Anaerobic Digestion of Pineapple Peels and Cores through Biogas Production

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Abstract

Malaysia is one of the countries that contributed about 1% production of pineapple. It produce great amount of waste per year. Pineapple wastes consist of peels, cores and crowns. Therefore, the environmental pollution occurs as the waste burnt in an open field. The illegal activities of disposing the waste are also happened as the landfills are limited. In order to reduce the environmental pollution, the pineapple waste which is rich in cellulose, hemicellulose and other carbohydrates is used in generation of biogas by anaerobic digestion. The pineapple waste is mixed in the 2 litres bioreactor with the inoculum which is wastewater. The initial pH value for the peels, cores, wastewater, water, and digester consist of pineapple with water and pineapple with wastewater were recorded. The ratio of pineapple peels to cores is 7:5 whereas the ratio of wastewater to pineapple peel and cores for 3 experiments are 4:2, 4:4 and 4:6 respectively. The biogas yield is observed and recorded for HRT 18 days. For comparison purpose, the constant sample was set up using water and pineapple peels and cores with the same ratio as experiment 1. The biogas yield is observed and recorded for 18 days. Lastly, the final pH values were recorded. The data recorded may vary the theory caused by the limitation faced and some recommendations were discuss.

Keywords: Anaerobic digestion, biogas, bioreactor, hydraulic retention time (HRT), pH

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1. Introduction

Pineapple or scientific name is *Ananas comosus* is a type of tropical plant and was introduced to Malaya in the 16th century by Portuguese. Pineapple plantation continues to expand in some areas in Malaysia especially in Johor. Pineapple waste consist of sucrose, glucose and fructose (Abdullah & Mat, 2008). Pineapple waste is a by-product resulting from the processing of pineapple that consists of peel, core and crown. Malaysia contributes to 1% of world pineapple production and at the same time produce great amount of waste generation per year (Mohd Zain et al, 2012). The solid residual of pineapple waste that produced in Malaysia estimated 450 000 tonnes per year (Moon and Woodroof, 1986). The pineapple waste is either used as animal feed or being disposed to the soil which may lead environmental problems (Correia et al., 2004).

After harvesting activities, most of the pineapple residue is disposed and either serves as fertilizer or is burnt in an open field. However, these methods only contribute to air pollution (Wan and Zainuddin, 2013). Therefore, the waste is disposed in illegal ways since disposal of these wastes is expensive due to high costs of transportation and a limited availability of landfills. Thus, possible ways to handle pineapple waste without affecting the quality of the environment is by converting this waste into a value product by some of related processes.

Wastewater is any water that had been contaminated with unwanted materials (Bitton, 2005). Treatment of wastewater will produced sludge for disposal or beneficial used and it may takes several days or weeks to produce it (Turovskiy & Mathai, 2005). Wastewater contains of nutrient for aquatic plant but it may also contains of toxic compound that may lead to environmental problems (Metcalf & Eddy, 2003). Types of microorganism in wastewater are fungi, protozoa, rotifers and nematodes, and bacteria. Bacteria is unicellular organism (Gerardi & Zimmerman, 2004). Carbon and energy sources are the main component for bacteria growth in wastewater (Gerardi, 2006).

The treatment of organic industrial waste and agricultural waste including those from fruit and vegetable waste (FVW) processing has been widely used anaerobic digestion (Marty, 1984; Misi and Forster,2002) and the process of converting FVW to methane gas is commercially viable (Bouallagui, Touhami, Ben Cheikh, & Hamdi, 2005). Anaerobic digestion might occur as the waste are normally used as animal feed or are disposed of in landfills, which leads to the methane leakage from the landfill site (Viswanath, Devi, & Nand, 1992). The two stages of anaerobic treatment consist of waste conversion by acid forming bacteria followed by stabilization with methane forming bacteria (PERRY L. Mc.CARTY, 1964). Consequently, the environment problem was occurs directly, including the formation of methane gas that can cause global warming. After the research was made from one of the organization, it has been conclude that the biogas production is the main advantage of anaerobic digestion, which can be used for the production of renewable energy (Arhoun, Bakkali, Mail, Rodriguez-maroto, & Garcia-herruzo, 2013). Anaerobic digestion produce high energy generation rate of biogas (González-González & Cuadros, 2015). Meanwhile, the major limitation of anaerobic digestion of this waste in a one-stage is because of the high biodegradable organic content in fruit wastes (Bouallagui et al., 2001) where acidogens and methanogens are combined in one vessel.

