Evaluation of Agricultural Wastes for Biogas Production

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Abstract

The effects of the addition of agricultural wastes to anaerobic digestion systems were studied using food scraps as a model substrate and cow dung as an inocula. Anaerobic digestion experiments were performed using a floating drum type system and operated at ambient temperature. Agricultural wastes examined in this research were potato peel, baggasse, orange peel and soy pulp. The volumetric flow rate of biogas generated from co-digestion of food scraps with potato peel increased by 1,300 mL d^{-1}, while addition of soy pulp was shown to reduce the amount of gas produced by 700 mL d^{-1}. Characterization of the potato peel showed that it contained the largest amount of carbohydrate compared with other agricultural wastes. For all cases the percentage of methane remained constant at approximately 45%, which was shown to be enough for combustion. Furthermore, an increase in agricultural waste loading from 25 to 125 g d^{-1} resulted in an increase in the volumetric flow rate of biogas by almost 400 mL d^{-1}.

Keywords : Anaerobic digestion; biogas; agricultural wastes; cow dung and co-digestion.

1. Introduction

The production of biogas by anaerobic digestion of organic solid, such as grassland biomass [1] , municipal waste [2] , sewage sludge [3] and animal manure [4], have been studied intensively due to an increase in demand for renewable energy. Since organic wastes account for as high as 61% of the total waste collected in Thailand [5], they present a potential for massive production of bioenergy. The main benefit of this process is that the biogas produced from undesired wastes could be captured and employed either as transportation fuel or for generating clean electricity. Currently, more maize and elephant grass were specifically grown for the production of biogas for generating electricity. In Germany, the number of such power plant rose dramatically from 100 in 1990 to 4000 in 2011[6].

Organic wastes undergo four major biological reactions before they are changed into biogas. As shown in Fig.1, the first biological reaction, hydrolysis, is where carbohydrate, protein and fat in organic wastes are converted to smaller molecules such as monosaccharide, amino acid and long chain fatty acid. Next, in the acidogenesis step, monosaccharide and amino acid are transformed into volatile fatty acid, which is then turned into acetic acid, carbon dioxide and hydrogen by a group of acetogenic bacteria. In the final step, acetic acid is consumed by the methanogenic bacteria, and biogas is produced in this process [7].

Previous studies have reported that the production of biogas can be enhanced by adding agricultural materials to the organic substrate and the inoculums [8,9] . Co-digestion of kitchen wastes and pig manures

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with raw straws resulted in a 46 to 75% increase in the methane yield [8]. However, digestion activity was found to be reduced when the percentage of kitchen wastes in the feedstock exceeds 26%. Wendy Mussoline et al. simulated a farm-scale co-digestion of pig manure with rice straws using optimum parameters obtained from an experiment in a pilot-scale digestor ($1m^3$). The simulation demonstrated that a 100 ha of rice field can generate 100,000 m^3 CH_4 yr^{-1}, which can be used to produce 365 MWh of electricity [8]. Moreover, pre-treatment of rice straws was shown to reduce digestion time by roughly 50% [9]. Apart from power generation, the benefit of anaerobic digestion can be expressed in terms of Greenhouse gas emissions (GHG) reduction. GHG reduction of 114 and 523 $kgCO_2e$ t^{-1} was accomplished by co-digestion of food wastes, vegetable and fruit wastes and sewage waste water instead of sending them to landfills [10].

The main challenge that we faced now is associated with the current anaerobic digestion technology of cow dung. So far anaerobic digestion of pig manures is a proven technology that has been widely implement by pig farm owners, but cattle farm owners have not yet join the efforts because cow dung is less active in the production of biogas compared to pig manures. According to the Department of Livestock Development, the number of cattle in Thailand in 2010 was 8,595,428, which was comparable to the number of pigs which was 8,537,703 at the time [11]. Since cattle's excretion is estimated to be $1.1x10^9$tonnesper year, it is clear that more renewable energy can be available if cow dung can also be used to produce biogas. It would be interesting to investigate how the addition of agricultural wastes to cow dung and food scraps can increase the generation of biogas.

