E3S Web of Conferences **181**, 01006 (2020) http://doi.org/10.1051/e3sconf/202018101006
ICSREE 2020

How return sludge increase biogas production from cow manure?

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Abstract. The energy needs in Indonesia are mainly fulfilled by fossil fuels based energy. Since there is the rise of fuel price, Indonesia government considers seeking alternative energies from renewable resources. Biogas becomes one of the alternative energy that supplies energy needs and manages cow manure waste in Indonesia. To increase adoption of biogas technology, biogas production through methane enrichment is required. The experiment was conducted with return sludge system. These instruments consist of a series portable bio-digester, gas holder and return sludge unit. There were three treatments on biogas production without and with sludge addition or re-use bio-digester sludge that produced after biogas production as raw material for next biogas production. Biogas that produced was observed every two days during 40 days. The results showed that the addition of bio-digester sludge increased biogas production and methane concentration. The optimum retention time of biogas production with sludge addition was 20 days with accumulation biogas volume of 156.38 liters or increased of 38.75 from biogas production without bio-digester sludge). The optimum retention time to increase methane level was 15 days with methane enrichment from 0.8% to 29.41%.

1 Introduction

52% of national energy needs in Indonesia are supplied from fossil fuels based energy. In 2006, subsidy for fulfilling fossil fuels based energy in Indonesia reached 60.6 million with 40% of imported energy. The fact, higher consumption of fossil fuels based energy will result in the scarcity of fossil fuels based energy. In November 2006, the price of fossil fuels based energy reached US$ 72/barrel. Even it was higher in the end of April 2008 of US$ 119/barrel. This phenomenon affected not only on the increase of subsidy but also on the force in energy saving. One of the ways to take over this problem is seeking an alternative renewable energies such as a biogas technology, wind energy, solar energy, bio-fuels (including biodiesel, bio-ethanol and bio-oil), and so on. Biogas and biomass are among types of renewable energy sources that given more attention in the National Research Agenda of 2009. According to 2009 Achievement Goals and 2025 Targets of National Research Agenda target of biogas production from cow manure was expected of 5000 liters volume of household scale biogas [1].

Biogas contains methane (CH_4), a flammable gas that produced from fermentation of organic matter by anaerobic bacteria [2].Methane can be used as fuel because its calorific value is high about 4800-6700 kcal/m^3. Pure CH_4 (100%) has a calorific value of 8900 kcal/m^3 [3]. In generally, all types of organic materials can be processed to produce biogas [4]. However the homogeneous organic matter such as cattle manure and urine that can be utilize for optimum biogas production. Some wastes from livestock sector are manure, urine and feed leftover [5-6]. Livestock waste becomes a big problem cause water and air pollution through releases CH_4 in atmosphere. Methane is a greenhouse gases (GHGs) that contributes the increase of global temperature (global warming) which is equivalent to 21 times from carbon dioxide (CO_2) [7,8]. So utilization of livestock waste not only produces biogas but also manage livestock waste.

According to Ambar *et al.* [9], rumen fluid can be used as starter in biogas production. The addition of rumen fluid can accelerate the retention time of biogas production. Based on her study, we assumed that the decomposition of livestock waste is non complete. It means there are some organic materials that have been not decomposed during biogas production. Therefore, we

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will investigate the utilization of bio-digester sludge as an additional mixture in biogas production using return sludge system in this paper.

So far today bio-digester sludge is only used as fertilizer [10], so further investigation on the utilization bio-digester sludge as addition raw material in biogas production are needed. In this paper, we proved that the return sludge system in biogas production was able to increase biogas volume and CH_4 concentration.

2 Methodology

2.1 Materials

Materials included: cow manure and bio-digester sludge were obtained from Agrotechnology Innovation Center (PIAT) of Universitas Gadjah Mada, Yogyakarta. Three portable bio-digesters and water were also prepared by PIAT of Universitas Gadjah Mada, Yogyakarta. Instruments included of a series portable bio-digester, gas holder and return sludge unit. Details of the series of instruments are showed in Fig. 1. Cow manure digested through anaerobic fermentation in bio-digester system with three variations in retention time of 10, 15 and 20 days.

