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The Potential of Biogas Production with Co-Digestion between Food Waste and Cow Dung

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Abstract

The objective of this research was to analyze the potential of biogas production with co-digestion between food waste and cow dung. The experiment research was batched with small scale and scale up with semi-continuous, temperature was operated within 35 - 37 °C. The suitable condition for biogas production between food waste and cow dung was presented with 75:25 (T1). 55 mL of the biogas potential was obtained which is considered as small scale. Thus, the scale up was presented in 75:25 (T1) ratio. In term of scale up the biogas obtained from the production is 650 ml which is higher than small scale. The scale up reactor of biogas production was 100 liters. Chemical oxygen demand (COD) was reduced from 30,000 to 5,000 - 7,000 mL L^{-1}. The efficiency of COD was obtained 76.67 - 83.3 %, respectively. In term of total solid, it was decreased from 19,000 to 16,500 mL L^{-1}. Initial VFA was presented 4,000 mL L^{-1}, and final was presented 3,800 mL L^{-1}, respectively. However, the biogas production from food waste and cow dung can enhance the performance of municipal solid waste and alternative energy production. Finally, the finding of co-digestion in biogas production system suggested utilization in household and communities.

Keywords: Biogas production, Food waste, Cow dung, Anaerobic digestion, Co-digestion

Introduction

Nowadays, the demand of fossil fuel is high in many countries around the world which has a direct impact on the amount of energy available at present time. In order to reduce negative impact, energy and environmental issues and taken into consideration as a top priority [1]. Alternative energy is one of the best choices for fuel and environmentally friendly such as wind, hydro, solar, biomass and biogas. Biogas is one of economically and environmentally friendly alternative energy resource. It has great advantages that low nutrient requirement, energy saving, and biogas production without pre-treatment [2]. The biogas is including different gases; CH_4 (50 - 60 %), CO_2 (20 - 30 %), H_2S (less than 5 %), and other gases, respectively. Biogas is production through anaerobic digestion with biochemical reaction (Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis). Hydrolysis is conversion of food waste (protein, carbohydrate, lipids) with hydrolyzing bacteria and convert to sugar, amino acid, and long chain fatty acids, respectively. The next stage is acidogenesis that converted the product from hydrolysis into volatile fatty acid (Propionic acid, butyric acid and ethanol). The third stage is acetogenesis that was converted propionic acid, butyric acid, and ethanol into acetic acid, hydrogen, and carbon dioxide. Finally, the methanogenic bacteria were biogas production in methanogenesis stage. There are several raw materials for biogas production such as Napier grass [3], cassava [4], wastewater [5], and food waste [6]. However, one of interesting raw materials for biogas production was food waste which has high amount of municipal solid waste. One of the factors that contributes to the increases of food waste was rapid economic growth that is expected to increase by 278 - 416 million tons [7]. It is a major problem that related to energy, water, land use, and greenhouse gas [8]. Food waste (FW) includes food material vegetables, fruits, bakery, and etc that major of municipal solid waste. The amount of municipal solid waste has been increasing rapidly, therefore the available landfill space was not adequate [9]. Therefore, food waste as a source for alternative energy corresponds to energy concept. In term of degradable of food waste, it includes major of carbohydrates ($C_6H_{12}O_6$), proteins ($C_{13}H_{25}O_7N_3S$), and lipids ($C_{12}H_{24}O_6$), respectively. Moreover, the parameters that effect potential of biogas production is controlled with types of waste, concentration, temperature, toxic materials, volatile fatty acid (VFA), pH, alkalinity, hydraulic retention time (HRT), solid retention time (SRT), F/M ratio, and total solid [10]. Co-digestion of organic matter offers the possibility to enhance technical for biogas production, and organic waste treatment. Moreover, the anaerobic digestion performance was improved [11]. The improvement objective of biogas gas yield is based on improved composition, since co-substrates are usually complementary to the major waste in the most cases [12]. This research focused on the analysis of the potential of biogas production with co-digestion between food waste and cow dung in small scale and scale up, respectively. The parameters that effect anaerobic digestion system were measured. Finally, this research can be suggesting the suitable condition for co-digestion between food waste and cow dung.

Materials and methods

Materials

In this research, preliminary analysis of the material properties (food waste and cow dung) were analyzed, consisting of moisture content, pH, carbon, nitrogen, and C/N ratio (**Table 1**).

Table 1 Characteristic of food waste and cow dung.

