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Biogas Production from Wastes of Tofu Industry with Effects of Water Hyacinth and Cow Manure Additions

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Abstract. Biogas is one of the potential sources of energy to cope with the limitations of fossil energy. On the other hand, liquid waste of tofu industry, water hyacinth, and cow manure are poorly managed that can potentially pollute the environment. The type of those wastes was potential source for biogas production through anaerobic digestion due to high content of protein and nutrient. This study aims to determine the effect of addition of liquid waste of tofu industry (WT) and water hyacinth (WH) to cow manure (CM) on the biogas production. The amount of water hyacinth and cow manure were varied at 0-4 kg, while the liquid waste of tofu industry was fixed to 8 kg. The anaerobic digestion was conducted in biodigester container equipped with thermometer and biogas shelter. The biogas production was then analyzed using Gas chromatography–mass spectrometry (GC-MS). The optimum biogas was achieved at raw material ratio of 4:2:2 (WT:WH:CM) for 21 d. At this condition, 60 ppm of CH_4 and 10,744 ppm of CO_2 were obtained. Thus, the utilization of liquid waste of tofu industry, water hyacinth and cow manure as raw material of biogas production can minimize the environment problem and supply energy.

Keywords: biogas; tofu; water hyacinth; cow manure; anaerobic digestion

1. Introduction

The increased energy demand is triggered by the increased transportation uses, industrial development, and human growth. The existence of unrenewable energy sources such as natural gas, coal and petroleum will ultimately run out. Renewable energy utilization is an alternative that can be used to replace the use of fuel oil or natural gas as fossil fuels, such as biogas [1]. Biogas is a process produced from organic waste that can be decomposed by certain microorganism in anaerobic environment [2]. So far, many researchers still utilize various resource of organic wastes and also combine them to acquire the optimum results [3-5]. However, these renewable energy sources should be further explored.

Most tofu factories still use simple technology which causes relatively high waste production. Tofu production is a process involving soybean milling, boiling, filtration, protein coagulation, preservation, and packaging [6]. During the process, up to 30 % of soybeans become waste. However, only a small portion of waste is used as feed nutrition, while most of it is burned and or reclaimed as industrial waste, which contributes to serious pollution problems [7].

The abundance of liquid waste in the production process if it is disposed of directly can pollute the environment, especially to the quantity and quality of water [8, 9]. The liquid waste is a pollutant waste, with COD values ranging from 4000-6000 mg/L and BOD content ranging from 3000-4000 mg/L. Tofu industry wastewater is biodegradable or easily biologically degraded [10, 11].

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Tofu liquid waste contains high levels of organic compounds and nutrients consisting of the content of N, P, K and Mg, protein, fat, crude fiber and ash which have the potential to produce biogas through anaerobic digestion process [12]. In general, biogas contains methane, CO_2, H_2S and a little water, which can be used as a substitute for kerosene or liquid petroleum gas. By converting tofu wastewater into biogas, tofu factory owners not only contribute to protecting the environment but also increase their income by reducing fuel consumption in the tofu-making process [7, 13].
Cow manure is known as waste that can produce biogas due to the high content of cellulose and hemicellulose [14]. On the other hand, water hyacinth also contains about 40-60 % cellulose and hemicellulose and small content of lignin [15]. The contents lead to a potential value for biogas production [16], because the little amount of lignin makes an easier process to break down structural linkages at the initial conditions [17].
Conventional energy that is scarce and the high production of tofu liquid waste that always pollutes the environment, encourages the creation of researches related to alternative energy that is environmentally friendly as a solution to these problems. This study utilizes tofu liquid waste combined with water hyacinth as a substrate which is expected to increase the heating value of biogas. In addition, it also utilizes the addition of bio-starter cow dung which is useful to accelerate the process of biogas production from tofu industrial wastewater.

2. Materials and methods

2.1. Raw material preparation
Water hyacinth was taken from the Sipai river in Martapura, South Kalimantan. It was then cut to a size of 2 cm and then dried for ± 6 h in sunny weather. Liquid waste from tofu factory was taken from industry of Tahu Sekumpul. Raw materials for tofu wastewater about 8 l were placed in biodigester and then 4 kg dry water hyacinth was added. The mixture was then added with a starter of 2 kg cow manure. The substrate composition for anaerobic fermentation was shown in Table 1.