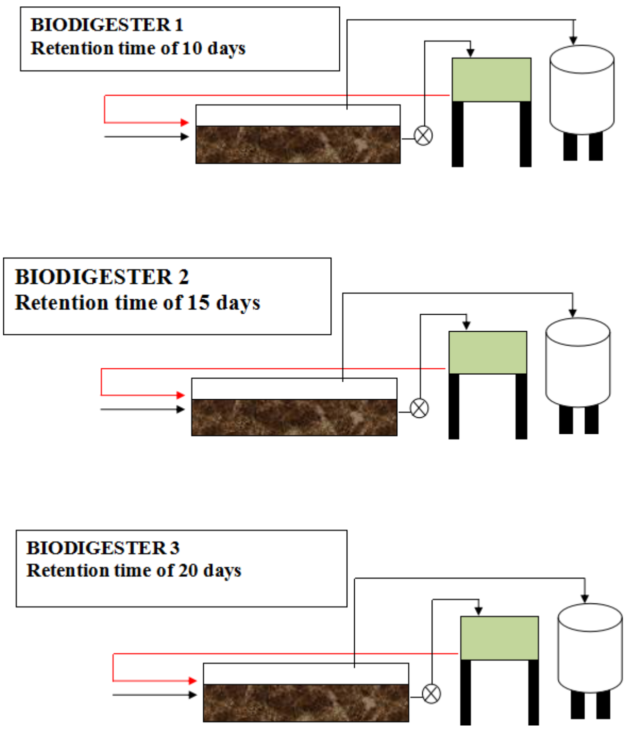

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Fig. 1. The series of biodigester with return sludge system for biogas production.

2.2 Biogas production without return sludge system

Cow manure that used as raw material was prepared with water in mixture ratio of 1:2 for biogas production. Before it used as raw material, cow manure was analyzed with parameters of pH, temperature, COD, *E-coli*, dry content, ash content and volatile solid. The materials were entered in bio-digester via feeder until 2/3 of total volume of bio-digester with variation retention time of 10, 15, and 20 days respectively. Biogas was observed every two days to identify biogas succeed to generated from bio-digester. Biogas that generated from bio-digester was collected in the gas holder. Biogas volume and methane concentration taken from gas holder were measured by Gas Chromatography (GC) after retention time of 10, 20 and 30 days respectively (biogas samples named as bio-digester 1, 2 and 3 respectively). Biogas sludge that produced after 10, 20 and 30 days of retention time(biogas sludge named as bio-digester sludge 1, 2 and 3 respectively) were taken and analyzed with parameters of pH, temperature, COD, *E-coli*, dry content, ash content and volatile solid. Each samples analysis was repeated three times.

2.3 Biogas production with return sludge system

Residues from biogas production, sludge biogas, were came out from bio-digester1, 2 and 3 and pumped to return sludge unit. Procedure of biogas production with return sludge addition is the same as the previous biogas production steps but in this step, raw materials mixed with biogas sludge from bio-digester 1, 2 and 3 respectively. Every two days, biogas was observed to identify biogas succeed to be generated from bio-digester. Then biogas samples that generated with bio-digester sludge 1, 2 and 3 addition were analyzed by GC after 20, 30 and 40 days of retention time respectively (biogas samples named as bio-digester 1, 2 and 3 respectively). Each samples analysis was repeated three times.

3 Results and Discussion

3.1 Input material characteristics

Aim of characterization of input material and bio-digester sludge were to determine the physical and chemical characteristics of materials. Characteristics of raw material were shown in Table 1. The characteristics of bio-digester sludge after retention time of 20, 30 and 40 days were presented in Table 2.

3.2 Biogas production

The addition of biogas sludge into bio-digester (with return sludge system) influences on volume of biogas compared with biogas production without return sludge system. Observation of biogas samples without and with return sludge system were shown in Fig. 2. Volume of biogas after digestion process for 12, 14, 18 and 20 days with return sludge addition (bio-digester sludge 1) increased from the results without return sludge system. The increase in volume of biogas production with return sludge addition due to the amount of organic matters and microbes expressed with COD value of bio-digester sludge 1was higher compared with cow manure alone as raw materials (see Table 1 and Table 2). It was predicted that during digestion process cow manure was not degraded completely. The presence of microbes in digestion process with the addition of bio-digester sludge speed digestion process.

Table 1. Characteristics of raw material.

No	Parameter	Value
1	pH	6.89
2	Temperature	28°C
3	COD	7689.6 mg/L
4	VS measurement	74.8%
5	TSS measurement	4090 mg/L
6	Water content	94.16%
7	*E-coli*	2.000.000.000
8	C/N mixture ratio	24

Table 2. Characteristics of bio-digester sludge.

