The Influences of Stirring and Cow Manure Added on Biogas Production From Vegetable Waste Using Anaerobic Digester

N O Abdullah¹, E S Pandebesie¹

¹Department of Environmental Engineering, Sepuluh Nopember Institute of Technology, Indonesia

Email: nurjannahoktorina@gmail.com

Abstract. Based on Indonesian Government Regulation number 18, 2008, solid waste management should be conducted from the source to minimize the amount of waste. The process includes the waste from domestic, commercial, and institution. This also includes in 3R program (reduce, reuse, and recycle). Vegetable waste from market is a potential material to produce biogas due to its chemical composition (hemi-cellulose, cellulose, and lignin) which transform the biomass to be the raw material of biogas. Acid substance of vegetable becomes an obstacle in process of producing biogas. There has to be buffer material which can improve the performance of biogas process. Cow manure is a material which can be easily obtained as buffer. This research used 24 biogas reactor in volume 6 L by batch method. Biogas volume is measured by checking the preferment in manometer. Methane measurement is conducted by using Gas Chromatography (GC) Hewlett Packard (HP-series 6890) in day 15 and 30. The research was started by sample characterization, sample test by total solid analysis, volatile solid, lignin, ratio C/N, ammonium, and ash. Analysis of pH, temperature, and biogas volume is conducted every day.

1. Introduction

Approximately 1.5 billion ton/year of vegetable and fruit were produced worldwide and 45% of them were wasted. Based on Indonesian Government Regulation number 18, 2008, solid waste management should be conducted from the source to minimize the amount of waste. The process includes the waste from domestic, commercial, and institution. This also includes in 3R program (reduce, reuse, and recycle). Biogas is an environmentally advantageous energy source which is mostly comprised of methane (60%) and carbon dioxide (35-40%). Moreover, biogas contains a low quantity of other gases such as ammonia (NH₃), hydrogen sulfide (H₂S), hydrogen (H₂), oxygen (O₂), nitrogen (N₂), and carbon monoxide (CO) [1,2]. Biogas is the gas evolved from a process known as anaerobic digestion (AD). AD is known as the degradation of organic compounds to simple substances by microorganisms which live as syntrophy under the lack of oxygen with releasing biogas [3,4]. Vegetable waste from market is a potential material to produce biogas due to its chemical composition 40-50% cellulose, 20%-35% hemi-cellulose, and 15%-30% lignins which transform the biomass to be the raw material of biogas. Acid substance of vegetable becomes an obstacle in process of producing biogas. There has to be buffer material which can improve the performance of biogas process. Cow manure is a material which can be easily obtained as buffer.

Another factor to produce biogas is mixing. The importance of mixing in achieving efficient substrate conversion has been reported by several researchers [5]. The main factors affecting digester mixing are the mixing strategy, intensity, duration, and the location of the mixer. Adequate mixing
was shown to improve the distribution of substrates, enzymes, and microorganism throughout the digester [6], whereas inadequate mixing was shown to result in stratification and formation of floating layer of solids. Continuous mixing was shown to improve biogas production compared to unmix. Nevertheless, intermediate mixing appears to be the most optimal for substrate conversion. Mixing intensity was also shown to affect digester performance and biogas production [7]. The effect of mixing on aerobic digestion of manure was evaluated in lab-scale and pilot scale experiments at 55°C. They investigated the effect of continuous (control), minimal (mixing for 10 min prior to extraction/feeding), and intermittent mixing (with holding mixing for 2 h prior to extraction/feeding) on methane production in three lab-scale continuously stirred tank reactors. They found that the intermittent and minimal mixing strategies improved methane productions by 1.3% and 12.5%, respectively as compared with continuous mixing.

2. Methods

The digester experiments were carried out in a batch system with a total volume of 6,000 mL. The digester was supported by the mixer and gas sampler. Gas sampling was located at positions corresponding to the top of digester contents. The digester had one outlet at the bottom. The contents of the digester were mixed as controlled by manually 8 times/day which was carried out for 5 minutes. Digester was run at temperature of mesophilic. As for the samples conducted in this experiment were cow manure and vegetable wastes as substrates. The cow manure was taken from Pegirian slaughterhouse located in Surabaya, Indonesia. Vegetable wastes have been collected from local market. It was manually screened to remove any inorganic material like bones, stones, polythene bags, and citrus material like lemon residues. Experiments were operated in batch system. The biogas produced was measured daily by calculating increase water level in the manometer. Measurement of methane rate in the biogas using Gas Chromatography (GC) Hewlett Packard (HP-series 6890). The schematic diagram of experimental laboratory set up as shown in Figure 1.

