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ORGANIC CYCLE SYSTEM: THE RECYCLING OF BIOGAS SLUDGE OF COW MANURE AS BIOCHAR FOR BIOGAS PURIFICATION

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ABSTRACT: The increase in intensive using of production elements has been reflected on the increasing of organic waste. Without appropriate treatment, waste leads to the contamination of environment. The conversion of organic waste into material with economic value will contribute to increasing productivity, for example in biogas system. Today, the utilization of waste, biogas sludge, as bio-fertilizer has been developed. However, the utilization of biogas sludge from cow manure as biochar is still rare. The aims of this study were to investigate the recycling of biogas sludge from cow manure as biochar in biogas purification. Biochar made of biogas sludge from cow manure as adsorbent in biogas purification leads to the cycle loop of biogas system. We also investigated the effect of mass variation of biochar made of biogas sludge from cow manure on biogas purification performance. The variation of zeolite and biochar made of biogas sludge with mass ratio of 0:80; 20:60; 40:40; 60:20; and 80:0 had been put inthe adsorption column of biogas purification. The results showed that the increase in biochar mass affected on methane enrichment of biogas. The highest methane enrichment was performed by biochar with ratio 40:40. The utilization of biochar mass above 50% of the total mass per each column decreased methane enrichment. From this study, we concluded that biogas sludge has potential to be used as adsorbent in biogas purification. Biochar from biogas sludge leads to organic cycle system in biogas system that provides option in sustainable energy and additional benefits for farmers.

Keywords: Organic cycle system, Biogas, Biochar, Biogas sludge

1. INTRODUCTION

Livestock contribution to environmental problems is on a massive scale. Along with economic growth, food demand including meat and milk will increase day by day. The global production of meat is projected to be more than 460 million tonnes in 2050 [1]. In Indonesia, there are the increase in consumption of meat 12.5%, egg 6.64%, chicken 11.22% at 2018 compared to 2016. The data showed that this condition has correlation with livestock population in Indonesia [2]. The impact on environment may be direct, through grazing and organic waste, or indirect, such as the expansion of land for feeding. The organic waste from livestock comes from their manure. Livestock manure is primarily composed of organic material and water, and it is accumulated annually without treatment. If the waste get into the water or accumulate, it can contaminate freshwater and soil. Moreover, in aerobic condition, the organic material is decomposed, producing methane and carbon dioxide gases. Indonesia ranks 6thas contributor in GHGs emission specially in agricultural sector[3]. This emissions were dominated by enteric fermentation of livestock, land use change, the use of fertilizer and livestock manure.

The population of livestock in Indonesia increases annually and unfortunately is not accompanied by a good waste management. Most of the livestock farmer groups in Indonesia still maintain conventional management without waste treatment. The organic cycle system is expected to be an alternative solution in livestock waste management. The cycle of organic material is managed through 9R (reuse, reduce, recycle, refill, replace, repair, replant, rebuild, and reward) [4]. It means livestock manure can be recycled into renewable resources to high value product like biogas. Biogas technology allows us to use methane generated in anaerobic condition for cooking or lighting. The organic cycle system can provide sustainable economic, social, and environmental aspects out of organic waste. Moreover, if organic cycle system is developed with circular economy system model, it will give a good local economic. The development of circular economy does not only utilize organic waste but also practice a profitable business from organic waste [5]. The circular economy in livestock sector means maximizing natural resource yields by circulating the production [6] for example by turning livestock waste into energy. Today, the development of circular economy model in livestock sector does not only change waste into energy but also waste into material [7].

Fig. 1 The highest 20 countries in green gas emissions in agriculture [8]

In biogas production, the waste will produce solid by-product like biogas sludge. Many reported the use of biogas sludge for fertilizing [9]-[10]. The studies about the use of biogas sludge as biochar are still rare although biochar has the economic added value. Biochar is a solid material obtained from thermochemical conversion of biomass in limitless oxygen condition [11]. Biochar is commonly used as soil enrichment. Commonly, pyrolysis is used in thermal conversion of biomass to biochar. Pyrolysis at 200-900ºC and under oxygen free biomass will be degraded thermally and become char. There are two types of pyrolysis, slow and fast pyrolysis (Fig.2) but slow pyrolysis is prefer than fast pyrolysis because giving high yield in biochar production.

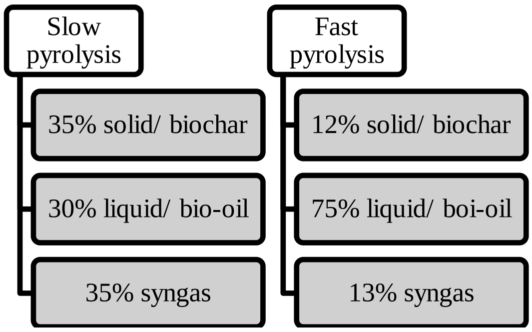

Fig. 2 Product from thermal conversion of biomass by slow and fast pyrolysis [11]

In general biochar has many pores at its surface. Many pores are capable to adsorb karbon dioxide molecules from biogas mixture. Pyrolysis of biomass will make chemical contents in biomass likes aromatic carbons will form aromatic polymers that faciliate pores formation (Fig. 3) [12].