Parameter	Biodigester sludge 1	Biodigester Sludge 2	Biodigester Sludge 3
pH	6.32	6.12	7.11
TSS	1860 mg/L	5590 mg/L	9640 mg/L
E-coli	1.500.000.000	1.100.000.000	2.300.000.000
COD	25.796 mg/L	29.651 mg/L	13.072 mg/L

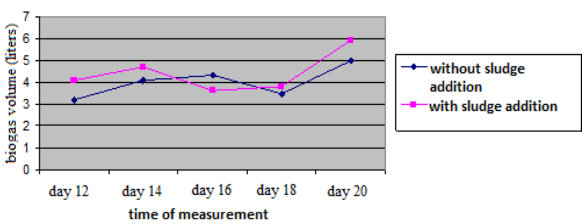

Fig. 2. Graph of biogas volume after production without sludge addition and with bio-digester sludge 1 addition.

Observation of biogas samples without and with return sludge addition (bio-digester sludge 2) were shown in Fig. 3. Because of an increase in microbes of bio-digester sludge 2, the production biogas volume could be generated until 30 days of digestion process. The greater amount of microbes resulted in the higher microorganism activity to generate biogas. After 24 days of digestion time, biogas production decreased to 6.1 liters. However the decline of biogas production was very small, about of 0.2 liters. The decrease of biogas volume was caused by the decrease of microorganism activity. Performance of biogas production without and with sludge addition after 40 days of digesting process in Fig. 4 was shown same phenomenon in Fig. 3.

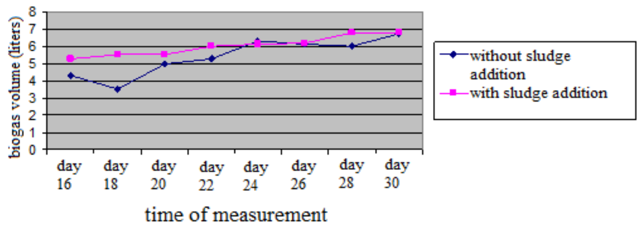

Fig. 3. Graph of biogas volume after production without sludge addition and with bio-digester sludge 2 addition.

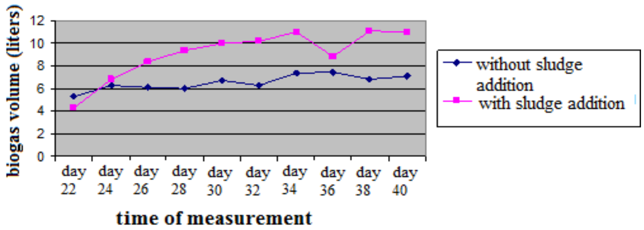

Fig. 4. Graph of biogas volume after production without sludge addition and with bio-digester sludge 3 addition

Percentages of the increase in biogas volume after biogas production with bio-digester sludge 3 addition were shown in Table 3. The highest in biogas volume was generated by biogas with sludge addition after digesting process for 40 days. Biogas volume increased of 38.75% because the system produced biogas in the longest retention time compared to the others bio-digester sludge.

Table 3. Volume of biogas.

Biogas sample	Bio-digester 1	Bio-digester 2	Bio-digester 3
Without sludge addition	20.1	43.2	65.5
With bio-digester sludge addition	22.1	48.2	90.88
The increase in biogas volume	9.95%	11.57%	38.75%
Biogas sample	Bio-digester 1	Bio-digester 2	Bio-digester 3

3.3 Measurement of methane concentration of biogas

After digestion process with bio-digester sludge 1 addition, CH_4 in biogas that was produced only a small amount because the retention time was short. The first 10 days was included the initial phase of biogas formation so that CH_4 concentration that produced was still low (see Fig. 5). According to Darmawan [11], retention time has a significant effect on the performance of biogas production. The short retention time will inhibit the growth of anaerobic microbes, especially the methane-forming bacteria.

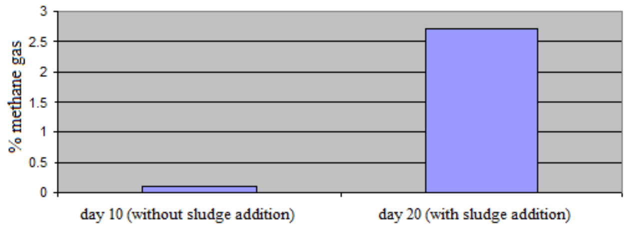

Fig. 5. Methane concentration after biogas production with the addition of bio-digester sludge 1.

