Preliminary Study on Biogas Production from Organic Kitchen Waste Degradation

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ABSTRACT

Biogas is an important development in the pursuit of renewable energy and sustainable development in Malaysia. Biogas is obtained through anaerobic digestion of organic waste (i.e. agricultural waste, food waste). Tons of food waste are generated from high concentration point sources e.g. restaurants, cafés, markets et cetera and finally dumped at landfills. This paper presents the preliminary study of anaerobic digestion of local kitchen waste for biogas production. In this study a modified 22L High Density Polyethylene (HDPE) reactor was designed for a batch anaerobic system. The kitchen waste was obtained from two cafeterias, grinded and fermented anaerobically for 11 days. The three layers (top, middle and bottom) of the food waste (substrate) in the HDPE reactor were analyzed daily. Metabolic products produced from the anaerobic digestion were acetic acid, propionic acid, and butyric acid. Throughout the fermentation process, the pH range was from 3.8 to 2.8. The Chemical Oxygen Demand (COD) range during the digestion process was 45-226 mg/L. The resident microorganisms in the reactor were found as rod-shape Gram (+) and Gram (-), cocci Gram (+) and yeast. However, the volume of biogas produced was very low at 133 μmol L^{-1} d^{-1}. The low pH range in the reactor was hypothesized to be the reason for the low production of biogas.

Keywords: *biogas, microorganism degradation, kitchen waste, organic waste*

Introduction

Kitchen waste has been a tremendous source of carbon and nitrogen that are freely and easily available in the local environment. Restaurants and cafeterias have been contributing a major portion of such waste. Currently, about 50% of 0.8 to 1.3 kg waste produced per capita per day in the Malaysian household is organic waste (Bavani & Phon, 2009; Fauziah, Simon & Agamuthu, 2004). Therefore, the utilization and manipulation of kitchen waste should be explored and be beneficial to the community. Beyond that, this waste should be used to balance the ecosystem naturally as it is mostly organic materials. Without proper treatment, the waste is not only polluting the system, but eventually also taking a lot of space and cost to manage. A few solutions towards managing the household waste involve vermicomposting and recycling (Abdul Jalil, 2010). Due to the lack of local research on biogas or biohydrogen production from organic waste, thus, this study aims to screen and to evaluate the potential of biogas production from kitchen waste of selected cafeterias around UiTM Pahang, Malaysia. This research is a preliminary study in observing a few important parameters in producing biogas from kitchen waste using a modified reactor made of HDPE.

Literature Review

The oil crises have brought great interest in the exploration of renewable energy. Biogas can act as a promising alternative fuel by substituting considerable amounts of fossil fuel (Bari, 1996). According to Wu (2008), the solar energy stored in biomass (organic matter formed by photosynthetic capture of solar energy and stored as chemical energy) released as biogas through anaerobic digestion which consists of a mixture of methane, carbon dioxide and some

trace gases. Food waste is one of the largest contributions in biomass which is always disposed using landfill dumping or incineration methods. However, the disposal of food waste at landfill occupies large-scale areas and the incineration of wet food waste consumes a lot of energy. Improper disposal of food waste causes odor, potential vermin and scavengers' infestation (Chua, Yip & Nie, 2008). Thus, food waste recycling is possible to reduce the costs of waste treatments, odors and refuses from landfills, and air pollutants from incineration (Lai, Ke & Chung, 2009).

Food waste is defined as uneaten portion of meals, leftovers and trimmings from food preparation from restaurants, kitchens and cafeterias (Chua et al., 2008). The composition of food waste from kitchen varies and will affect the production of organic acids in acidogenesis stage (Hafid et al., 2010). The portion of food waste consists of meat, bones, fats and oils, greens and fruits, carbohydrates and moisture (Chua et. al., 2008). According to Wang, Wang, Ren and Wang (2005) and Zhang, Wei-min and Pin-jin (2006), kitchen waste contains high carbohydrate content that can be broken down to soluble sugars such as glucose, fructose, and galactose in the saccharification process. The soluble sugars will then be utilized for acidogenic bacteria growth that is commonly found in kitchen waste for organic acids production. Anaerobic digestion is a natural process in which microorganisms break down biodegradable material in the absence of oxygen and can be used to treat various organic wastes and thus recover bioenergy in the form of biogas (Wu, 2008). Anaerobic treatments and digestion of organic matter have been reported as a suitable method for the treatment of organic waste and the production of energy from biogas combustion can be used for cooking, heating and electric generation (Fernandez, Sanchez & Font, 2005). The high moisture content in food waste is feasible for composting and anaerobic degradation (Chua et al., 2008). Paola, Francesco, Daniele and David (2007) described an anaerobic process as involving three distinct stages. Firstly, the hydrolysis of long chain hydrocarbon into smaller chain hydrocarbon. The second stage is the conversion of smaller chain hydrocarbon from organic matter to acetic acid, fatty acid and hydrogen by acetogenic bacteria. At this stage, the pH will drop due to the formation of acid. The final stage of anaerobic process is the methanogenesis which is the conversion of acetic acid into methane and carbon dioxide.