Table 1. The composition of fermentation substrates.

Digester (Tofu waste: hyacinth: cow manure)	Waste of tofu (kg)	Hyacinth (kg)	Cow manure (kg)
4:2:1	8	4	2
4:0:1	8	0	2
4:1:1	8	2	2
4:2:0.5	8	4	1
4:2:2	8	4	4

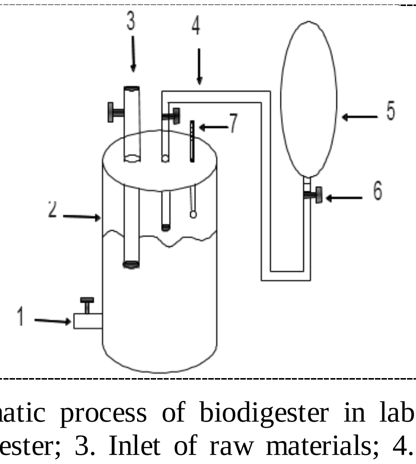

Figure 1. Schematic process of biodigester in laboratory scale: 1. Outlet; 2. Biodigester; 3. Inlet of raw materials; 4. Biogas hose; 5. Biogas shelter; 6. Control valve; and 7. Thermometer.

2.2. Anaerobic process
The mixture was reacted with the anaerobic digestion method for 28 d, measured by pH and temperature every day during the process. During the 28-day process, the biogas content, the amount of heat and the liquid compost were analyzed in accordance with a predetermined time range. Biogas produced by each digester was taken by injection of 10 mL per sample to analyze CH_4 and CO_2 content every 7, 14, 21, and 28 d using GC-MS. As for the analysis of liquid compost fertilizer, each sample was taken with a measuring cup of 50 ml per sample to analyze the amount of N, P, K content using the Kdejahl method. The schematic process of anaerobic process in biodigester was shown in Figure 1.

3. Results and discussion

3.1. Kinetic profile of methane and carbon dioxide productions
Figure 2 shows the production of methane and carbon dioxide in the process of breaking down raw materials for tofu waste, water hyacinth, and cow dung. The formation of methane and carbon dioxide on the seventh day was caused by the degradation of organic matter in the biodigester as the hydrolysis process. Hydrolysis is the decomposition of complex compounds or long chain compounds into simple compounds. At this stage, organic materials such as proteins, lipids, and fats are degraded into short-chain compounds, such as peptides, amino acids, and simple sugars. O'Reilly et al. [18] revealed that species such as Methanosaeta were predominantly present in raw materials from low-strength psychophilic synthetic waste bioreactors to treat. Cellulose hydrolysis bacteria group was found to be dominant in biogas reactors using raw materials with rich in lignocellulose such as pig manure and stalk [19, 20]. The significant production of methane was found at 28 d after pass through the lag phase as commonly occured in the fermentation process [21].