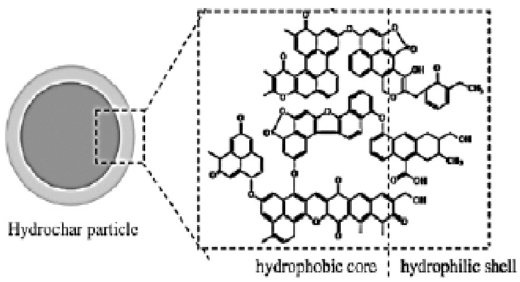

Fig. 3 Chemical structure of biochar [13]

Biochar from livestock waste and sludge have been produced. Moreover, utilization of biochar from livestock manure or sludge have been investigated the capability in carbon dioxide adsorption but in application in biogas is rare. The utilization of biochar from livestock waste or sludge gives chance of development alternative adsorbent. In this study, we tried to investigate biogas sludge utilization as biochar for biogas purification.

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2. METHODOLOGY

2.1 Materials

Biogas sludge from cow manure is used for raw material in biochar production. Before the biochar production process beginned, biogas sludge was dried under the sunlight for 24 hours. Then dried biogas sludge was pyrolyzed at 225ºC for four hours in pyrolysis reactor. The pyrolysis of biogas sludge generated biochar that can be used for biogas purification.

2.2Biogas Purification

Biogas purification is a method to clean biogas content from impurities such as carbon dioxide, hydrogen sulfide, volatile organic compound, et cetera [14]. In this study, we investigated the utilization of biogas sludge-basedbiochar to capture carbon dioxide in biogas. Carbon dioxide capturing on the surface of biochar was expected to increase methane composition and calorific value.

The increasing number of biogas plants will also increase adsorbent demand. To fulfill the demand, biochar production from biogas sludge will be an alternative solution.

Biogas purification was carried out by the adsorption method with two integrated adsorption columns. The length and diameter of the column was 200 mm and 40 mm respectively (Fig. 4). The design of the column was adopted from Lalhmingsanga [15] with modification.

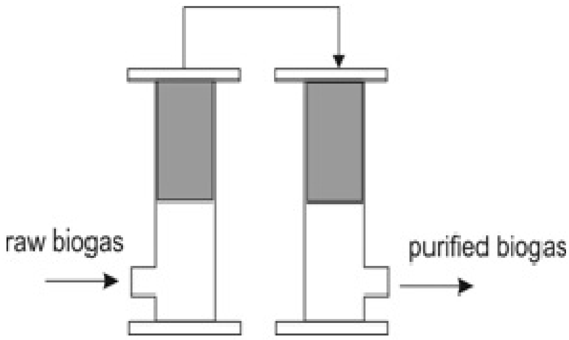

Fig. 4 Design of adsorption column [10]

(E). $\frac{dc}{dt}$ refers to difference concentration of methane or carbon dioxide per unit time (ppm). $Vch$is volume of chamber (m^3) while Ach is area of top chamber (m^2). $mW$is the molecular weight of gas, mV is the volume of gas molecule (22.4 liters), and T is average temperature in gas sampling (ºC). We conducted T-test to analyzed methane and carbon dioxide emission in ppm.

Each column contained 80 grams of adsorption. The composition formulation of adsorbents is shown in Table 1. The adsorption process was carried out at gas pressure ranged between 5-7 bar for 10 minutes. The methane compositions in biogas were analyzed by gas chromatography (GC).

Table 1 Formulation of adsorbents in biogas purification

Samples	zeolite (grams)	biochar (grams)
AS 1	80	0
AS 2	60	20
AS 3	40	40
AS 4	20	60
AS 5	0	80

3. RESULTS AND DISCUSSION

3.1 Biogas Purification

Biogas purification aims to minimize impurities in biogas such as carbon dioxide and increase its methane composition. Before and after the adsorption, the composition of biogas was analyzed using gas chromatography (GC). In this study, the capability of biochar to capture carbon dioxide (CO_2) was shown by the increase in methane (CH_4) composition. The biogas compositions before and after the adsorption are presented in Table 2.

Table 2 Methane compositions in biogas before and after adsorption

Samples	CH_4 before adsorption (ppm)	CH_4 after adsorption (ppm)	The increase in CH_4 (%)
AS 1	139448.78	140112.10	0.48
AS 2	138768.05	148754.20	7.20
AS 3	103153.36	126439.67	22.57
AS 4	113874.55	120584.95	5.89
AS 5	148599.30	143036.02	-3.74

Table 2 shows that after the adsorption using biogas sludge-based biochar, the methane in biogas increased. It means the biochar was capable to capture carbon dioxide. The performance of livestock waste-based biochar in capturing carbon dioxide is also reported by Minh-Viet and Byeong [16]. The combination of zeolite and biochar that could increase methane were AS 1, AS 2, AS 3, and AS 4. Carbon dioxide adsorption capacity at different mass of biochar resulted in different methane enrichment. The increase in methane performed by AS 1 was the lowest increase (0.48%). The higher increase in methane was performed by AS 2 (7.20%). By adding biochar composition in the combination of adsorbent, methane content increased. The highest methane enrichment was performed by AS 3 with the composition of 40 grams of zeolite and 40 grams of biochar.