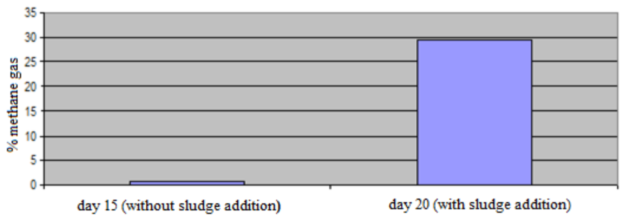

Fig. 6. Methane concentration after biogas production with the addition of bio-digester sludge 2.

After digestion process during 15 days CH4concentration in biogas was only 0.8% but after 30 days biogas production with bio-digester sludge 2addition, concentration of CH4increased dramatically to 29.41% (see Fig. 6). The increase of CH4 concentration was happened in the range of optimum retention time. The ideal retention time is in the range of 10-60 days. The same trend in the increase of CH4 concentration was also shown by bio-digester 3 (see Fig. 7). But the increase of CH4 concentration of biogas bio-digester 3 was slower than biogas bio-digester 2.

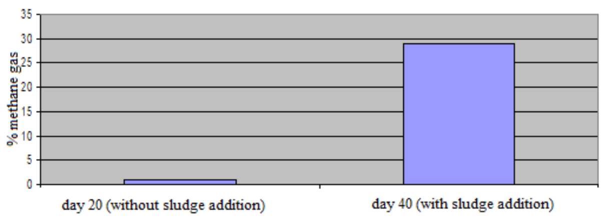

Fig. 7. Methane concentration after biogas production with the addition of bio-digester sludge 3.

3.4 Factors affecting in biogas production

3.4.1 pH

The effect of pH in bio-digester sludge was shown in Fig. 8. From the figure showed that pH of bio-digester sludge after biogas production increased compared with raw material input, except in bio-digester sludge 1. After retention time, organic acids were formed and lead to decrease pH. However after few days of digestion process, the methanogenic bacteria were gradually getting active until the neutral pH reached. The increase in pH level were occurred on day 28. From this result we concluded that more optimum methanogenesis process will increase pH level into neutral.

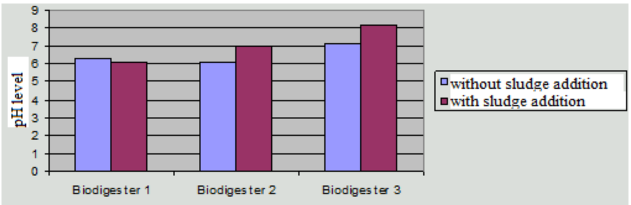

Fig. 8. pHof bio-digester sludge after biogas production.

3.4.2 Total suspended solids (TTS)

Total suspended solids (TTS) of bio-digester sludge after biogas production were lower than raw material input (see Fig. 9). According to Darmawan [11] during digestion process TSS level will decrease because bacteria in biogas mixture decompose complex molecules into simple molecules that can dissolved in water. Bio-digester sludge that mixed with raw material of biogas contained more bacterial decomposers and broke down organic materials more efficient.

Fig. 9. TTS of bio-digester sludge after biogas production

3.4.3 Temperature

Bio-digester sludge after biogas production has different temperature from raw material input due to the effect of microorganism activity. Bio-digester sludge have temperature in range 26-28^oC (see Fig. 10). It means biogas production was happened in mesophilic phase (20-40^oC). Based on reference, anaerobic digestion in mesophilic condition can produce biogas and reduce amount of pathogenic bacteria [6] that in this case pathogenic bacteria was *E-coli*.

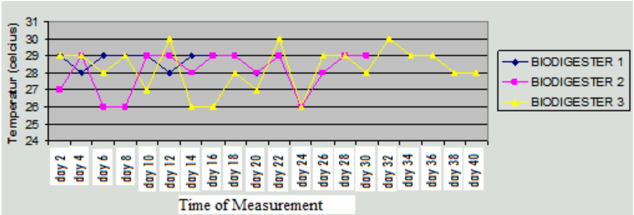

Fig. 10. Temperature of bio-digester sludge after biogas production.

4 Conclusion

The addition of bio-digester sludge into portable bio-digester and mixed with cow manure for biogas production increased biogas volume and CH_4 concentration. The optimum of biogas production with sludge addition was happened with retention time of 20 days. After 20 days of retention time, accumulated biogas was 156.38 liters or increased of 38.75%. Biogas production with sludge addition increased CH_4concentration optimally after 15 days of retention time with the increase in CH_4concentration from 0.8% to 29.41%.

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