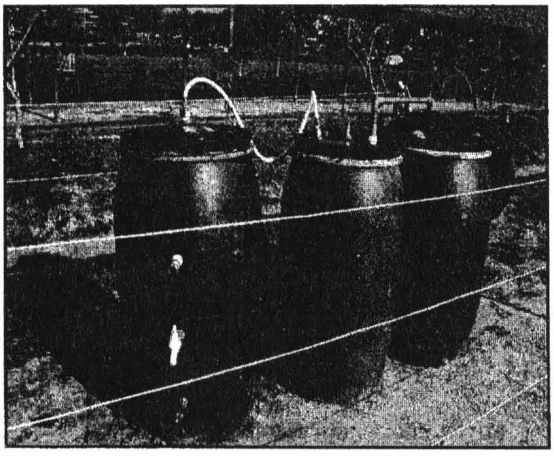
Material and Methods

Sample Collection and Preparation

Food waste was collected from two local cafeterias in UiTM, Jengka. The collected food waste was initially grinded with 1:1 ratio of water for the purpose of waste homogenization. Waste homogenization is very important to ensure representative sampling. The leftover that had thick gravy appearance was then used as feedstock or substrate for methane production.

Experimental Set Up

The experiment was conducted in a modified PTFE reactor with the total capacity of 22L. The grinded food waste working volume of the reactor was 16.5 L. The reactor was tightly sealed to avoid the loss of biogas produced during the 11 days fermentation. The reactor was connected to a modified PTFE tank (Tank 1) which was filled with water for gas collection and an empty tank (Tank 2) was used for volume determination by water displacement method (Figure 1). The samples were collected every 24 hours. The biogas produced was collected and stored in bottles containing acidic water.



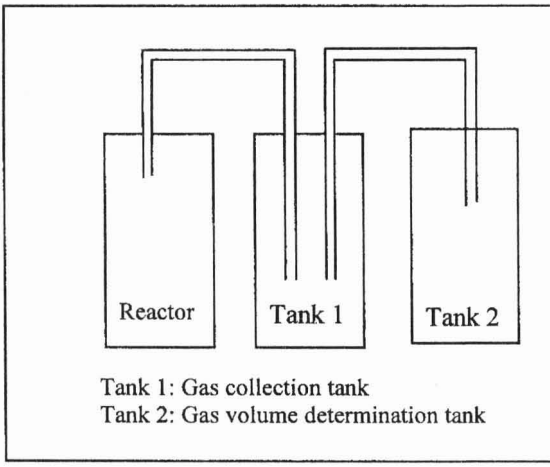


Figure 1 Photo of reactor set-up and the schematic diagram

Sample Analysis

Methane Assay

1 ml of gas sample was taken using a gastight syringe and measured with a gas chromatography (GC Shimadzu) equipped with thermal conductivity detector and a molecular sieve column (PorapakQ) with nitrogen gas as the carrier gas.

Chemical Oxygen Demand Assay

Samples were analyzed for COD by using Hach Method. Proper dilutions of samples were made prior to digestion.

Volatile Organic Acids Determination

Samples were centrifuged at 10 000 rpm for 10 minutes. Supernatants were double filtered by using 0.45 μm syringe filter. The supernatants were then manually injected into isocratic HPLC pump (Waters 1515). The dual λ absorbance detector was set at 240nm (Waters 2487). Mobile phase, column and flow rate were 0.1 % v/v phosphoric acid, Shodex RCSpak KC-811 and 1 ml/min respectively.