Biomethanation of fruit waste is process that adds energy in the form of methane, high stabilized effluent which is neutral in pH and odorless (Bardiya, Somayaji, & Khanna, 1996). Bardiya, Somayaji, & Khanna, (1996) used 1.6L to 1.8L cattle dung slurry for their research. They used banana peel and pineapple waste as their substrates. For the method, banana peels or pineapple waste is added to the contents when methane content reached over 40%. Methane content in the biogas produced was analyzed by using a gas chromatograph. As the result, biomethanation of banana peel at day 40 gave the results that methane produced was 0.925 litres. For biomethanation of pineapple waste, after day 40 the methane produced was 1.3 litres.

Chulalaksananukul, Sinbuathong, & Chulalaksananukul, (2012) use some of method such as pineapple peels and cores, solid waste, indigenous microorganism ,batch reactor, fed batch reactor and 6 litres bioreactor. The microorganism that used in this research comes from industrial sewage and private company. The experiment was conducted in two type of experiment. First in batch process and another one in fed batch reactors that contains 4.8 litres of indigenous microorganism respectively. The observation was recorded every day until at day 30 for batch process, while day 20 for fed batch process. In further, at fed batch mode operations the discovered optimum condition was applied. The organic loading rate of 1,2 and 3 kg of organic fed and operated for the day 30 to achieve maximum methane production in about 11.2 litres. Another process which is biogas production in fed batch reactor shows the biogas production and methane concentration at HRT of 20 day using various organic loading rates was recorded. The result shows that an organic loading rate of $1 kg/m^3/day$, the amount of gases as well as the percentage of methane was highest in about 7.86 litres production of accumulative gas.

The aim of this experiment to determine the amount of biogas produced in anaerobic digestion of pineapple peels and cores as well as pollution reduction. Ratio of inoculum to pineapple waste (peels and cores) is the parameter that used in this experiment to observe the production of biogas.

2. Methodology

2.1 Substrates and inoculum

Pineapple peel and core used in this study was purchased from Bandar Seri Alam, Johor. The samples collected were stored at cooled place before used. Both pineapple peel and pineapple core were shredded using blender. The ratio of pineapple peels to core is 7:5. Meanwhile, the inoculum used in this research was sewage water from Indah Water Konsortium Sdn. Bhd (IWK) at Tampoi, Johor.

2.2 Laboratory digester

The experiment was conducted in 2 litres bioreactors. The bioreactor were wrapped with aluminium foil to avoid algae growth. The biogas and effluent gas was collected by using water displacement method.

2.3 Operation

The biogas production was started up by applying with powdered pineapple consisted of peels and cores. Single stage batch processes were operated at 25°C temperature with the ratio of pineapple peels and cores to inoculum are 4:2, 4:4 and 4:6 respectively. The constant sample was also set up by mixing the pineapple peels and cores with water. The ratio used for constant sample is 4:2. The pH of pineapple waste (peels with cores), inoculum, and water were tested and recorded before mixed them into the digester. The pH of the mixtures also were recorded.

2.4 Pilot studies

The observation of total amount of biogas was recorded every 2 days. The effect of varying loading rates of pineapple peels and pineapple cores by using the ratios and hydraulic retention times of 18 days were used. The three different sets results in different volumes of biogas production. In other hand, in constant sample, the presence of biogas is observed. The pH of the mixture were tested and compared with the initial pH value.

