PRODUCTION OF BIOGAS VIA ANAEROBIC DIGESTION OF FOOD AND PLANT WASTES

Tharisyini K. Kulothungan, Noor Yahida Yahya, Nasratun Masngut

Abstract

Biogas is a clean energy that can substitute or reduce the usage of liquid petroleum gas (LPG) and natural gas. However, the availability of feedstock used for the production is a major downside. In this study, a small-scale unit of biogas was produced from food (vegetable and fruit wastes) and plant wastes via anaerobic digestion (AD) reaction process. The reaction parameters used in this study were the reaction condition and retention time. The experiment was conducted for 14 days to test the influence of reaction parameters towards the yield of biogas. From the study, it was observed that the yield of biogas was higher in a light AD condition (0.7470 ml/g) compared to the dark condition (0.025 ml/g). Furthermore, as the retention time increases, the yield of biogas also increases slightly. In addition, the finding affirms the possibility of biogas production using a mixture of food and plant wastes with further study is needed for the parameter's ranges used in the study.

Keywords Biogas, Anaerobic digestion, Food waste, Plant waste.

Introduction

Fossil fuels depletion is a major issue faced by humans today. Besides that, the use of fossil fuels is accountable for environmental problems such as global warming, air and water

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pollution, causing health problems and affecting people's quality of life (Kumar and Ramanathan 2020; Owamah 2020). As a result, alternate energy from wind, solar, sea, hydro, geo and biomass has gained a superior growth globally. Biogas from biomass is a promising replacement for traditional fossil fuels, as it is renewable, green, eco-friendly and economical in nature (Hasan and Ammenberg 2019). Biogas is a colourless combustible gas, produced when organic materials break down under anaerobic conditions by microorganisms (Mirmohamadsadeghi et al. 2019). It is mainly composed of methane, 50 % to 70 %, and carbon dioxide, 30 % to 50 %. It can produce heat and electricity, and can be used for cooking.

Anaerobic digestion (AD) reaction is used for the conversion of the feedstock (biomass) into biogas (Panyaping and Moontee 2018; Heydari et al. 2021; Vijin Prabhu et al. 2021). There are four main steps of AD process; hydrolysis, acidogenesis, acetogenesis and methanogenesis. AD begins with the hydrolysis of the biomass to form smaller and water-soluble compounds (such as glucose, peptides, amino acids, glycerol) catalysed by acidogenic bacteria. Then, it continues with the decomposition of the substrates into volatile fatty acid (VFA) by acidogenic bacteria. Then, it is followed with the acetogenesis step, where the catalysis of acetogenic bacteria converted VFA into acetate, H_2 and CO_2. Lastly, the methanogenesis step takes place where acetate, H_2 and CO_2 are utilised by methanogenic bacteria to produce the biogas (Chew et al. 2021).

Considering all of the steps in AD reaction process, those steps further depend on several factors such as feedstocks, temperature, pH, retention time, nutrient, solid to water content, organic loading rate, C/N ratio, mixing and pretreatments (Vijin Prabhu et al. 2021). The factors need to be screened and optimised to understand the correlation of the reaction process with the yield of the biogas. In this study, a small-scale unit of the anaerobic digester was built to facilitate the AD reaction process. Food waste consisting of vegetable and fruit wastes, as well as plant waste were used as feedstock to produce biogas. The AD reaction parameters included in the study are reaction condition (temperature) and retention time towards the production of biogas. This pilot study was conducted for the purpose of the potential evaluation of the mixture of the waste to produce biogas.

Methodology

Materials

1.5 l container, 1.5 m tube, tube clamps, Mylar balloon, plasticine, tape, measuring cylinder, water basin.

Preparation of Feedstock

Approximately 1 kg of food (vegetable and fruit) and plant wastes were collected and stored in a container. Then, the wastes were mesh and mixed vigorously with water and microbial consortium in a fixed amount of 400 g of wastes, 200 ml of water and 200 ml of microbial consortium (white sugar).

Anaerobic Digestion Reaction

The AD reaction to produce biogas was followed and modified by several standard AD reaction processes (Menon et al. 2016; Panyaping and Moontee 2018; Zhang et al. 2018; Vijin Prabhu et al. 2021). 500 g of the prepared substrate (prepared feedstock) were weighed and transferred into the set-up digester, as shown in Figure 1 in two different reaction conditions (under the sun and in a dark room). The reaction was allowed to occur for 14 days. The observation was recorded (in terms of the changes in the Mylar balloon size) and the yield of biogas was measured using the water displacement method and calculated using Equation (1).

$$\text{Amount of biogas produced} = \frac{Volume\ of\ wet\ biogas\ captured\ (ml)}{Mass\ of\ raw\ materials\ (g)} \tag{1}$$

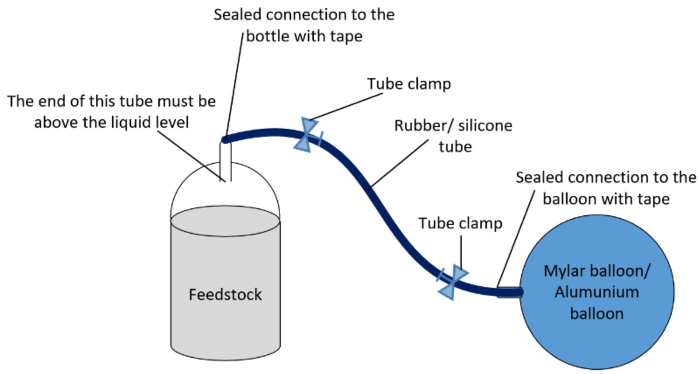

Figure 1: Anaerobic digester setup.