The goal of this research is to improve the biogas yield by co-digesting food scraps and cow dung with different kinds of agricultural wastes, such as potato peel, baggases, orange peel and soy pulp. A floating drum type system was connected to a 20L HDPE reactor to measure the volumetric float rate of biogas. The effect of agricultural waste and food scraps loading had been investigated. Biogas composition was found occasionally throughout the experiment.

2. Methodology

2.1 Preparation and characterization of agricultural wastes

Food scraps and agricultural wastes were obtained from restaurants and local market in PhathumThani province and were finely cut then stored as slurry in a plastic tank. The carbohydrate contents of each of the agricultural wastes were found to be 25g/100g for potato peel, 10-20g/100g for bagasse, 1.9-10 g/100g for orange peel and 14g/100g for soy pulp. The protein contents for soy pulp is approximately 30-50g/100g of soy pulp, which is the highest among all of the agricultural wastes. Pig manures and cow dung were obtained from a local farm near Klong 13 in Phathumthani province. To make an inoculum, pig manures and cow dung were mixed with water.

2.2 Anaerobic digestion

A simplified version of the floating drum set-up for anaerobic digestion is shown in Fig 2. The production of CH_4 was performed inside a 20L plastic tank connected to a floating drum and an empty 20L tank, that was employed to measure the volume of gas generated. During the experiment, gas samples were collected in a plastic bag and analyzed for the percentages of CH_4, CO_2 and O_2 using a portable Gas Data

GFM Series. Gas quantities were measured through water displacement. The experiment can be divided into four parts. The first part was conducted to compare the performance of pig manures and cow manures as aninocula in terms of biogas volumetric flow rate (measured in mL d^{-1})

and biogas composition. In the second part, agricultural wastes were added along with food scraps into cow dung that have been fermented in the plastic tank for at least ten days. Agricultural wastes that gave high volumetric flow rate of biogas were used in the third part of the experiment. This part investigates the effect of a continuous increase in agricultural waste loading from 25 to 125 g d^{-1}. The final part of this research confirmed the results of the third part by doing experiment with the agricultural wastes that gave the largest generation of biogas. Four series of experiment are shown in Table 1

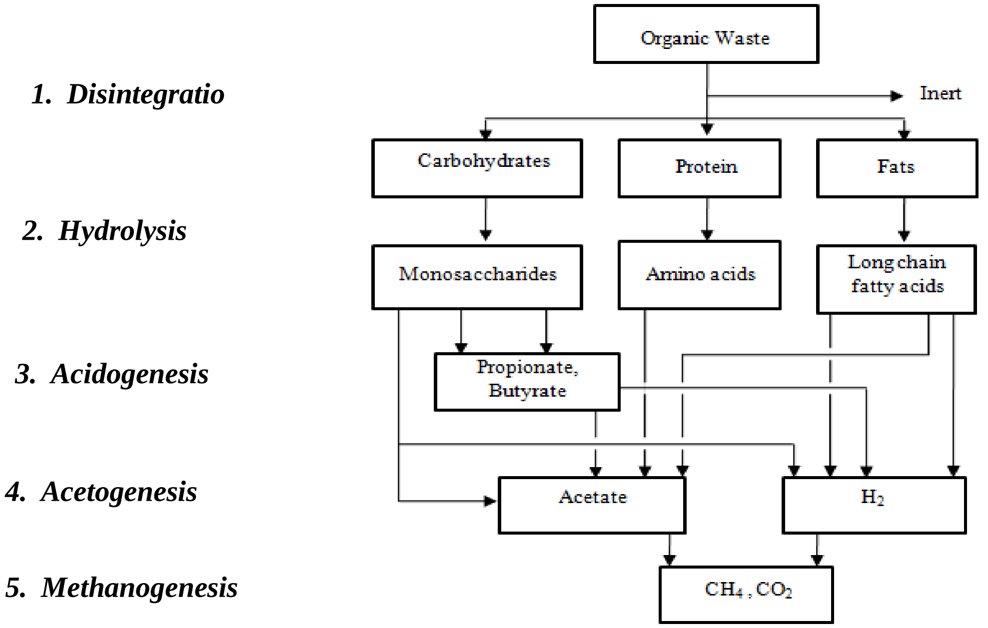


Fig.1. Flow diagram of the process for the production of biogas from organic wastes.