Biochar is a solid material formed by thermochemical decomposition of biomass.The main element of biochar is carbon (C). Because of the carbonization process, biochar has a porous structure that can be used to capture carbon dioxide [18]. The surface pores of biochar havea key role in capturing carbon dioxide so the increase of biochar mass will increase the surface pores of biochar [19]. The results showed that carbon dioxide adsorption is the function of pore surface area. In addition, minerals content in biochar likes K, Na, Ca, and Mg have a role to facilitate carbon dioxide adsorption because of the increase in adsorbent affinity to carbon dioxide molecules [20]. However, the increase in methane was lower compared to AS 3 when biochar was added to be 60 grams. Even the use of 80 grams of biochar actually decreased the methane composition of biogas from 148599.30 ppm to 143036.02 ppm. In other words, there was a decrease of -3.74% in methane concentration. It means biochar is not only to adsorp carbon dioxide but also methane molecules although capability of carbon dioxide adsorption is bigger than methane [21-22].

Previous study reported that biochar captures carbon dioxide more than methane [20]. It means biochar can adsorb methane, but not as much as adsorbing carbon dioxide. In fact, the use of 80 grams of biochar under these conditions caused the reduction of methane. It was possible that carbon dioxide had been maximally adsorbed and in these conditions, methane was also adsorbed.

The optimum combination of adsorbent in this study was performed by AS 3 with the formulation of 40 grams zeolite and 40 grams of biochar (see Fig. 5.

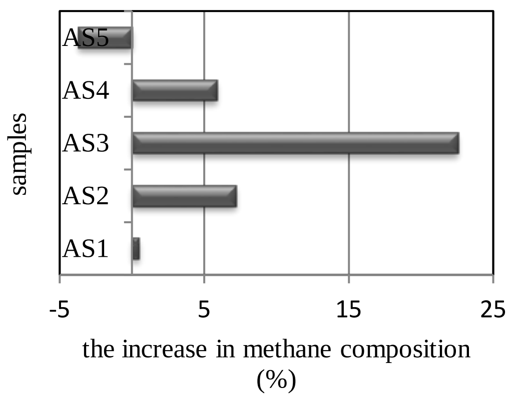

Fig. 5 The increase in methane composition after adsorption using AS 1, As 2, AS 3, AS 4 and AS 5

3.2 Recommendation of Organic Cycle System in Biogas Technology

Based on this study, biochar from biogas sludge has the potential to be developed to advance carbon dioxide capturing in biogas purification. The same result also reported by Margaretha [23]Although this investigation is an initial study but the use of biogas sludge as biochar for biogas purification will lead to organic cycle system and circular economy.

Therefore, in this study we recommended a new concept in biogas system that is integrated with biogas purification using biogas sludge. Sludge that produced from biogas production was recycled to be adsorbent in biogas purification. This concept aims to develop a model that has no effect on environment and ensure that there is no reduction in waste production [5]. It also becomes a solution in managing livestock waste, upgrading the quality of biogas, and increasing self-sufficiency energy. Moreover, biochar that have been used for purification can be used as soil enrichment. In this concept, no waste is wasted.

Biochar utilization that is integrated with biogas system is appealing because it is a safer method of organic waste management. The concept of organic cycle system in biogas system is shown in Fig. 6.

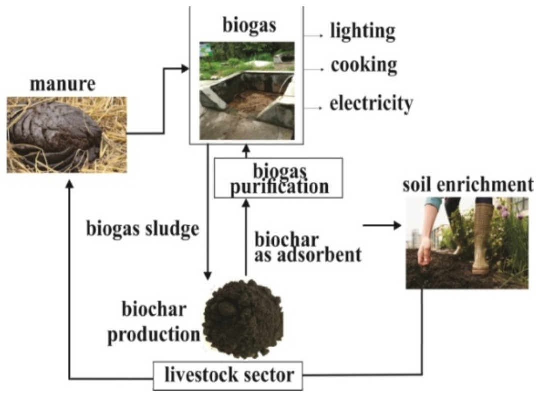

Fig. 6 Concept of organic cycle system in biogas system

This concept maybe can be considering as circular economy system in biogas implementation that integrated with livestock sector. Further study about financial assessment in circular economy of integrated biogas system must be done after that.

4. CONCLUSION

From this study we concluded that the optimum mass of biochar in the combination of adsorbent for biogas purification was 40 grams. The combination of zeolite and biochar with the composition of 40:40 can increase 22.57% of methane composition in biogas compared to biogas before purification. In this study, the utilization of biochar from biogas sludge is more appealing in biogas system. Besides being able to increase methane composition in biogas purification, the concept of organic cycle system in biogas system leads to zero waste management.

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