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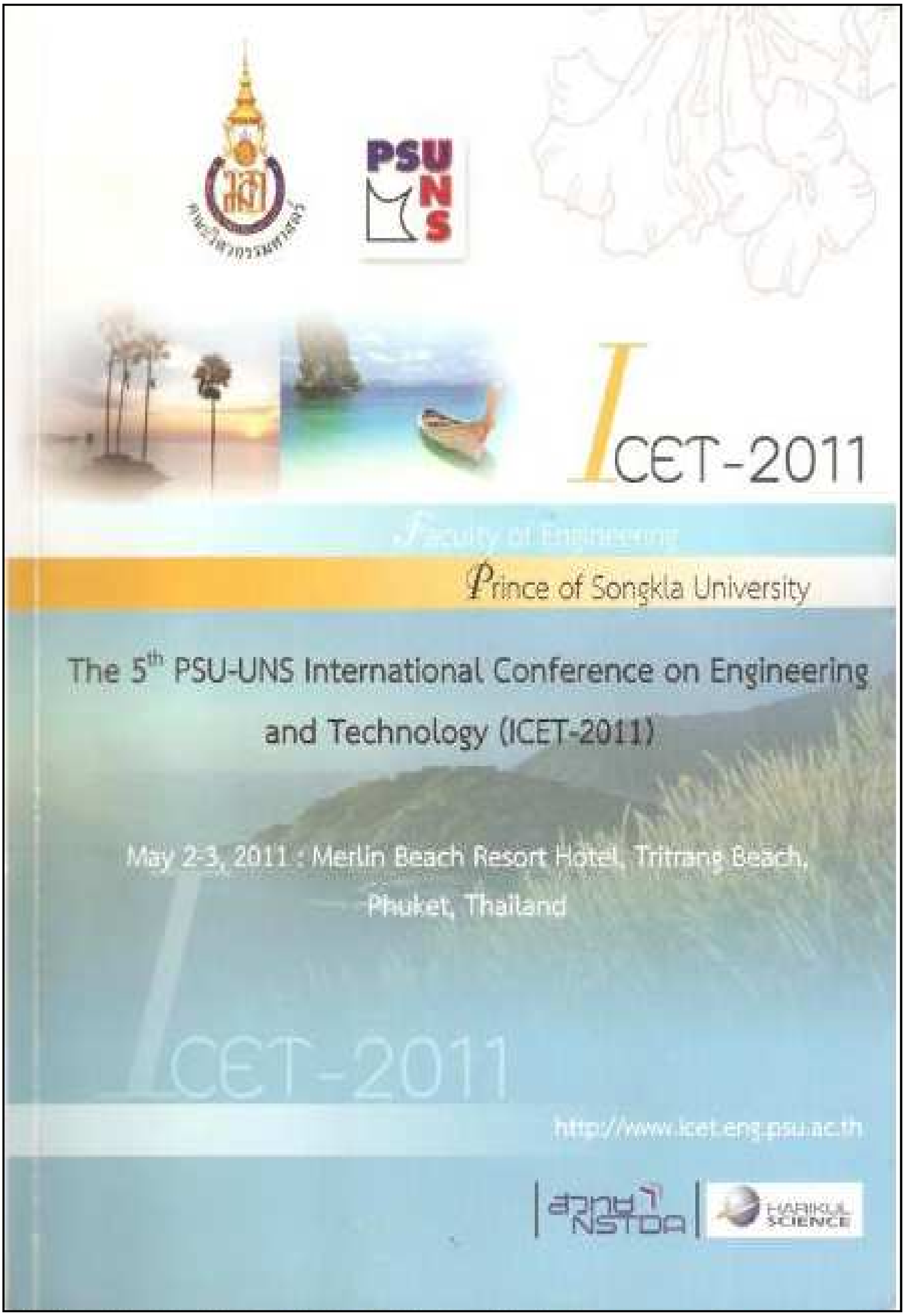
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BIOGAS PRODUCTION BY ANAEROBIC BATCH CO-DIGESTION OF PIG MANURE AND RUBBER LEAVES

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Abstract: *Co-digestion of various wastes has been shown to improve the digestibility of the material and biogas yield. The possible use of rubber leaves (RL) from rubber tree waste co-digestion with pig manure (PM) was evaluated in laboratory study by batch tests under room temperature. The length of batch experiment was 44 days. Furthermore, co-digestion in varying proportions of PM and RL were studied. The effects of increasing concentration of rubber leaves expressed as percentage of total solids (TS). The carbon-to-nitrogen ratios (C/N ratio) were investigated and feedstock proportions of rubber leaves and pig manure were 8-20% of TS. A maximum methane yield of 0.38 l CH_4/kg $TS_{removed}$ was obtained at 12% of TS and 11.72:1 of C/N ratios. A methane content of up to 58% was obtained from this proportion of PM and RL of 50:50 whereas PM alone had produced biogas with 41%. Co-digestion can improve the methane production and the methane yield by 40% compared with digestion of PM waste alone.*