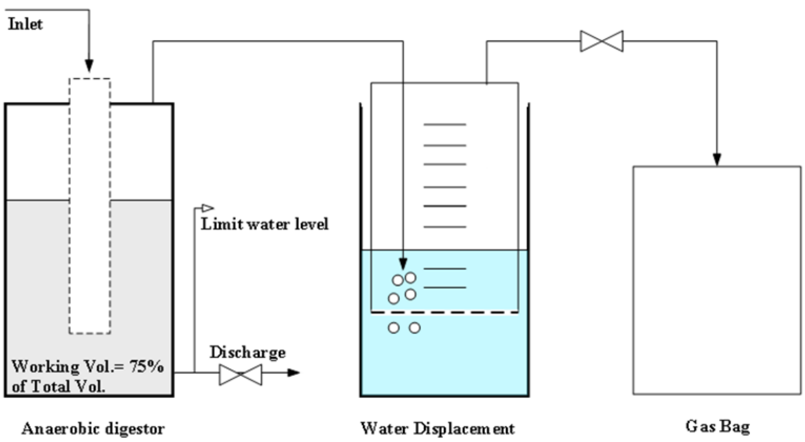


Fig.2. A simplified drawing of a floating drum type digestor system.

Table 1. Summary of all of the experiments for the anaerobic digestion.

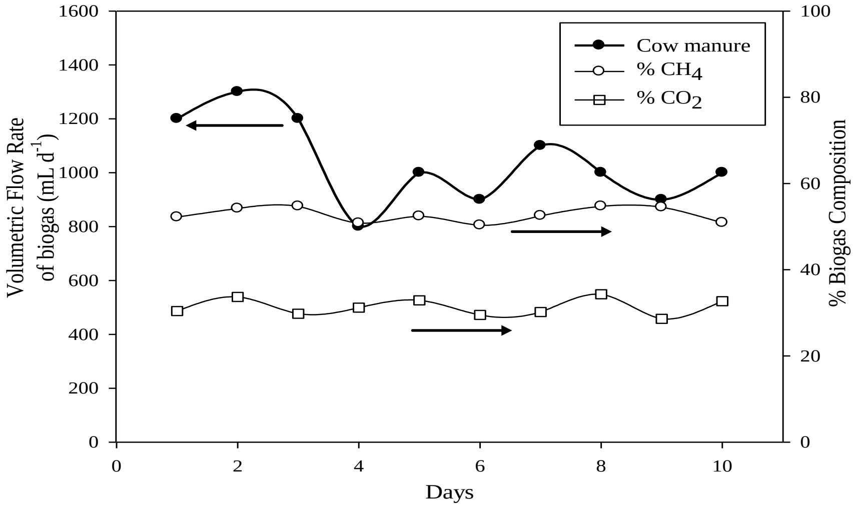
Experiment	Inocula	Manure:Water	Food scraps loading (g)	Agricultural wastes loading (g)
1	Pig manures Cow dung	3:2 3:2	- -	- -
2	Cow dung	3:2	300	100
3	Cow dung Cow dung	3:2 3:2	100 300	25-125 25-125
4	Cow dung	3:2	300	25-75

3. Results

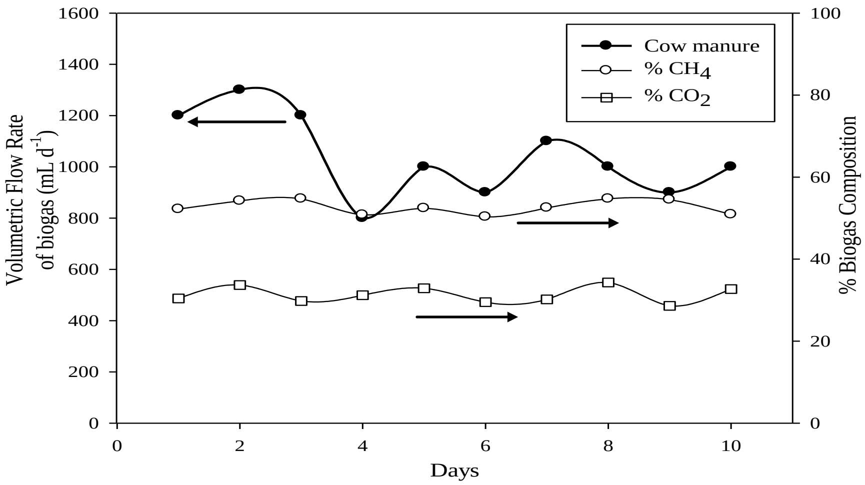
An inoculum consisting of pig manures was compared to that consisting of cow dung in Fig. 3. It can be clearly observed that much more biogas is produced from pig manure inoculum than from cow dung. The volumetric flow rate of biogas from pig manure inoculum varied from 30,000 mL d^{-1} to 32,000 mL d^{-1} after 11 days of digestion. However, it can be seen in Fig.1b that the volumetric flow rate of biogas from cow manure was only 800 to 1300 mL d^{-1}. Moreover, the composition of CH_4 in the biogas generated remained very stable at 65% for pig manure inoculum. The biogas composition of CH_4 from cow dung was only around 50%.

