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PRESENCE OF BIOGAS FROM FOOD WASTES: A PRELIMINARY STUDY

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Abstract

The accumulation of solid organic waste is thought to be reaching critical level in almost all regions of the world including Malaysia. These organic wastes need to be managed in a sustainable way to avoid depletion of natural resources, minimize risk to human health, reduce environmental burdens and maintain an overall balance in the ecosystem. There are numbers of method currently being applied to the treatment and management of solid organic waste. One of the methods is anaerobic digestion. Anaerobic digestion is a biological process in which the microorganisms will break down biodegradable material in the absence of oxygen yielding the product biogas. Food waste with high content of carbon can be considered as a good source of substrate to produce biogas via fermentation process. In this research, the digestion of food waste (FW) and sludge water (SW) was used. The experiment was conducted in the digester model with different ratio of SW and FW. The digester model was filled with different ratio of SW to FW by mass. The ratio are 1:1, 1:3, 1:5, and one model which acts as a control. The amount of biogas collected was observed every 5 days. From the observation, it shows that the amount of biogas collected and the production rate with ratio 1:5 is higher as compared to the other model. From the observation, it can be predicted that the production rate of biogas can be increased when it has large amount of food waste with a large number of carbon content. From the result obtained, it shows that the food wastes have the potential in producing biogas.

Keywords: Anaerobic digestion, biogas, food waste

1.0 INTRODUCTION

Biogas is a combustible mix of gases produced by anaerobic digestion (AD) or fermentation of biodegradable materials such as biomass, manure or sewage, municipal waste, green waste and energy crop (Ilaboya et al., 2010). It is stated by Velmurugan & Ramanujan (2011), that AD is the biological degradation by a complex microbial ecosystem of organic and occasionally inorganic substrates in the absence of an organic source while in accordance to Al Seadi et al. (2008), AD is a microbiological process of decomposition of organic matter, in which oxygen is absence, a norm to many natural environments and widely applied at present to produce biogas in airproof reactor tanks, commonly named as digesters. Biogas contains methane (CH_4) and carbon dioxide (CO_2) with traces of hydrogen sulphide (H_2S) and water vapor.

According to Sagagi et al. (2009), there are four metabolic stages involved in the production of methane using AD process. Firstly, the particulate organic matters such as cellulose, hemi-cellulose, pectin, and lignin undergo hydrolysis by extra cellular enzymes to convert polymers into monomers. Then, the soluble organic matter and the products of hydrolysis are converted into organic acids, alcohols, hydrogen and carbon dioxide by the bacteria of acidogenic. Thirdly, the acetogenic bacteria convert the acidogen products into acetic acid, hydrogen and carbon dioxide. Finally, methanogenic bacteria are accountable for methane production from the aforementioned substances as well as directly from other substrates of which formic acid and methanol are the most important.

Over the years, Malaysia has been experiencing rapid growth in population, urbanization, and industrialization. This rapid development has resulted in the generation of massive amount of Municipal Solid Wastes (MSW) (Johari et al., 2014). Presently, only landfill applications were used as the main disposal method in Malaysia. Eventually, amount of landfill available for disposal will sacre thus, demanding for the development of new disposal method. Food wastes are categorized as MSW and rich in organic content makes it a perfect candidate for anaerobic digestion. Thus, this research aims to quantify the potential of food wastes to produces biogas under anaerobic condition.

2.0 BACKGROUND STUDY

2.1 Production of Biogas through AD

Biogas is commonly produced from AD of various digestible organic substrates and wastes or from landfills. For the AD systems, biogas production and gas composition highly depending on the feedstock (digestible substrates) and the operational conditions. Anaerobic digestion is widely applied for treatment of organic wastes that are easily degradable and have relatively high moisture contents (Zhang et al., 2007).