Parameter	Food waste(vegetable and fruit)	Cow dung
Moisture content (%w/w wet weight)	72.80 ± 0.30	42.50 ± 0.26
pH	4.09 ± 0.04	8.20 ± 0.02
Total carbon content (%)	19.17 ± 0.76	22.73 ± 0.40
Nitrogen content (%)	0.28 ± 0.04	1.07 ± 0.09
C/N ratio	70.13 ± 8.55	21.33 ± 1.49

Research Preparation

The initial research preparation was obtained from small scale in laboratory. The reactor was 1.25 liters and working volume was 1 L (**Figure 1**). Substrates in each rector were fixed ratio with 75: 25, 25:75, 50:50, and 100:0, respectively (**Table 2**). Then, the suitable ratio was fixed in scale up with semi-continuous operation and parameters monitoring until finish testing **(Figure 2**) [13]. The semi-continuous operation in this research was fed and released with the same time (every 3 days). Semi-continuous was suitable for microorganisms that was biogas production with steady state.

Table 2 Substrates in reactor with each ratio.

Substrates	Ratio			
	75:25 (T1)	25:75 (T2)	50:50 (T2)	100:0 (T4)
Vegetable and fruit (kg)	0.4	0.2	0.3	0.6
Cow dung (kg)	0.2	0.4	0.3	0
Water (mL)	1	1	1	1

Figure 1 Small scale biogas production in laboratory.

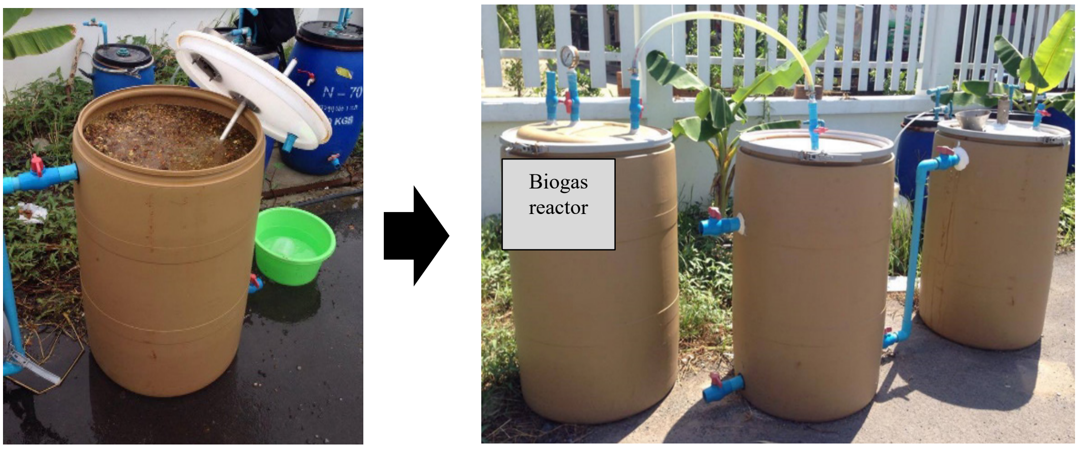

Figure 2 Scale up biogas production with suitable ratio.

The scale up reactor of biogas production was 100 L. Every 3 days was mixed 15 min, 1,200 rpm. This system can be led to steady state because food waste that already fermented was released from the biogas production system. Moreover, the biogas production system was not shock loaded from a sudden increase in organic composition.

Table 3 Analytical monitoring parameters for biogas production.

Parameters	Unit	Method	Frequency
pH		pH meter	Every week
Temperature	°C	Thermometer	Every week
Volatile fatty acid	mL/L	Titration	Every week
COD	mL/L	Close reflux method	Every week
Total solid	mL/L	Oven 103 - 105 °C	Every week
Biogas	mL	Multi-gas detector	Every week

Results and discussion

Biogas production

The biogas production from co-digestion between vegetable, fruit, and cow dung was presented in **Figure 3**. Hydraulic retention time was 50 days that was obtained T1 56.7 mL, T2 36.9 mL, T3 27.9 mL, and T4 9 mL, respectively. The suitable ratio for biogas production was T1 (75:25) that presented 56.7 mL. Generally, cow dung and pig manure were favor for biogas production. Thus, methanogenic bacteria (Methane forming Archaea) in this research was obtained from cow dung. The cow dung was including genus Methanobrevibacter that methanogenic bacteria [14]. In term of inhibitory compound for biogas production is high amount of metal element, and heavy metal. Moreover, these compounds can be micronutrients for microorganisms in the biogas production system when low amount.