3. Results and discussion

This experiment was conducted by mixing the powder peel and core with wastewater using the ratio calculated for experiment 1, 2 and 3 with hydraulic retention time (HRT) of 18 days. All the experiments were repeated twice to get accurate data. The powder pineapple peel and core were used instead of chopped pineapple peel and core due to increase the surface area. The larger the surface areas between pineapples peel and core the higher the rate of reaction to produce the biogas. The volume of wastewater for experiment 1, 2 and 3 are fixed while the weight for pineapple peel and core is manipulated. The ratio of wastewater to pineapple peel and core for experiment 1 is 4:2. For experiment 2 and 3 the weight of pineapple peel and core is being scaled up to 4:4 and 4:6 respectively. For each 1 kg of pineapple, the ratio for pineapple peel to pineapple core is 7:5. There are one more bioreactor being set which act as control sample consist of mixing pineapple peel and core with water. The purpose is to compare the presence and volume of biogas production of mixing pineapple peel and core with wastewater and mixing of pineapple peel and core with water. The control sample use the ratio same as experiment 1. So, the comparison between control sample and experiment 1 were been made.

Table 1: Initial pH value

Substances	**EXP 1**	**EXP 2**	**EXP 3**
Core	4.10	4.10	4.10
Peel	4.90	4.90	4.90
Wastewater (inoculum)	6.50	6.50	6.50
Mixture(peel + core + wastewater)	5.15	4.35	4.10
Water	6.40		
Constant (peel + core + water)	4.30		

For the initial pH value stated in Table 1, the pH value of pineapple's cores, pineapple's peel and inoculum is 4.1, 4.9 and 6.5 respectively. From the reading it shows that the pineapple core is more acidic than pineapple peel. The pH reading for mixture of inoculum with pineapple waste is depends on the ratio given. For first experiment, the ratio inoculum to pineapple waste is 4:2 and the pH value of the mixture is 5.15. For second experiment, ratio of inoculum to pineapple waste is 4:4 and the pH value of the mixture is 4.35. For third experiment, ratio of inoculum to pineapple waste is 4:6 and the pH value of the mixture is 4.1. For the constant sample which is the inoculum is replace with water and the ratio is the same with experiment 1, 4:2 and pH mixture is 4.3. As for water, the pH recorded as 6.4 which have less 0.1 from pH wastewater. After 18 days, pH value of all done experiment is taken. For first, second, third and blank experiment the pH reading for the mixture is 2.05, 2.0, 1.9 and 1.5 respectively as recorded in Table 2. From observation, pH reading is fall from the initial reading due to wastewater that contain alum from the treatment in IWK (Siti Noorain Roslan, 2013). Bacteria in wastewater only active in pH average 6.8 to 7.2 (Gerardi, 2006). Since the pH mixtures are too acidic, the bacteria are not active thus there is no gas presence in this experiment.

Table 2 : Final H value

Substances	**EXP 1**	**EXP 2**	**EXP 3**
Mixture (peel + core + wastewater)	2.05	2.00	1.90
Water in gas collector	5.05	4.80	4.70
Constant (peel + core + water)	1.50		

After the pineapple peel and core mixed with wastewater, the anaerobic digestion has occurred. The sucrose in the pineapple peel and core reacted with the wastewater in the bioreactor. It was supervised for every 2 days to observe the presence and volume of biogas in the gas collector. This experiment was repeated twice to get the accurate data. Unfortunately, there is no presence of biogas in bioreactors of experiment 1, 2, 3 from day 2 until day 14. However, the control sample produces the biogas after day 4. This is may cause by the different types of bacteria in the wastewater and water. The bacteria in the wastewater cannot react with the pineapple waste. It shows that bacteria in the wastewater not compatible for anaerobic digestion while in water, the bacteria are active so it reacts with pineapple waste by anaerobic digestion and produced the biogas.

Table 3 : The bio as resence

Da s	EXP 1	EXP 2	EXP 3	Constant
2	Nil	Nil	Nil	Nil
4	Nil	Nil	Nil	Presence
6	Nil	Nil	Nil	Presence
8	Nil	Nil	Nil	Presence
10	Nil	Nil	Nil	Presence
12	Nil	Nil	Nil	Presence
14	Nil	Nil	Nil	Presence

The HRT set for this experiment is 18 days which is quite short because the biogas production will produce in a few weeks. Chulalaksananukul, Sinbuathong, & Chulalaksananukul, (2012) found that methane and biogas produce at day 25 for the reaction of pineapple waste with industrial sewage by anaerobic digestion. The initial biogas yield was low and increased slowly and became stable after fourth week. (Chulalaksananukul et al., 2012). Viswanath et al (1992) found that in 16, 20 and 24 days the mixture become stable. Therefore, the data in table 3 assumed that the HRT for this experiment is not enough, so the mixture not able to produce the biogas yet.