![Figure 1. Design of Digester](image-url)
This research used a variable of stirring time, cow manure added, 10% and 20% of total solid. The stirring time was 8 times for 5 minutes, 4 times for 5 minutes, and without stirring. Vegetable waste were added by cow manure. After that, vegetable waste pH was neutralized using NaOH until the pH becomes neutral. The concentration of total solids of the mixture variation in this study was 10% and 20%. Table 1 showed the variables used in this study. The variables used in this study was the influence of the stirring time, the effect of cow manure, and the total effect of solid.

Table 1. Research Variable

| No. | Stirring Time (%) | Cow Manure |
|-----|------------------|------------|
|     | (A)              | Total Solid 10% (B) | Total Solid 20% (B) |
| 1   | 8 Times          | A1B1       | A1B2       |
| 2   | 4 Times          | A2B1       | A2B2       |
| 3   | 0 Times          | KK1        | KK2        |

A1B1: Total solids 10% and stirring 8 times/day
A2B1: Total solids 10% and stirring 4 times/day
KK1: control and without stirring times
A1B2: Total solids 20% and stirring 8 times/day
A2B2: Total solids 20% and stirring 4 times/day
KK2: control stirring times

3. Results

3.1 Characterization of Samples

The samples has been characterized and the results have been tabulated as follows. The batch digestion in lab-scale was carried out in 6,000 mL with working volume of 5,000 mL at temperature of 35 ± 1 °C. Characteristics of substrates are important parameters in designing and operating anaerobic reactors. The initial characteristics of substrates strongly affect the biogas yield and anaerobic process stability. Substrates used in this study were individually analyzed for their initial physicochemical characteristics and the results are presented in Table 2. The initial pH of vegetable wastes was lower than the optimum pH required for anaerobic digestion, while the pH of cow manure used for this experiment was comparatively high i.e., 7.9. When substrate was mixed with individual substrate mixtures, pH of the substrate mixtures increased, hence pH was not adjusted artificially. The pH of
digestion mixtures A1B1, A2B1, A1B2, and A2B2 after mixing with cow manure was 7.1; 6.9; 7.2; 7.1 respectively. C/N ratios of individual substrates used in this study were either greater or lesser than that of reported optimum range of C/N ratio for anaerobic digestion. C/N ratio of vegetable wastes relatively higher as compared to cow manure, which is due to high nitrogen content of vegetable wastes mainly organic form like protein [5]. Such types of organic wastes like vegetable wastes with relatively high content of lignocelluloses always have low biogas potential [6].

Table 2. Characteristics of vegetable wastes and cow manure

| Parameters       | Vegetable Wastes | Cow Manure |
|------------------|------------------|------------|
| Water content (%)| 90.49            | 57.4       |
| Volatile solids (%)| 93.90        | 81.66      |
| Carbon (%)       | 52.17            | 45.37      |
| Hydrogen (%)     | 6.26             | 5.44       |
| Oxygen (%)       | 38.24            | 33.81      |
| Nitrogen (%)     | 1.58             | 2.06       |
| Ash (%)          | 0.61             | 11.8       |
| P-Total (%)      | 1.14             | 1.52       |
| Lignin           | 6.09             | 9.74       |
| C/N              | 32.81            | 21.92      |
| pH               | 5.6              | 7.9        |

For co-digestion of vegetable wastes and cow manure, C/N ratio of 32.81 was not desirable, as it yielded 38% lesser biogas than a mixture with C/N ratio 20. Lower C/N ratio of feedstock or higher organic nitrogen content leads to accumulation of ammonia nitrogen and high pH of 8.5 or more which can inhibit methanogenesis. While, on the other hand at higher C/N ratio of feedstock or lesser organic nitrogen content, methanogens consume nitrogen more rapidly resulting in nitrogen deficiency and hence low biogas yield [7]. The C/N ratio of substrate in range of 20-30 is considered optimum for anaerobic digestion [7]. High C/N ratio of vegetable wastes was used to adjust the C/N ratio of cow manure to 20-30 by mixing both the co-substrates in different ratios without addition of any external nutrients.