Microorganism Screening

Five media, Mac Conkey Agar (MCA), Saboured Dextrose Agar (SDA), Nutrient Agar (NA), de Man, Rogosa and Sharpe Agar (MRSA), and Potato Dextrose Agar (PDA) were used as selective and non-selective media for residence microorganism screening from the sample. Samples were incubated at 37°C for 24 hours. The microorganisms were stained using Gram's staining and simple staining for bacteria and fungi respectively.

pH Profile

The pH values of the samples were analyzed by using a pH meter 3305 Jenway.

Limitation

Several limitations were notified in this study. Firstly, the sample was a mixture of grinded leftover cooked food and waste from preparation food. Secondly, the sampling of the three

layers food waste can only be obtained at certain period, as the grinded waste has been precipitated at the base of the HDPE reactor. Thirdly, the screening identification of the microorganism was done using a few selected available agar media. Fourthly, the external environment of the reactor was not consistent, as it was placed at an unroofed ground near to the cafeteria.

Results and Discussion

Biogas Production

The amount of producible biogas and methane content are some of the important aspects of anaerobic digestion. The chemical composition of feedstock determines the biogas yield potential. The biogas produced in this study was very low, with a total of 133 μmol L^{-1} d^{-1} (CO_2 at 62.97 μmol L^{-1} d^{-1}, CH_4 at 1.887 μmol L^{-1} d^{-1}, and H_2 at 68.91 μmol L^{-1} d^{-1}). It was not comparable to the production of biohydrogen by Buitron and Carvajal (2010), for obtaining maximum volumetric hydrogen production rate of 48 mmol H_2 per liter reactor per day. This may be due to the feed load and infiltration of air (Karim, Hoffmann, Klasson & Dahhan, 2005). Normally, the incubation or retention time of various type of waste to produce biogas or biohydrogen ranged from 14 to 140 days (Hecht & Griehl, 2009; El-Mashad and Zhang, 2010). A study of biogas production from cassava tubers in Thailand showed better yield after only 10 days of incubation and the harvested methane was the maximum at 67.92% from 1.95 L^{-1} d^{-1} yield (Anunputtikul & Rodtong, 2004).

Organic Acid and pH

Organic acids fermentation is highly affected by aeration, pH, temperature, inocula and substrate characteristics (Bernd, 2007; Zhang, Pin-jing, Ning-fang & Li-ming, 2008). The temperature should range from 30 to 60 degree C. Methane producing bacteria require a neutral to slightly alkaline environment (pH 6.8 to 8.5) in order to produce methane. Acid forming bacteria grow much faster than methane forming bacteria. If acid-producing bacteria grow too fast, they may produce more acid than the methane forming bacteria can consume. Besides, when the pH drops, the system may become unbalanced and inhibit the activity of methane forming bacteria, thus methane production may stop entirely (Chua et al., 2008).

In this study, the pH profile started at acidic point (Figure 2) due to huge amount of grinded organic material (feedstock). The grinded feedstock looked like broth gravy with a slightly pungent smell. The pH was increasing throughout the incubation time. The pH profile co-related with the organic acids formation (Figure 3). The acetic acid and butyric acid were found throughout the incubation, while the propionic acid was only found at the end of 11 days. These three major volatile organic acids acted as indicators of acid-forming bacteria being present in the reactor. The fluctuating production of the organic acids may be due to inconstant external environment (temperature and humidity).