One of the reasons why the experiment not accomplished is the source of wastewater itself. IWK is where the wastewater had been taken and used in this experiment. Wastewater from IWK contains too many unknown materials from many sources such as residential, industries, hospitals, hotels, factories, airports and etc. These unknown materials contain water, urea, dung, hairs, food, vomit, paper, sand, grit, sanitary napkins and many more. Microbial pathogen that consists in the wastewater is separated in three groups which are viruses, bacteria and the pathogenic protozoan (Toze, 1997). These materials will produce bacteria and these bacteria are not suitable in biogas production. These materials will produce bacteria and these bacteria may not suitable in biogas production. As result, after leaving the experiment within 18 days, the collector does not contain any gas that supposed to be evolved. This is assuming that the bacteria do not react with pineapple peels and cores. From ensilage on pineapple processing waste for methane generation (Rani & Nand, 2004) they used cow dung slurry as their inoculum and there is a presence of gas after leave it in period of time. Furthermore, the bacteria are active in temperature 30°C to 35°C (Gerardi, 2006) but in this experiment the average temperature is 25°C.

In addition, the factors influencing the size of the bioreactor also effect the chemical reaction that occurs between sludge and pineapple waste. Bioreactor is a system in which a biological conversion is affected. Although this definition can apply to any conversion involving enzymes, microorganisms, and animal or plant cells (Williams, 2002) .Based on our observation, the water in the test tube does not change in a timely manner. This situation shows the reaction occurs may produces a gas, but due to the large size of the bioreactor caused the resulting gas filled the air above the bioreactors. Brownian rules have stated that, irregular motion exhibited by minute particles of matter when suspended in a fluid. The random motion of particles suspended in a fluid resulting from their collision with the quick atoms or molecules in the gas or liquid (Haw, 2012).

The effect has been observed in all types of colloidal solid-in-gas, and liquid-in-gas. The effect, being independent of all external factors, is ascribed to the thermal motion of the molecules of the fluid. The resulting gas filled the empty space in the container and compressed so that it fills the space.

Next, the biogas produce are soluble in water. Based on observation after the experiment was done, there are yellowish residues at the bottom of the water displacement and this indicated that the biogas produce might be soluble in water. For example from experiment 1, the value of pH before the experiment is 6.5. After the completion of experiment was done in 18 day, the pH value is decrease until 5.05. The result shows that the water is in acidic condition. By the research that we made, the biogas is soluble in water at certain temperature. The solubility of a substance depends on the physical and chemical properties as well as temperature, partial pressure and the pH of the solution. According to the theory, the biogas is soluble in water; 20g per kg water at standard temperature and pressure. The solubility of methane in water decreases with increasing temperature in the presence of hydrates (Subramanian, 1999).

4. Conclusion

In these experiments, after 18 days all the main experiments did not show the expected result. As refer in some journal, the HRT should be in average 40 days. Wastewater from IWK contains too many materials and probably the bacteria are not suitable in biogas production. The mixture should expose to the sunlight (temperature 30°C to 35°C) to make sure the bacteria active for the reaction. The size of reactor also plays vital reason why the experiment failed. The volume of mixture is too small in the reactor used. The size of bioreactor should in smaller in size and the volume of mixture is increased until half and above the container. So that, there are a small space for gas production to compress and when the limitation of gas occurs, the gas will push up into the tube and flow to the gas stream. Bioreactor that which has the shape like a nozzle on interiors part may help to increase the gas velocity toward the direction of the tube. Surprisingly, blank reactor shows the positive result. This is may be the bacteria in water suitable with pineapple waste.

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