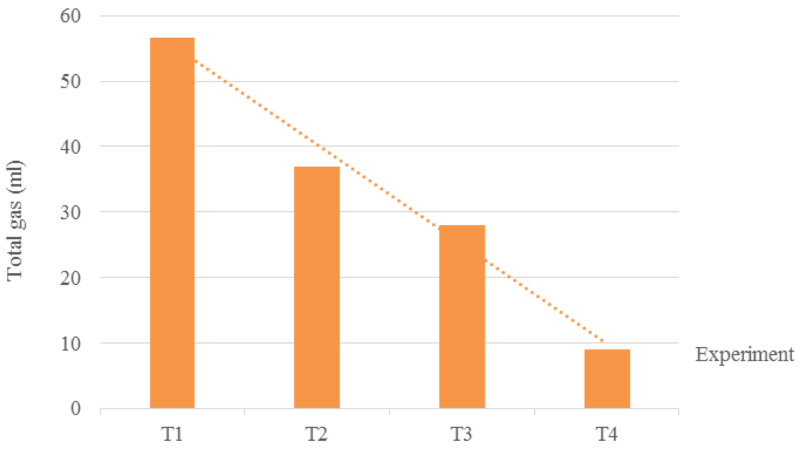

Figure 3 Biogas production from co-digestion between vegetable, fruit, and cow dung with small scale.

The food waste substrate was obtained from municipal solid waste that contaminated with metal element (sodium, potassium, and calcium) and heavy metal (copper, zinc) from several types of municipal solid waste such as batteries, light bulb, and some solution. Thus, food waste also contained high amount of metal element and heavy metal, respectively. Therefore, biogas production from food waste in small scale produced low amount of biogas [6]. However, the suitable condition (ratio) was selected for scale up and high production than small scale. In term of scale up (from small T1) was obtained higher than small scale (**Figure 4**) that monitored every week. The highest biogas production was presented in 2 weeks that 650 mL then it decreased to 500 mL in 3 weeks, respectively.

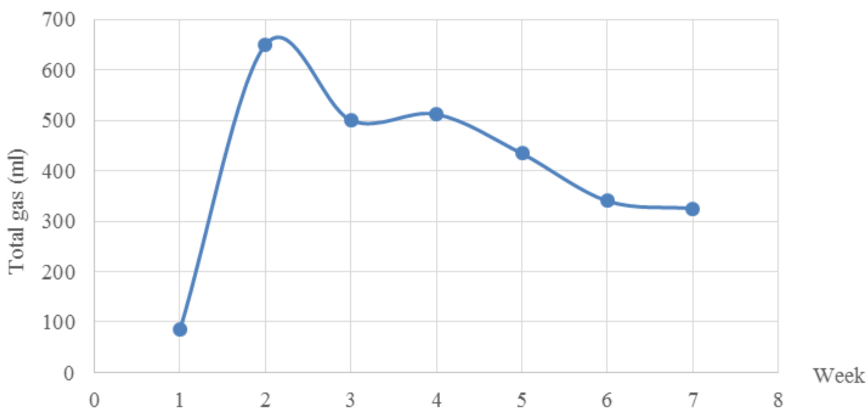

Figure 4 Biogas production from co-digestion between vegetable, fruit, and cow dung with scale up.

Although, scale up of biogas production was presented the biogas production higher than small scale, it was lower than biogas production from other substrate such as Napier grass, and wastewater. The reasonable of low biogas production was occurred with inhibition of metal and heavy meatal. Therefore, this system should be upgrade for high production rate and then the system can be useful for waste minimizing and alternative energy production, respectively.

Chemical Oxygen Demand (COD) and Total Solid (TS)

The degradation of organic matter in the system was measured in term of chemical oxygen demand (COD). The chemical oxygen demand was presented in **Figure 5**. The initial COD concentration was 30,000 mL L^{-1} until 2 weeks that degradable organic matter and decrease COD to 5,000 mL L^{-1}. COD was related to biogas production due to organic matter decrease that was presented high amount of biogas production. Therefore, organic matter (COD) was degradable with microorganisms in biogas production system. Moreover, the 1 important to consider the organic matter was total solid due to food waste was solid waste, thus total solid was measured. **Figure 6** was presented the amount of total solid in the biogas production system.

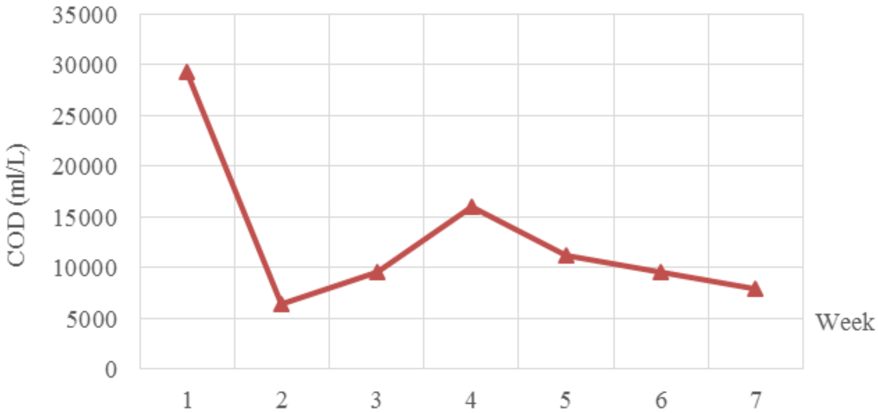

Figure 5 Initial and final of chemical oxygen demand in biogas production system.