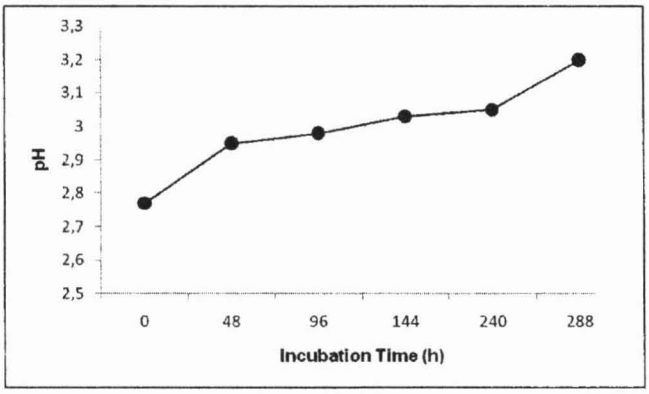


Figure 2 pH profile of fermented food waste

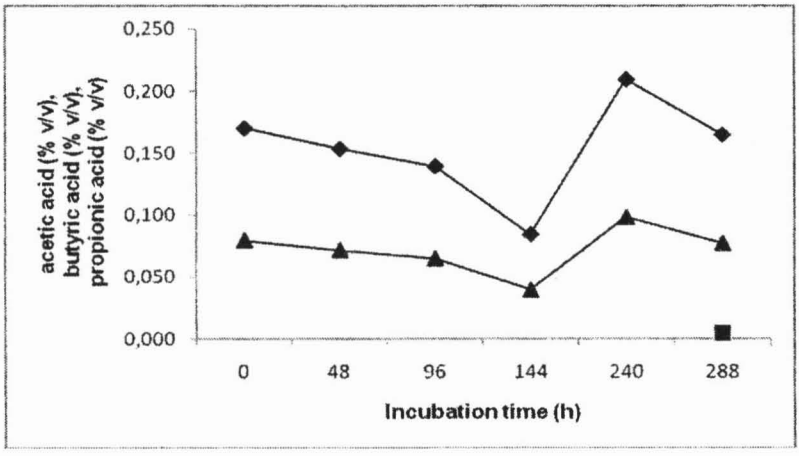


Figure 3 Formation of organic acid in food waste fermentation. Acetic acid (♦), butyric acid (▲) and propionic acid (■).

COD Loading

The preliminary COD loading increase may be due to the aerobic condition at the beginning that contribute to the aerobic microorganisms activity. After day 10, there was a sudden decrease of COD value from 155 g/L to 53 g/L. This showed the anaerobic activity has stabilized and the reduction of COD is about 65%.

Microorganism Screening

The surface screening of resident microorganism was done with a few types of media. The isolation was done aerobically, thus the microorganisms obtained were aerobic and facultative anaerobes. The isolated microorganisms were studied based on the morphology character. Figure 4 shows some of the microorganism found in the reactor. The Mac Conkey Agar (MCA) served as selective agar that only select Gram's negative bacteria against the Gram's positive bacteria. The viable bacterium on Figure 4A was rod-shape with average size of 0.4μm. The MRSA is a useful media for Lactobacilli sp. Two cultured bacteria and yeast obtained from MRSA were observed at Figure 4B, 4D and 4C respectively. The yeast was eye-drop shape, bigger in size, with average length and diameter at 0.785 μm and 0.355 μm respectively. The bacteria, on the other hand, were rod-shape; Gram's positive and also found

reproducing the daughter cell by binary fission. The average size of the bacteria was 0.414 μm.

On the NA media, two types of microorganisms were found (Figure 4E). NA is generally used in microorganism isolation as it is a nutrient-rich and nonsuppression medium type. The bacteria obtained were diplococcal type, Gram's positive, with average length of 0.123 μm. The yeast average length, width and surface area were 0.87 μm, 0.355 μm and 0.49 μm^2 respectively. The last figure, 4F, showed yeast had been obtained on the SDA. The SDA is a medium used for fungi screening. The average length and width of the yeast were 1.0 μm and 0.385 μm respectively. Overall, the microorganism screening showed that the resident microorganism in the reactor were mostly acidogenic bacteria and also a few types of yeast. Besides obligate anaerobic bacteria and methanogenic archaea (for example; *Clostridium* sp. and *Methanobacterium* sp. respectively), some finding of *Entrobacter* sp. and *Pseudomonas* sp. were found useful in producing biogas and biohydrogen from organic waste (Wang and Wan, 2009).

Conclusion

The production of biogas harvested in this study was only at traceable amount. The limitations and short retention time applied in this study were hypothesized to be the causes for the low production. However, the surface screening on a few parameters in this study showed a considerable result. Further detailed analysis of the whole system should be applied to enhance the biogas production.

Future Development and Recommendation

This preliminary study has given a rough idea on biogas production via microorganism degradation of kitchen waste. The unlimited source of organic waste would be the promising feedstock for future improvement. In order to have maximum yield of biogas, a few recommendations on the production system should be considered. The retention time of the feedstock is suggested to be prolonged up to 30 days or until the production of methane cease. The addition of pure inocula of methanogenic bacteria such *Clostridium* sp. would be highly suggested to accelerate the degradation. However, the treatment towards this obligate anaerobic species should be strictly followed. The mixing properties of the reactor would also influence the homogenization and aeration of the feedstock. Furthermore, mixing would consistently help the heat and mass transfer of the reactor.