There are four main stages normally involved in the AD process including hydrolysis, fermentation, anaerobic oxidation, and methanogenesis. Each step occasionally involves a different type of microorganisms and the product from one stage is a precursor for the next step (Zhang et al., 2014). Hydrolysis occurs in the first stage of anaerobic digestion process where all the polymeric organic materials are hydrolyzed into monomers such as glucose, fatty acids, and amino acids (Ahmad et al., 2011). The second stage is acidogenesis and it is also known as fermentation of small molecular materials formed from the first stage resulting in volatile fatty acids such as acetate, carbonic acids and butyric acids (Adekunle & Okolie 2015). The third stage is known as acetogenesis where all organic substrates from the previous stage are further degraded into acetate, H_2 and CO_2. The final stage is methanogenesis which is methane formation step. Methane generated at this stage via two routes. The first one is in which the methanogens consuming acetates and releasing CH_4 and CO_2. The second route is where the CO_2 is reduced by hydrogen gas produced from the oxidation of organic acid in the previous stage (Sagagi et al., 2009).

Biogas production systems have several benefits, such as eliminating greenhouse gas, reduction of odor, enrichment of bio-fertilizer, production of heat and power, and many more (Al Imam et al., 2013). In the last 30 years, literatures regarding digestion of organic substances from different origins were published at ever growing rate. A variety of methods to produce biogas were reported. This includes from the utilization of animal dung, kitchen waste and agricultural industry waste, for instance, palm oil mill effluent (POME).

2.2 Factors Affecting Biogas Production

A number of factors can affect the rate of biogas being produced such as the nature of the substrate, temperature, pH, loading rate, retention time and alkalinity. Besides that, organic material added as inoculums in the fermentative organic substrate (Mateescu & Constantinescu 2011) and the size of inoculums matter for the rate of gas generation (Namsree et al., 2012) However, it is reported that the yield of biogas is highly dependent on the temperature, OLR, pH and C:N ratio (Ponsa et al., 2008). According to Liu et al. (2009), a certain amount of inoculums should be added together with the substrate to provide the required microorganisms to start reactions in a normal start-up of a batch digester. An experiment conducted by Singh et al. (2010) uses inoculums that were collected from four different sources such as tannery waste treatment plant, municipal waste treatment, distillery, and sludge of a field scale biogas reactor was added to cow dung slurry to develop inoculums in a batch reactor. The primary contributor of the substrates used for biogas is agricultural sector, which accounts for the largest potential for biogas feedstock (Al Seadi et al., 2008). The substrates (feedstock) consist of fresh or ensiled plant material, animal excrements such as manure and slurry, agricultural residues and by-products, wastes from agricultural or food production and organic fraction of municipal waste such as organic household waste (Gerlach et al., 2013).

2.3 Substrates for Biogas

The commonly used raw material in anaerobic digestion to produce biogas including cow dung, poultry waste, water hyacinth, straw, leaf, human and animal excrement, domestic rubbish and industrial solid and liquid wastes. Most of them are easily found in Malaysia (Al Imam et al., 2013). In this research, the substrates that will be tested are based on the food pyramid. For example, chicken fat, rice, vegetables, and fish. These food wastes were used to predict the presence of biogas.

Due to the high population in the urban area, there is a massive amount of municipal waste being produced every day. If this abundance of municipal assets were not properly managed by relevant parties, it will contribute to environmental pollution in ground water, soil and etc. For the record, cleaning up the mess produced by this situation will cost the nation huge amount money. Thus, rather than wasting money on the cleaning up process, it is always better to treat the problem from its root. So, the main purpose of this experiment is to evaluate the potential of these municipal waste especially food waste to be converted into greener product- biogas.

3.0 METHODOLOGY

3.1 Sample Collection

Sample used in this experiment was food wastes which were collected from Bandar Seri Alam located in Johor, Malaysia. The food wastes were divided into chicken, fish, rice, and vegetables.

3.2 Preparation of Food Waste

The food waste was collected and stored in the container for 3 days prior to the experiment. This is because the complex organic materials are degraded from macromolecules into low molecular weight compounds by acidogenic bacteria to volatile fatty acids and alcohols, which are then easily metabolized into methane and carbon dioxide by methanogens or archaea (Zhang et al., 2014).

3.3 Operating Condition

The ratio (w/w) is represented by sludge waste (SW) to food waste (FW). The mass for SW is constant, which is 100g. While the mass for FW was varied from 100g, 300g and 500g. The ratios used are 1:1, 1:3 and 1:5. The sample data collection is done within the duration of 15 days.