Key Words: ***Biogas/ Anaerobic co-digestion/ Methane/ Pig manure/ Rubber leave***

1. Introduction

Increasing in energy demand and the issues about rapid depletion non-renewable energy resources as well as their environmental shortcomings led researchers to investigate alternative energy sources during the last two decades. Renewable energy resources draw attention all over the world because of sustainable and improvement in environmental quality. Biomass and agricultural waste represent a large potential renewable energy source, which could benefit society with a clean fuel in the form of methane. Biogas technology has been known for a long time, but in recent years the interesting in it has been significantly increased, especially due to the higher cost of living and low cost fulfill of biomass.

Anaerobic digestion is a proven and established technology for treating many types of organic wastes, both solid and liquid. This alternative allows the production of energy in the form of biogas, which contains mainly methane (CH_4) and carbon dioxide (CO_2) and a solid product that can be used as an amendment of soils. Co-digestion is a promising technology widely applied two or more organic residues are well described in the literature [1]. Thus, co-digestion between manure and cellulolytic would give balancing in nutrients, appropriate C/N ratio, and stable pH that needed to increase methane production, because of the added plant materials with high carbon content provides the preliminary energy source for the microorganisms growth and could improve the C/N ratio of the feedstock, thereby decreasing the risk of ammonia inhibition to the digestion process. [2]. Anaerobic digestion of pig manure (PM) alone produces low methane yield due to the high content of water and fibers of this material. It is hence clear that if it is desired to produce more methane yield to meet local energy needs, there is a need to look for other feedstock, along with PM.

In rural areas of developing countries various cellulosic biomass (cow manure, agricultural residues, leafy biomass, etc.) are available in plenty which have a good potential to producing biogas. The biogas potential of leafy biomass feedstock is almost twice that which can be produced by animal dung. Rubber tree is a major industrial drop in the south of Thailand. Rubber leaves (RL), a surplus waste from the rubber tree, has been defined as organic matter formed by photosynthetic capture of solar energy and stored as chemical energy, which are a suitable raw material for biogas production. The solar energy stored in biomass could be released as biogas through anaerobic digestion. The pigs produce large amounts of manure, which are suitable substrate for anaerobic digestion and excellent co-substrate due to its high buffering capacity and rich in a wide variety of nutrients needed by the methanogens. Moreover it has been demonstrated that the composted PM is a valuable fertilizer for increasing crop yield and improving in technical feasibility of the process

This study presents the biogas production achieved in batch reactors using PM and high carbon content RL at different fractions in order to determine optimum mixture for successful co-digestion. The effects of RL waste adding and total solid (TS) of 8-20% in feedstock were evaluated for methane production using co-digestion batch system. The total volatile fatty acids (VFAs), alkalinity, pH, methane yield, and organic substance removal were investigated.

2. Material

2.1. Operating procedure

RL, a leafy biomass waste was obtained from a source of rubber tree plantation (Songkhla, Thailand). The RL was grinded into smaller pieces with an electric grinder. Fresh PM used in these experiments was obtaining from a pig farm (Faculty of Natural Resources of Prince of Songkla University, Thailand) was stored less than 24 hours. The RL and PM waste were weighted and mixed together. The design of experiment for biogas production in laboratory scale is described in Table 1. Batch biodegradability assays were carried out with 8 different proportions of the two solid wastes at room temperature (28±2°C) and for a period of 44 days in order to reach reactor stabilization. The TS concentration in each reactor was 8-20%. In each set of trials, a digestion of PM alone was used as a control and the digestions were run in duplicate.

Table 1. *Proportion of initial waste in biogas reactor*

No.	PM:RL	Shred	% TS	C/N Ratio
R1	50:50	/	8	11.72
R2	50:50	/	12	11.72
R3	50:50	/	16	11.72
R4	50:50	/	20	11.72
R5	100:0	/	16	10.79
R6	25:75	/	16	12.06
R7	75:25	/	16	11.31
R8	50:50	×	16	11.72

2.2. Anaerobic digestion of PM and RL

The co-digestion of PM and RL were carried out in 8 sets of digestion reactor with a volume of 25 L reactors constructed by using plastic bottles with a working volume about 20 L. The biogas produced was collected in 6 L of PET bottles (see Fig. 1). The volume of gas collected was measured by the displacement of water from the collecting PET bottles and was recorded every day. The reactors were shaken manually for 0.5 min twice daily to mix their content.