Comparison of different type of agricultural wastes on volumetric flow rate of biogas is shown in Fig 4. It can be observed that potato peel, bagasse and orange peel can help improve the generation of biogas. After three days of digestion, the blank experiment (only food waste and cow dung inocula are digested) gave a volumetric flow rate of biogas of 2,200 mL d^{-1}. When potato peel was added, the flow rate of biogas increased from 2,200 mL d^{-1} to as high as 3,200 mL d^{-1}, which is the highest compared to other agricultural wastes. This is because according to the analysis of the composition of agriculatural wastes, potato peel contained the largest percentage of carbohydrate. Results also revealed that the addition of soy pulp caused a reduction in the flow rate of biogas from 2,200 mL d^{-1} to as low as 1,400 mL d^{-1}. This is because soy pulp contains the highest percentage of protein compared to other agricultural wastes. The composition of methane in the biogas for each experiment varied from 41% to 48%. An increase in composition of carbon dioxide from 20% to 43% was observed as digestion time was longer.

The result from an increase in agricultural waste loading into 100 grams of food wastes and cow dung is shown in Fig.5. A step-wise increase in the agricultural loading can represent start-up phases that usually take place at the beginning of a full-scale anaerobic digestion operation. The flow rate of biogas was shown to increase when the agricultural waste loading increase by 25 g d^{-1} to 125 g d^{-1} . After ten days of digestion (125 g of agricultural wastes added), the flow rate of biogas from potato peel was approximately 2500 mL d^{-1}. When the amount of food wastes increase from 100g to 300g , the flow rate of biogas also increase as shown in Fig 6. The result from the previous part was confirmed by digestion at three different loadings of potato peel. As shown in Fig 7, an increase in loading caused the flow rate of biogas to increase by approximately 250 to 2000 mL d^{-1}. The percentage of methane found was roughly 50% throughout the experiment. While the percentage of CO_2 was approximately 30%. Compared to other findings [10,12], the volumetric flow rate of biogas reported in this research is clearly lower. This is because cow dung is used as an inocula instead of pig matures.



(a)



(b)

Fig.3. Comparison between biogas production from pig (a) and cow matures (b) during digestion.

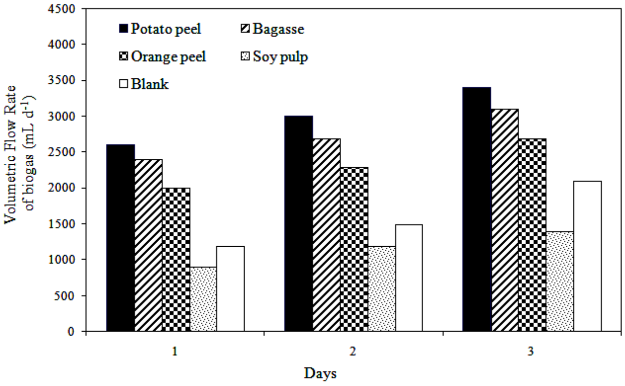


Fig.4. Volumetric flow rate of biogas from co-digestion of cow dung and food scraps with different kinds of agricultural wastes.