3.4 Waste Water Sampling

Waste water was collected from Indah Water Konsortium which is located in Johor Bahru. The waste water appears a bit cloudy or turbid upon collection but after a while, the sludge settled down at the bottom and filtration was performed until a sufficient amount of sludge waste was obtained. Waste water was used because it contains a variety of microorganisms including the ones responsible to break down the biodegradable material into methane and carbon dioxide.

3.5 Experimental Set-up

The set-up of the experiment is shown in Figure 1. The experiments were carried out in four identical modified containers that worked as a reactor or digester in order to produce the biogas. The container was equipped with two straws which was placed at the side of the container and the top of the container respectively. These straws served as inlet and outlet points of the raw materials. This container also equipped with a small flexible polyvinyl Chloride (PVC) tube located at the top of the container cap that is connected to the gas collector to channel the collected biogas to the gas collector unit.

Figure 1 Anaerobic Digester

The container was painted prior to feeding procedure in order to limit the amount of sunlight penetrating the digester which can disturb the bacterial activity. All openings were sealed using glue, adhesive tape, and plasticizer to make the digester air tight. This is because the digester should be maintained with oxygen-free for the digestion process to proceed. Gas collection from the digester was made by using a long clear plastic.

3.6 Results Interpretation

Amount of biogas produced being measured in terms of length of the plastic occupied by the biogas and recorded in cm. From this data, the volume of biogas was calculated by using the volume formula of a cylinder.

$$V = \left[\frac{\pi d^2}{4}\right] x \qquad \text{Equation (1)}$$

Where ;

V = Volume, cm3

d = Diameter of the plastic, cm

x = Length of plastic occupied by biogas, cm

π = 3.142

The diameter of the plastic was measured at 4 cm.

4.0 RESULTS & DISCUSSION

4.1 Volume of Biogas Produced

A 15-day observation experiment was conducted. Several digesters were labeled according to the ratio of SW: FW and one digester act as the control that contains 100g of food waste and 100 g of tap water (instead of SW).The reading was taken at every 5-day interval for 15 days consecutively. The results are represented in Table 1 and Figure 2. From Table 1, it can be seen that the results of biogas collected in clear plastic in unit centimeter (cm) were converted to volume of biogas in unit cubic centimetre (cm^3). The conversion was calculated by using the equation (1) in previous section 3.6.

Table 1 Amount of biogas collected from the anaerobic digestion of food waste.

Ratio (w/w)	Amount of gas collected, (x) cm			Volume of Biogas, cm^3 ($V=[\pi d^2/4]x$)		
	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15
Control	2.0	4.0	4.0	25.1	50.3	50.3
1:1	1.0	4.0	5.0	12.6	50.3	62.9
1:3	4.0	5.4	9.4	50.3	67.9	118.1
1:5	7.0	10.0	16.0	89.0	125.7	201.1

Meanwhile, Figure 2 shows the volume of biogas collected from the 15 days experiment for all digested in unit cubic centimeter (cm^3). From the illustrated data, it can be concluded that amount of food waste added into the container influenced the volume of biogas produced. The highest volume of biogas produced is in ratio 1:5 with a total of 201.06 cm^3 of biogas collected as compared to the other ratios. This situation may be attributed to the availability of more fermentable substrate (FW) in the digester. Figure 2 also shows that the volume of biogas produced increased throughout the observations period. This indicated that the microorganisms consumed on the substrate and producing biogas for that allocated time limit.