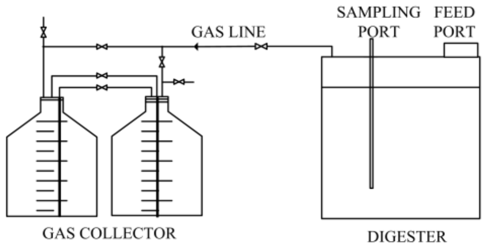

Fig. 1. *Sketch of the anaerobic digester*

2.3. Analytical

The biogas composition was determined using a gas chromatograph; fitted with a ShinCarbon ST 100/120 mesh column, a micropacked column and a thermal conductivity detector. The oven, detector and inlet temperatures were 40, 200, and 100 °C, respectively. The compounds detected were methane and carbon dioxide. The volume of biogas collected in the gas-tight aluminium bags. In all experiments the following data were determined: methane yield, total solids (TS), volatile solid (VS), pH, and alkalinity. Total volatile fatty acids (VFAs) were determined according to the APHA Standard Methods (1995) [4]. Total organic carbon (TOC) was measured by wet oxidation. Total nitrogen (TN) was estimated by the Kjeldahl method. Moisture was determined as described by AOAC standard methods.

Removal rates of TS were calculated after reactors stabilization (i.e., after more than 44 days of experiments) by equation (1)

$$\text{TS Removal } (\%) = \frac{TS_{initial} - TS_{final}}{TS_{initial}} \quad (1)$$

3. Result and discussion

3.1. Feedstock characteristics

Table 2 shows analyzed properties and characterization of initial waste.

Table 2. *Properties and characteristics of PM and RL*

Parameter	PM	RL
Organic Carbon (OC) % (dry wt.)	17.15	29.76
Total nitrogen (TN) % (dry wt.)	1.59	2.41
C/N ratio	10.79	12.34
Moisture (%)	2.31	0.19

Biogas production

The accumulative biogas production through the co-digestion of different feedstock is presented in Fig. 2. It indicates that mixed raw materials of PM and RL at 12% TS produced the highest volume of biogas (R2), whereas R3, R5, and R7, followed, respectively. For the biogas quality measuring by methane gas percentage, the result showed the highest figure of 58% CH_4 from R2, while for R3 is 50% CH_4 and R5 is 41% CH_4.

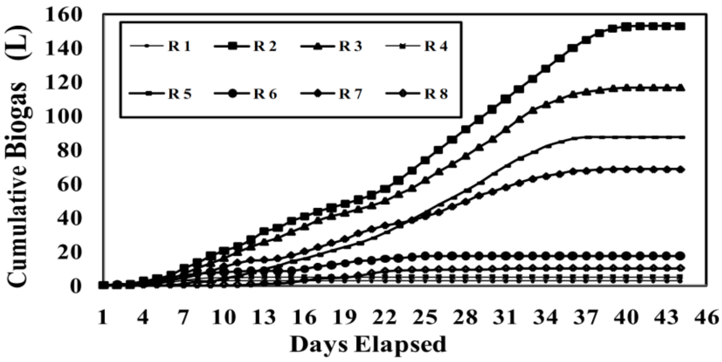

Fig. 2. *Cumulative curve of biogas production*

3.2 Effect of RL fraction on biogas production using co-digestion reactor

The single wastes and mixtures of wastes were studied with regard to methane production in batch assays for a period of 44 days. Fig. 3 shows the quantity of the total biogas production using RL fraction in feedstock at 0, 25, 50, and 75%, respectively, at 16%TS. It is clear shown that the maximum biogas occurs at 50% RL fraction, whereas at 75% RL produces minimum biogas. This demonstrated that a small amount of RL as co-substrate in the anaerobic digestion can highly increase the biogas production compared with PM alone. This could be due to positive synergism in the digestion medium, supplying missing nutrients and reducing/diluting of inhibitory materials in feed stocks by the co-substrates.

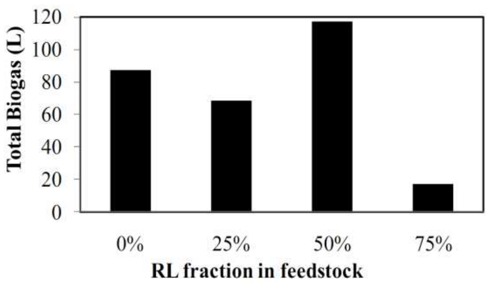

Fig. 3. *Effect of RL fraction on biogas production using co-digestion reactor*

3.3 Effect of percentages of TS in feedstock on biogas production using co-digestion reactor

In order to assess the TS in feedstock on biogas production, four sets of experiments are performed at 8% TS, 12% TS, 16% TS, and 20% TS, respectively, at the feedstock fraction of 50:50. Fig. 4 represents the quantity of the total biogas production against the percentages of TS in feedstock. It is obvious that the 12% TS gives the highest gas productivity. This could be attributed to organic overloading due to inefficient contact between the microorganisms and the substrate at the highest initial total solids concentration. These results agree with Radwan *et al.,* [3]. The biogas production at 8%TS was lowest, because the amount of initial seed low.