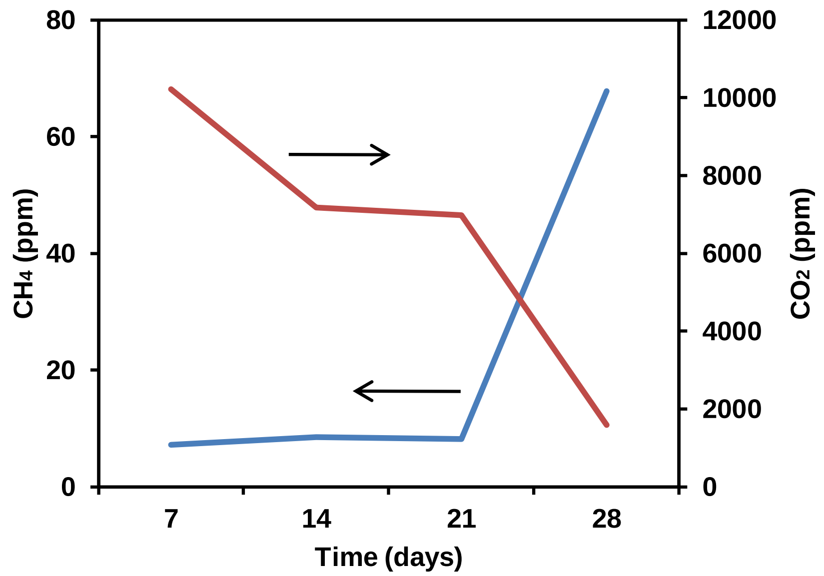

Figure 2. Profile of methane and carbon dioxide productions from waste materials of tofu waste (8 kg), hyacinth (4 kg) and cow manure (2 kg). Blue and red lines represent CH_4 and CO_2 contents, respectively.

3.2. Effect of hyacinth on biogas production
Figure 3 shows the production of methane and carbon dioxide at variation of water hyacinth with the content of tofu waste and cow manure of 8 kg and 2 kg, respectively. The greater the amount of water hyacinth led to the smaller the amount of methane and the greater carbon dioxide. The difference in results is obtained in research without waste tofu [22], where there is an increase in biogas production by increasing the amount of water hyacinth in a certain amount; however, carbon dioxide production

also increases. Decrease in methane levels and increase in carbon dioxide levels in this study due to substrate conditions. Large substrate size can inhibit the growth of microorganisms in the anaerobic fermentation process because microorganisms must degrade the particle size of the substrate first so that it takes longer for the microorganism to produce methane. The structure of the lignocellulose complex results in anaerobic degradation process running very slowly, especially in the hydrolysis process. On the other hand, the presence of tightly bound recalcitrant lignin, crystalline cellulose and hemicellulose polymers, can delay production and reduce biogas production during anaerobic digestion [23, 24].

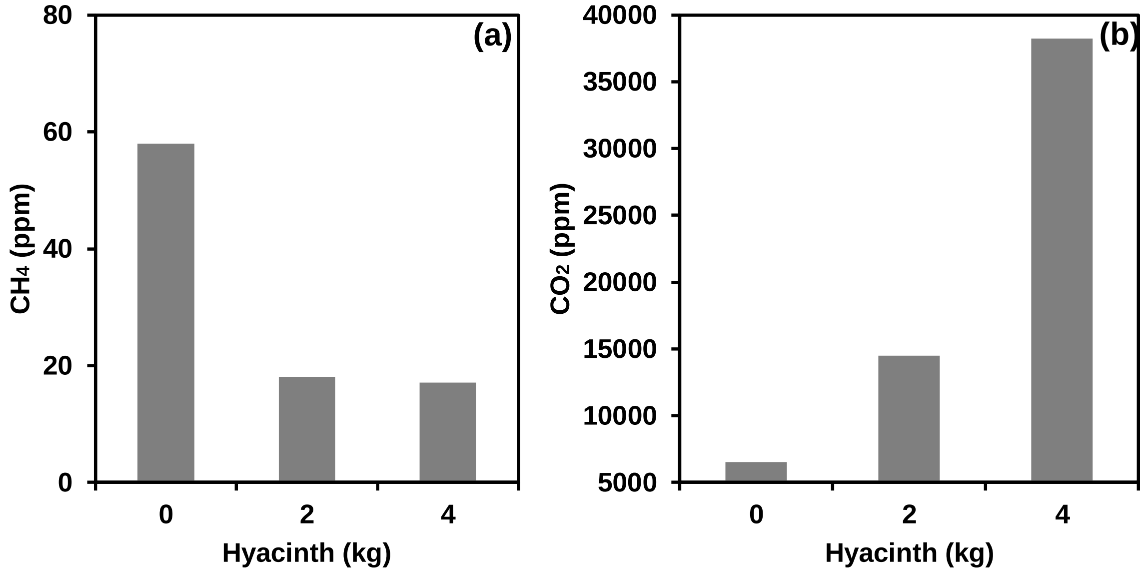

Figure 3. Effect of hyacinth on methane and carbon dioxide productions analyzed at experimental time of 21 d

3.3. Effect of cow manure on biogas production

Figure 4 presents the production of methane and carbon dioxide at variation of cow manure with the content of tofu waste and water hyacinth of 8 kg and 4 kg, respectively. The greater amount of cow dung produced greater methane [25, 26]. Cow manure is a habitat for various microorganisms that serve to accelerate the degradation of components in the digester. At this stage, there is degradation of organic matter in the biodigester, namely the hydrolysis process, where complex organic polymers will be converted into short organic components [27]. However, the amount of carbon dioxide experienced a significant decrease in the addition of 4 kg of cow dung; this probably due to a slight increase in alkalinity thus limiting the hydrolysis process from organic matter to produce carbon dioxide [26]. The methane content was undetected for the substrates without cow manure indicating the role of cow manure in the fermentation.