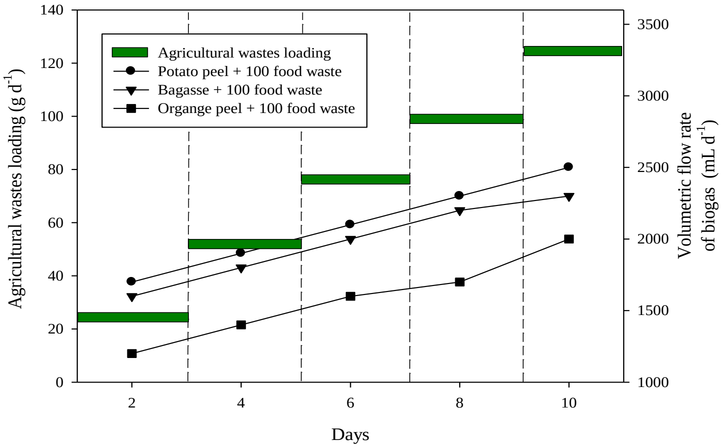


Fig.5. Effects on increasing the load of agricultural wastes on the flow rate of biogas (100g of food wastes).

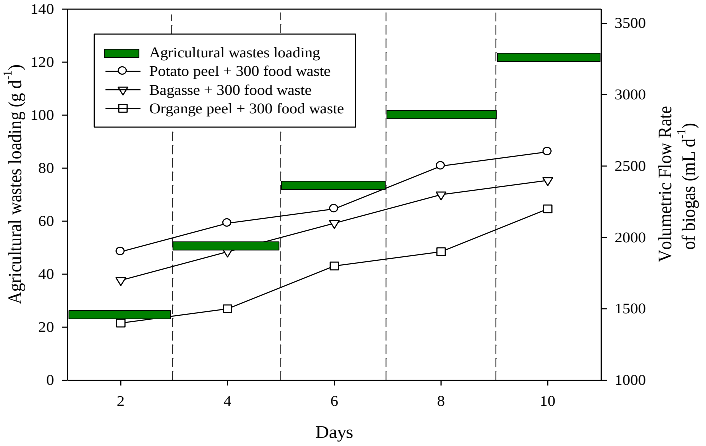


Fig.6. Effects on increasing the load of agricultural wastes on the flow rate of biogas (300g of food wastes).

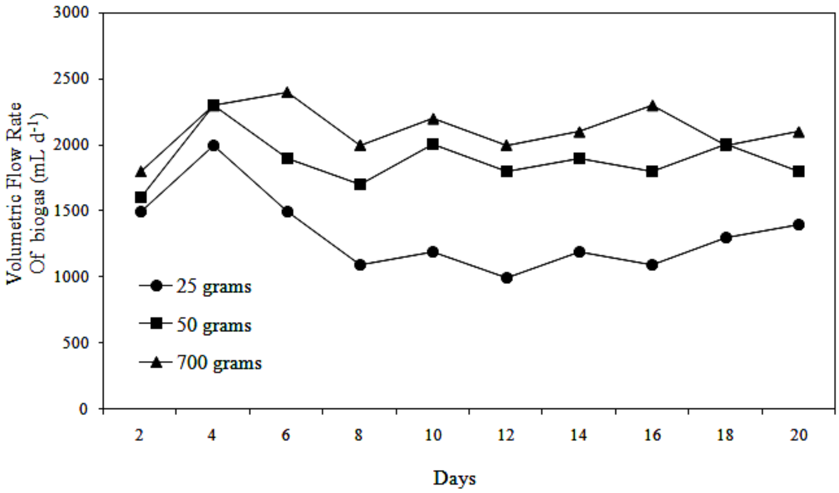


Fig.7. Digestion of cow dung and food scraps with three different loadings of potato peel.

4. Conclusion

The results obtained from this research suggested that co-digestion of food scraps with agricultural wastes can help improve biogas generation from cow dung. Out of the four agricultural wastes used (potato peel, bagasse, orange peel and soy pulp) potato peel was the most effective in increasing the generation of biogas. However, it was shown that soy pulp reduced the generation of biogas. An increase in the amount of food scraps and agricultural waste added result in an increase in the amount of biogas produce. Throughout the experiment, the composition of CH_4 in the biogas remained approximately at 40-50%. It has been proven that at this composition, the biogas is combustible.

5. Acknowledgments

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6. References

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