Results and Discussion

Analysis of Anaerobic Digestion Reaction Experiment

Reaction condition

Figure 2 indicates the biogas production at different reaction conditions for 14 days, which are in the present of light (under the sun) and in the absence of light (in dark room). The comparison in the reaction condition implies the temperature of the mixture inside the digester. The digester placed in the present of light will have a higher temperature compared to the digester placed in the absence of light. Therefore, it will lead to different growth of the bacteria in each AD step, since the enzymatic activity was different at different temperatures (Dai et al. 2021). Therefore, comparing both conditions, biogas production is higher in the present of light compared to the dark reaction condition.

This finding was in line with the basis that the biogas digester process generally works at high temperatures (Stephen Bernard et al. 2020). This result is also similar to the study by Miller et al. (2020), which stated that during the decreasing temperatures in the climates, there are significant decrease in the yield of biogas. This condition can further be explained by the increase of bacterial growth when the temperature increases. Moreover, high temperature can improve the rate of diffusion and ensure the favourability of the substrate properties in terms of physical and chemical aspects, as well as it can speed up the rate of pathogen destruction in anaerobic digestion (Chew et al. 2021).

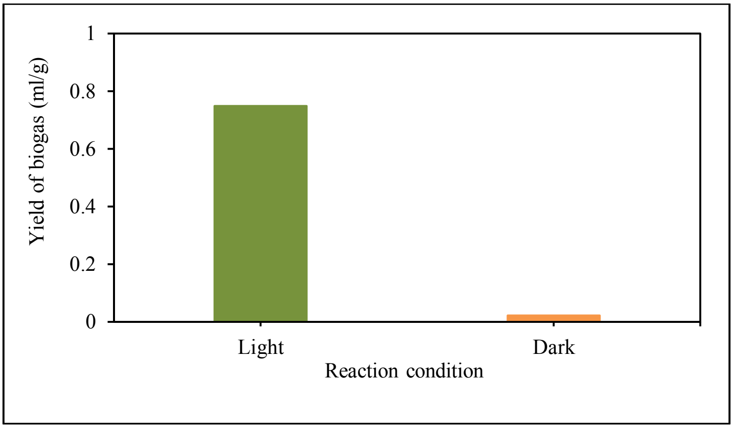

Figure 2: Effect of different reaction conditions towards biogas yield.

Retention time

Figure 3 shows the observation result of biogas production in the variation of retention time. It can clearly be seen in the figure, as the retention time increases from day 1 to day 4, the yield of biogas production also increases in the light digester (from 0.0150 ml/g to 0.7470 ml/g). A slight increase in the biogas yield (~0.01%) is also performed from day 4 to day 14, which indicates that in this study; the microorganisms require approximately 14 days to convert all the organic substrates into biogas.

On the other hand, the trend for dark digester was obviously different, where the yield of biogas is insignificant. The production of biogas is ranged only from 0.022 ml/g to 0.025 ml/g from day 1 to day 4. The amount of biogas is approximately maintained until day 14. From the results obtained, it can be explained that the increase in the biogas yield is due to the presence of nutrients (microbial consortium) in the substrate. The presence of microbial consortium in anaerobic digestion produces a high amount of carbon dioxide, which increases the biogas production due to the increases of the microbes' bioactivity (Parra-Orobio et al. 2021).

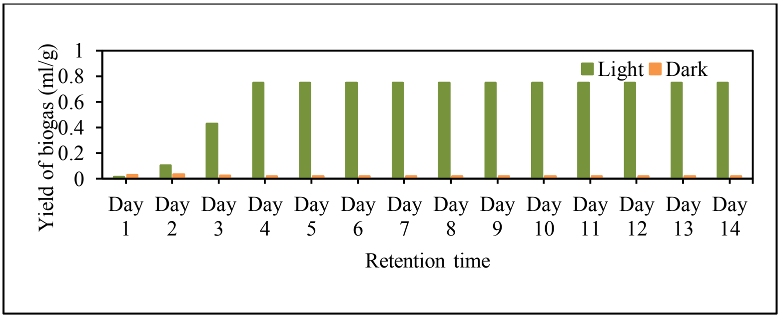

Figure 3: Effect of different retention times towards biogas yield.

Conclusion

In this study, biogas was successfully produced from the mixture of food and plant wastes under AD conditions. A small-scale anaerobic digester was built to conduct the experiment. The entire digestion reaction process was observed and measured in different reaction conditions and retention times. AD of the substrate demonstrated a biogas yield of 0.7470 ml/g in the presence of light and 0.025 ml/g in the absence of light for 14 days of observation. In addition, reaction temperature played a major role in the rise in biogas yield. Besides that, the addition of nutrients contributes to the production of biogas during the reaction process. A further study needs to be conducted to explore the parameter's ranges during AD reaction process to attain more understanding about the potential of the feedstock used in this study.

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