3.2 The Effect of Stirring Process on The Production of Biogas

The daily biogas production and methane content were determined. The obtained data revealed that the different stirring periods had the positive effect on the biogas production. It gave a higher biogas yield and biogas productivity. Moreover, the increase the stirring periods increase the biogas yield with about 54.29%; 41.05%; 56.06%; 48.12% at stirring periods of 8 times/day and 4 times/day for 5 minutes respectively. The obtained results, indicated that the stirring periods of 8 times/day was gave the highest value of biogas productivity at stirring period of 5 minutes. These highest values may be due to the complete homogenous of the digestion materials which led to increase the exposed surface area resulted in increasing the microbial growth and consequently increase the totals methanogenic bacteria. The frequency of the best stirring to the formation of biogas contained in the reactor with stirring 8 times for 5 minutes and the addition of cow manure on the total solid 20%. Reactor with stirring frequency 8 times creates a homogeneous substrate preventing stratification and formation of a surface crust, and ensures solids remain in suspension. Further, mixing also enables heat transfer, particle size reduction as digestion progresses and release of produced biogas from digester contents.
Table 3. Biogas Volume Production

| Total Solid | Reactor | Stirring Time | Volume of Biogas (mL) |
|-------------|---------|---------------|-----------------------|
| 10%         | A1B1    | 8 times       | 5.407                 |
|             | A2B1    | 4 times       | 4.192                 |
|             | KK1     | 0 times       | 2.471                 |
|             | A1B2    | 8 times       | 8.743                 |
| 20%         | A2B2    | 4 times       | 7.403                 |
|             | KK2     | 0 times       | 3.841                 |

Low solid is the percentage of the mixture with a water content of as much as (4-10: 96-90% w/w). Medium solid is the percentage of the mixture with a water content of as much (15-20: 85-80% w/w) [7,8]. Figure 3 showed the highest cumulative biogas volume and methane levels of biogas generated by a mixture of vegetable waste and cow manure 70:30 (%w/w) with total solid 10% and 20%. The cumulative biogas volume produced at reactor A1B1 was 5.607 mL. The cumulative biogas volume and methane levels produced in the same mixture with 20% total solid at reactor A1B2 was 8.743 mL.

Figure 3. Total Solids from Six Substrate Mixtures

Total solids and volatile solids reduction from six substrate mixtures is shown in Figure 3. Highest TS and VS reduction was observed for substrate mixture A1B2, while these were the lowest for KK1.
Higher volatile solids reduction yielded higher biogas as trend in VS reduction was similar to biogas yield. Substrate mixture A1B2, that produced the highest biogas also showed the highest VS reduction than all other substrate mixtures showing a relationship between biogas production and VS removal. These results are in accordance with another study where the same trends of TS and VS reduction and relationship between VS reduction and biogas yield have been reported [9]. Significant difference was found among solids reduction from six substrate mixtures. Volatile solids reduction from A1B2 was 1.39 times higher and TS reduction was 1.2 times higher than A1B1 which is total solid 10%. It might be due to higher fraction of vegetable wastes used in total solid 20% as compared to total solid 10%. Similar results have also been reported by several authors where higher VS reduction was achieved with high fractions of vegetable wastes used in substrate mixtures [9].

3.3 The Effect of Cow Manure Added on The Production of Biogas

The anaerobic digestion process is a set of biological reactions under the bacteria action, organized into several microbial populations, each of them playing successive roles for the transformation of complex organic mass into methane and carbon dioxide. All reactions, multiple, and complex, that take place in the digester can be divided into four main stages characterizing the action of different bacteria groups: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [9]. The addition of cow manure as a bio-activator in the anaerobic digester process was expected to increase the activity of the microorganisms to decompose organic matter and produce methane gas. In Figure 4 could be seen the results cumulative biogas formed by the addition of cow manure.

![Figure 4. Cumulative of Biogas Volume](image)

To determine the effect of cow manure on the formation of biogas is necessary comparison between the reactor. Best reactor with the addition of cow manure A1B2 contained in the reactor amounted to 8.768 mL. The influence of the addition of cow manure to the formation of biogas contained in the reactor with stirring frequency of 8 times and the addition of cow manure on the total solid 20%.

4. Conclusion

The highest cumulative biogas volume and methane levels generated by stirring 8 times and cow manure added. The highest cumulative volume produced in the reactor amounted to 8.743 mL A1B2 and methane percentage of 61.09%. The volume of biogas produced by the reactor without cow manure is lower than the reactor added cow manure.
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