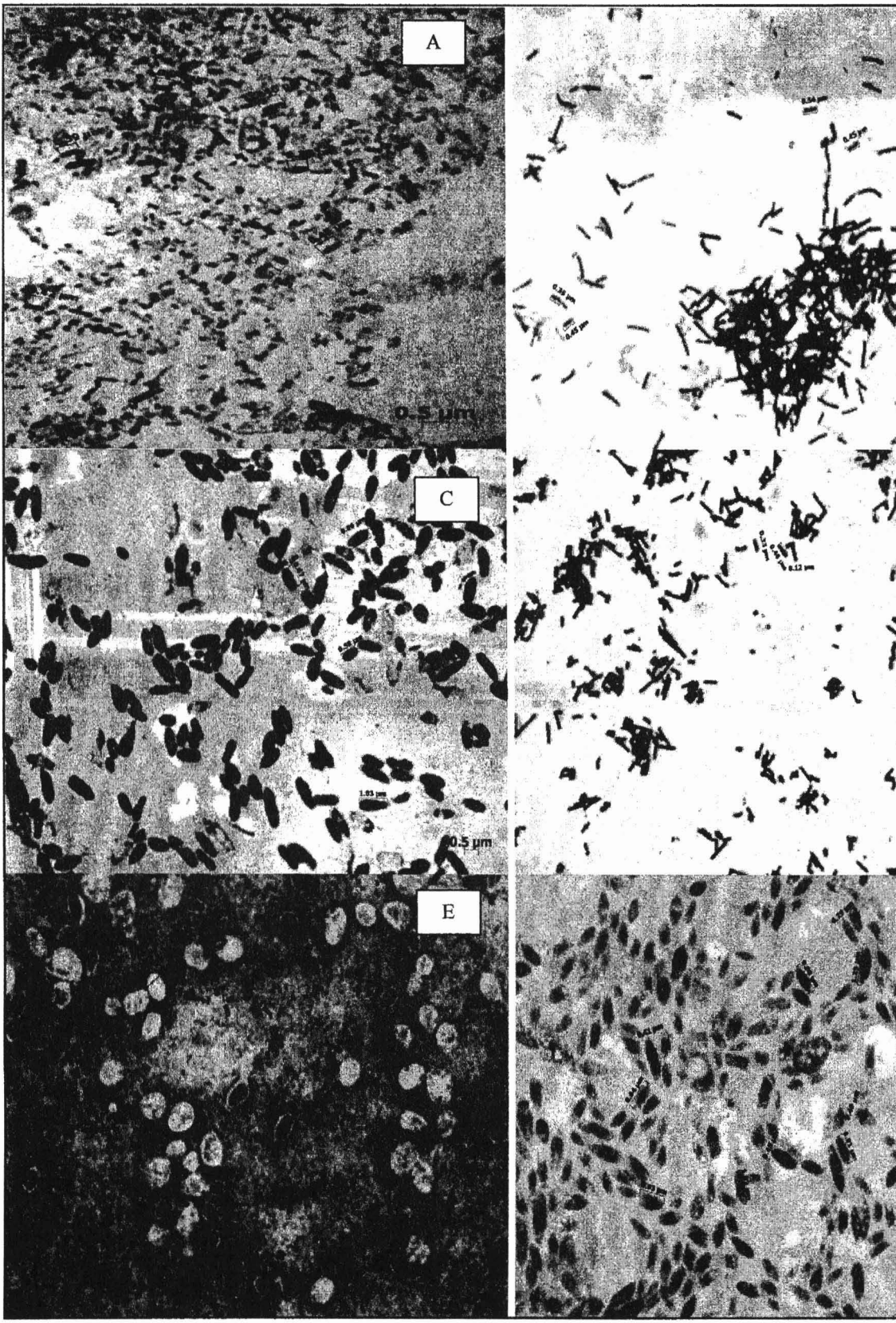


Figure 4 Staining of microorganisms from four types of media. A - MCA, B - MRSA, C - MRSA, D - MRSA, E - NA, and F – SDA.

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