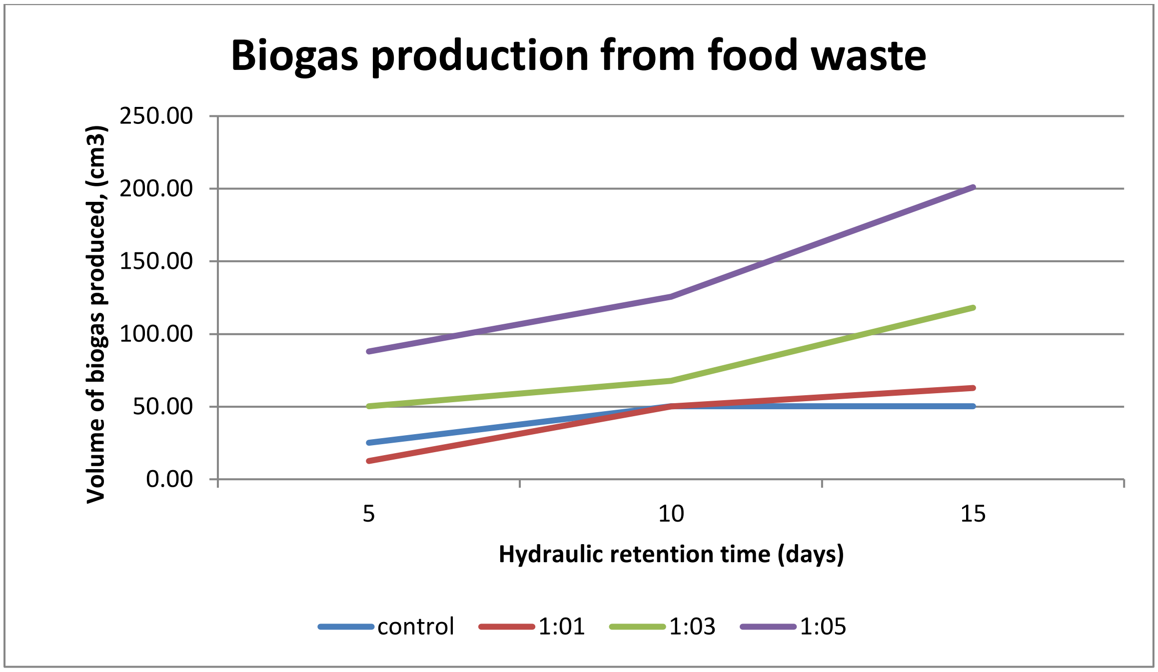

Figure 2 Volume of biogas collected from the anaerobic digestion of food wastes

The control digester contains only food waste (without the addition of SW) with ratio 1:1 (Tap water: FW) and was used to evaluate the effect of adding SW to the biogas production process. At the end of the observation period, the biogas production was slightly lower as compared to the one with the ratio of 1:1 (SW: FW). During the first 5 days, the biogas collected was a bit higher but the biogas production seems to be decreased after day 10 as there is no increasing volume of gas produced recorded. At the same time, the one with the ratio of 1:1 (SW: FW) shows slightly higher gas production until the end of the experiment.

The composition of food waste varies depending on the cultural habits, daily activity, region and etc (Arsova 2010). Commonly, food waste comprises of the mixture of these four main components - lipids, carbohydrate, protein and cellulose. Thus, biomethanation process is highly dependent on the concentration of these compounds in the food waste. For instance, fats provide the highest biogas yield but require a long retention time due to their poor bioavailability. Carbohydrates and proteins show much faster conversion rates but lower gas yields (Kobayashi et al., 2012). However, the system with an excess of lipids is subjected to volatile fatty acids (VFA) accumulation which will inhibit the production of biogas (Neves et al., 2007). Whereas, an excess of protein in digester will promote ammonium accumulation in the system which in turn will stop methanogenesis process (Khalid et al., 2011). The anaerobic digestion of organic material is a complex process, involving a number of different degradation steps. The microorganisms that participate in the process may be specific for each degradation step and thus could have different environmental requirements. Many factors contribute to an effective digestion processes such as temperature, pH, moisture, different types of carbon sources, nitrogen and carbon-to-nitrogen ratio (Khalid et al., 2011). This information is important in order to achieve maximum biogas production and to ensure process stability.

5.0 CONCLUSION

The experiment has shown that biogas could be produced by the digestion of food waste and sludge waste. From the results obtained, it can be concluded that amount of waste added affecting the amount of biogas being produced. The production of biogas can be enhanced by increasing the SW to FW ratio. Increasing the amount of readily degradable sugars can enhance the digestion process and producing more biogas. Thus, anaerobic digestion can be considered as one of the treatment methods to dispose high volume of food waste produced in Malaysia. For further research, it is good to take into consideration of the factors influencing the digestion process for instance pH and temperature. This is to ensure that the digestion process can proceed at an optimum rate.

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