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Design and Production of Methane Gas from Food Waste using Anaerobic Digestion

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Abstract

Biogas is one of beneficial and essential gas, which is widely used for the electricity, heat and transportation fuels. Biogas can be produced by digestion pyrolysis or hydro gasification. Digestion is a biological process that occurs in the absence of O_2 and presence of anaerobic organisms. The container in which the digestion takes place is called digester. In this work, the Biogas was produced through anaerobic digestion process at atmospheric pressure and the best temperatures between 30 - 65°C. When the temperature is below 15°C almost no gas is made. In this experiment, the food waste was incubated with sludge water in a tightly sealed container. Aerobic decomposition occurs first and CO_2 was produced while oxygen was consumed, once the oxygen has been depleted, the methanogen bacteria start growing and consumes the CO_2 to produce biogas. Therefore, one should expect an initial increase in CO_2 production followed by a decrease in CO_2 and a steady increase in methane production. The biogas obtained at the end of the reaction will be a mixture of CO_2 and CH_4. The CO_2 can be monitored using a CO_2 detection probe. The methane can be identified by burning it. The methane gas was collected in the plastic bottle to measure it by water displacement and then test it by using a Bunsen burner.

Key word- Biogas, Anaerobic Digestion, Methane, Food waste, CO_2

I. INTRODUCTION

Biogas is 60-80% methane and is created by a process called anaerobic digestion, at the end of the digestion period, it's leaving a nutrient- rich substance which is called digested. Anaerobic digestion is carried out by a range of bacteria in the absence of oxygen. Initially, carbon dioxide is produced aerobically by the decomposing organic matter until an anaerobic environment is created. After the initial digestion, a group of bacteria known as methanogens converts the feedstock into methane and carbon dioxide (Arsova et al. 2008).

Anaerobic digestion has a number of environmental benefits including the production of green energy and natural fertilizers. The process of converting organic feedstock into biogas can serve as a substitute for fossil fuels and artificial fertilizers, reducing the amount of greenhouse gases released into the atmosphere. The problems associated with waste disposal are also alleviated by the generation of useful products and decreased Methanogens are obligate anaerobes that cannot grow in the presence of oxygen. They use CO_2 as the final electron acceptor and Hydrogen as a source of electrons. The reduction of CO_2 produces methane gas as a byproduct of cellular metabolism. Methanogens are abundant in swamps and sludge water. They play an important role in biomass degradation and CO_2 consumption (VIJ, S. 2011).

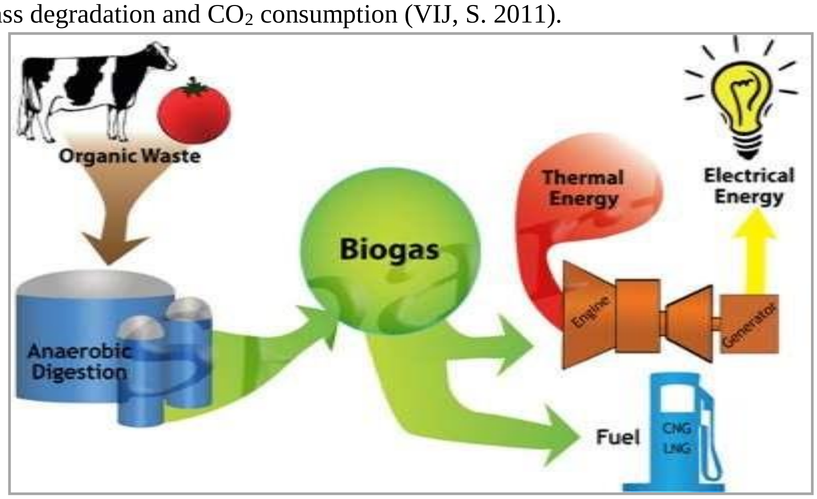

Fig. 1: Anaerobic Digestion for production of Biogas (G, Northrup .2015)

Food waste is the organic material having the high calorific value and nutritive value to microbes that is why the efficiency of methane production can be increased by several orders of magnitude. It means higher efficiency and size of the reactor and cost of biogas production is reduced. Also, in most of cities and places, food waste is disposed in the landfill or discarded, which causes the public health hazards and diseases like malaria, cholera. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences: It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease-bearing vectors. Also, it emits an unpleasant odor and methane which is a major greenhouse gas contributing to global warming (Distefano & Belenky, 2009). The sustainability of conventional energy together with their pollutions to the earth made renewable energy as the prime need for the time being. Municipal waste generation is increasing tremendously with the population and also the development of industrialization and urbanization. Municipal waste is being a nuisance to the earth by volatile organic compounds emission, leachate formation, attracting vectors (rodents, birds and insects) and also being jeopardy to the public health (Scaglia et al., 2009). Other waste management methods such as incineration & pyrolysis cause air pollution problems. The purpose of this research work is to conduct the production of biogas through anaerobic digestion & determine whether it is a green method or otherwise. Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of the bio- geochemical carbon cycle. Anaerobic digestion for production of biogas was shown in figure 1.

II. EXPERIMENTAL SETUP & METHODOLOGY

A. Materials and Apparatus

The materials that were used to construct the bio-digester are listed below.