3.4. Content in liquid products and calorific value

Table 2 shows the content of N, P and K from liquid products from the results of the biodigester and the calorific value of biogas. The nutritional content of the liquid product shows the potential material to be used as fertilizer for plants. Percentage of N content was higher when the water hyacinth was added, while P and K levels decreased. This was likely due to the amount of N content in water hyacinth in the degradation process [28]. However, the difficulty of degradation in the material with the addition of water hyacinth because of the recalcitrant lignin presence of tightly bound, crystalline cellulose and hemicellulose polymers, resulted in low heating values produced [23].

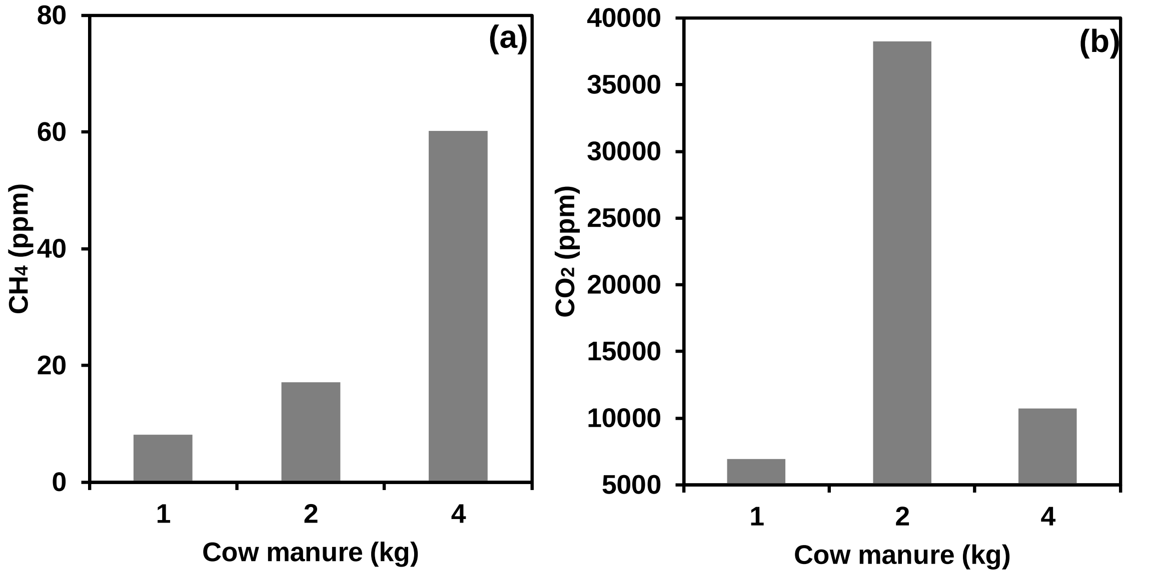

Figure 4. Effect of cow manure on methane and carbon dioxide productions analyzed at experimental time of 21 d

Table 2. Content of N, P, and K in liquid products and calorific value.

Hyacinth Content, kg	N, %	P, %	K, %	Calorific value, J/cm3
0	3.50	0.33	1.30	0.39
4	6.03	0.12	0.88	0.15

4. Conclusion

Tofu waste led to the potential material to be processed for biogas production. The optimum biogas was achieved at raw material ratio of waste of tofu to water hyacinth to cow manure (4:2:2) for 21 d. At this condition, 60 ppm of CH_4 and 10,744 ppm of CO_2 were obtained. Thus, the utilization of liquid waste of tofu industry, water hyacinth and cow manure as raw material of biogas production can minimize the environment problem and supply energy.

5. Acknowledgments

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