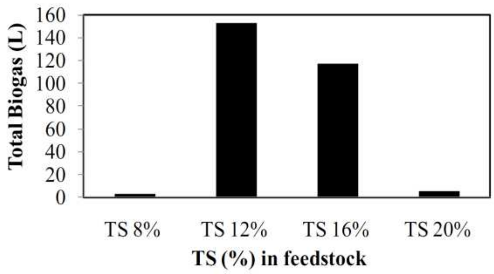

Fig. 4. *Effect of percentages of TS in feedstock on biogas production using co-digestion reactor*

3.4 Effect of size of RL in feedstock on biogas production using co-digestion reactor

In this study different sizes of RL in feedstock were used to determine the effect of feed size for biogas production. These experimental conditions were specified at 16% TS and at the feedstock fraction of 50:50. Table 3 shows the results obtained in this study clearly illustrate that the reduction of particle size increases substrate utilization, and hence gives enhanced biogas production. On the other hand, smaller particles would provide a large surface area available for the microorganisms, resulting in increased microbial activity; thus, the anaerobic biodegradability increased.

Table 3. *Effect of size of RL in feedstock on biogas production using co-digestion reactor*

Property	Shred	No Shred
Biogas Production (L)	117	29.76
Particle Size (mm^2)	2.81×2.81	50×40

3.5 TS removal

The total solids destruction for various co-digested of PM and RL leads to the reduction of organic matter that measured through TS removal. Fig. 6 presents the results of all experiments for 44 days of batch operation. It can then be seen that there is an increase in the TS removal with the decrease in the amount of RL fraction, especially with PM alone. The highest TS removal in the R5 because of microorganisms was degradation of organic matter digestible. It can be seen that TS removal depends mainly on the percentage of PM in the mixture of wastes, becoming higher with a higher amount of PM. These might influence the TS removal in all experimental.

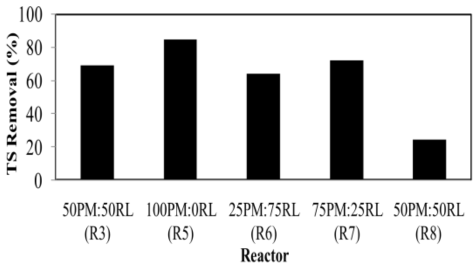

Fig. 6. *TS Removal for the different fraction tested at 16% TS*

Table 4 summarizes the results on biogas production of anaerobic digestion of PM and RL, the experiments lasted for 44 days. During the experimental period, methane content of the biogas was at about 41-58% and there were no significant differences among different reactors. Co-digestion of PM and RL can improve the methane production and the methane yield by 40% compared with digestion of PM waste alone. The marked increase in the methane yield could be due to positive synergism established in the digestion liquor and the supply of additional nutrients by the co-substrates. The waste PM fractions in the co-digestion with RL were on the total solid basis. After being digestion, all the waste became alkaline except pig manure alone. A mixture of rubber leaves that is not shred was slightly acidic. The results indicate that PM mixed with RL in the ratio of 50:50 at 12% TS (R3) gave the highest total biogas, percentage of methane, and yield of methane per kg of total solid.

Table 4. *Results of biogas production at 44-day batch anaerobic digestion*

No.	Total gas production (L)	CH_4 Content (%)	Total Methane (L)	CH_4 Yield (L/kg $TS_{removed}$)	pH	VFAs (mg/l)
R1	2.6	-	-	-	7.01	550
R2	153.1	58	88.8	0.38	7.22	500
R3	117	50	58.5	0.14	7.16	1500
R4	4.9	-	-	-	6.85	2000
R5	87.6	41	35.9	0.06	5.95	1250
R6	17.3	-	-	-	7.15	2250
R7	68.6	-	-	-	7.02	550
R8	10.1	-	-	-	5.5	1000

4. CONCLUSIONS

The present study demonstrate that anaerobic co-digestion of RL and PM is a feasible process as well as the effects of fraction ratio and TS in feedstock on the performance of the batch scale. Furthermore, anaerobic co-digestion of RL and PM is a viable alternative for recovering energy in the form of biogas with 41–58% methane content and increase total biogas production, compared with that of a control digestion using PM alone. The conclusions are the optimum total solid for biogas production is 12% TS. The optimum fraction of PM and RL for biogas production is 50:50. Results from this study suggest that PM and RL are potential substrates for anaerobic digestion for the production of biogas and could provide additional benefits to agriculturist in southern Thailand. Therefore, further research is planned to run a semi-continuous reactor to examine the effect of PM and RL feeding.

5. ACKNOWLEDGMENT

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