet: Anaerobic Digestion [Online]. United Kingdom: NNFCC http://www.nnfcc.co.uk/publications/nnfcc-renewable-fuels-and-energy-factsheet-anaerobic-digestion

[2] Saija R 2009 Biogas composition and upgrading to Biomethane. Published PhD thesis. University of Jyväskylä

[3] Indah Water Konsortium 2012 Sewage Treatment Methods [Online]. http://www.iwk.com.my/v/knowledge-arena/sewage-treatment-methods

[4] Loh S K, Noor F M and Ma A N 2009 Characterization of Palm Oil Mill Effluent (POME) for Process Control and Baseline Establishment. Malaysia MPOB Information Series

[5] Asian Palm Oil Company Limited 2004 Waste-to-Energy Project by a Palm Oil Manufacturer. Thailand.

[6] Fabien M 2003 An introduction to anaerobic digestion of organic wastes Remade Scotland

[7] Sharifuddin H A H, Zaharah A R 2004 Utilization of Organic Wastes and Natural Systems in Malaysian Agriculture Malaysian Palm Oil Board

[8] Schmidell W and Craveiro A M et al 1986 Anaerobic Digestion of Municipal Solid Wastes Water Science & Technology 18 163–17

[9] Shefali V 2002 Anaerobic digestion of biodegradable organics in municipal solid wastes Published MSc thesis. Columbia University

[10] Gamze G D and Goskel N D 2004 Effect of initial COD concentration, nutrient addition, temperature and microbial acclimation on anaerobic treatability of broiler and cattle manure. Bioresource technology 93 109-17