Total solid was presented the organic matter in the system. These results were obtained in last week the total solid was degraded with microorganisms in biogas production system. The second week obtained higher that initial total solid due to growth curve of microorganisms was in exponential phase (log phase). The exponential phase is high microorganisms was obtained; thus the total solid increased.

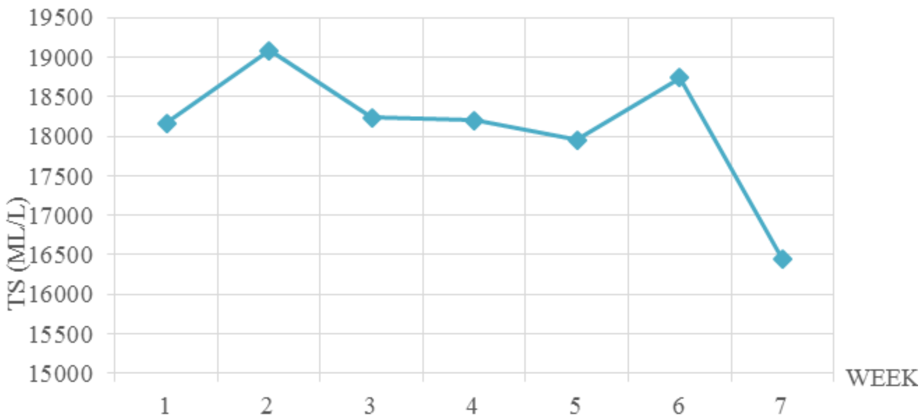

Figure 6 Total solid in biogas production system.

Volatile Fatty Acids (VFA)

Volatile fatty acid (acetic acid, butyric acid, or lactic acid) was effect on biogas production system. The volatile fatty acid was produced with microorganisms in stage of acidogenesis and acetogenesis, respectively. However, VFA can be enhance the biogas production when VFA and methane production were balanced [15]. The results were presented initial VFA was presented 4,000 mL L^{-1}, and final was presented 3,800 mL L^{-1}, respectively (**Figure 7**). These results were related to biogas production due to VFA is substrate of methanogen. The last week of biogas production was presented VFA 3,800 mLL^{-1}.

The methanogenic bacteria in biogas production system was less using VFA. Moreover, the excessive volatile fatty acid that has effect to inhibiting of methane production [16]. Therefore, the potential of biogas production was low. However, the improvement method such as the use of glucose can apply in anaerobic digestion system to enhance the microbial metabolisms for biogas production, due to glucose is monosaccharide that is compatible with microorganisms in anaerobic digestion system.

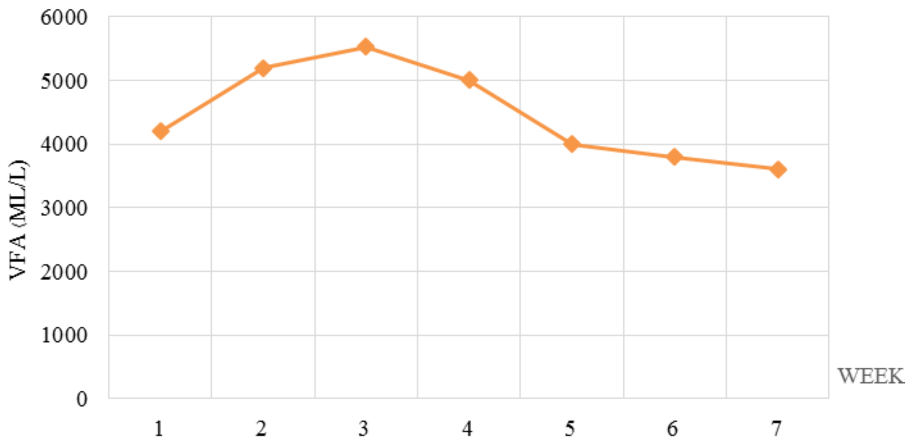

Figure 7 Volatile fatty acid in biogas production system.

In term of pH, the level of pH is around 5 - 6 which was low of pH due to the accumulation of volatile fatty acid. The optimum pH for biogas production was 6.5 - 7.5. The methanogenic bacteria are sensitive with low pH. Therefore, the biogas production system has maintained pH to obtained high biogas production

Conclusions

This research was analyzed the potential of biogas production with co-digestion between food waste and cow dung. Food waste is the major waste in household, and it has high potential for energy production. The biogas production was presented in this research however the potential has been improved with other method such as glucose can be used in anaerobic digestion system for enhance the production due to glucose is monosaccharide that easily to use with microorganisms in anaerobic digestion system. The finding of co-digestion in biogas production system that suggested utilization in household and communities. Finally, this research was considered to be suitable in urban area for food waste management and alternative energy production.

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