Plastic container at a length of 50 cm with the volume capacity of approximately 19 liters, CPVC (Chlorinated polyvinyl chloride) pipe (4 feet), elbows, tee, bucket, gas collection unit. Reducer, gum, ruler, and M-Seal, (blade, and knife) were utilized during the fabrication the digester. As well as, pH test paper, pairs of rubber gloves, pail, and various types of food waste, and tap water. The apparatus that were used for the experimentation are digester, blender, thermometer and gas stove burner.

B. Experimental Procedure

The following experimental procedures were used for the production of biogas from various waste material sources.

- First of all fabrication of the suitable design of bio- digester.
- Collect the food waste from the kitchen and preparation included homogenized in a kitchen blender.
- Dilution with water with 1:1 ratio and sampling for further analysis and feeding inside the digester.
- The food waste in the form of the paste was taken and mixed with tap water to make the fine slurry.
- A fresh sample was taken from the slurry for physicochemical analysis, such as the measure of pH of the sample before entering the digester.
- Finally, insert the slurry into the digester with the suitable temperature and pH.

Fig. 2: Amount of Methane Gas Produced from Grain, Fruit & Vegetable wastes.

Fig. 3: Design of the bio-digester

III. RESULTS AND DISCUSSION

A. Production Of Methane Gas from Food Waste

In this study, the wastes were blended with water before inserting into the digester. The three wastes were left six weeks respectively and the results obtained are shown in figure 2. Methane gas was successfully produced from the waste as expected before. From the figure 2 it was observed that the waste started to digest from the ninth day itself. Besides that, the figure 3 shows that the grain waste increases significantly.

As per the observation between the fruit and vegetable waste it was noticed that, on the ninth day onwards, the methane production gradually increased. Thus, it was likely that grain waste had the highest amount of methane gas was produced from the ninth day to day forty. The highest amount of methane was recorded as 2500 ml for grain waste on day 39 and 40 was shown in figure 4.

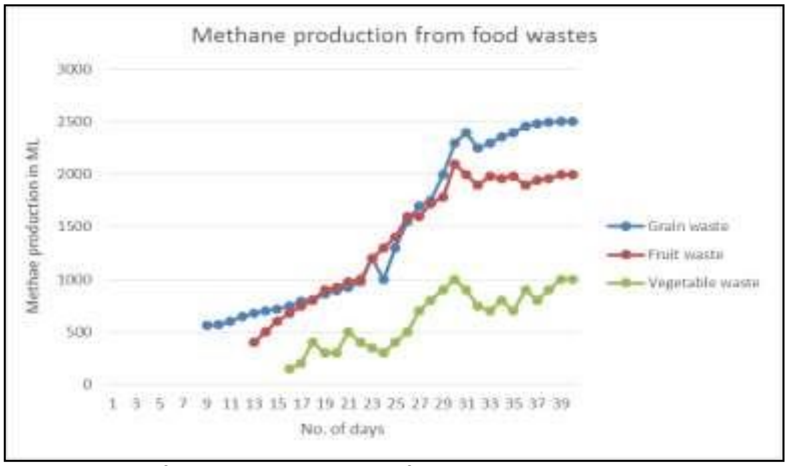

Fig. 4: Amount of Methane Gas Produced from Grain, Fruit and Vegetable wastes.

B. Methane Production from Grain Waste

Fig. 5: Biogas production from food waste Vs no. of days.

Figure 5 shows the volume of methane produced from the digestion of food waste (grain waste). The production of methane began on day 9 by producing 560 ml and increases each day until day 40 by producing 2500 ml. However, on day 39 and 40, it produces the highest volume of methane, which was 2500 ml.

1) Inside and Outside Temperature during First Study

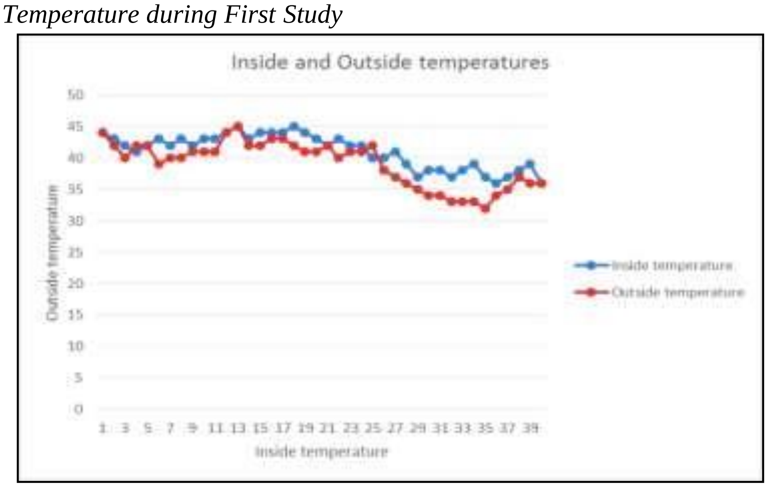

Fig. 6: Variation of temperature outside and inside the digester

Figure 6 shows the relationship between inside and outside temperature of grain waste within the 40 day retention period. Both temperatures were started with the same temperature on the first day, which was 44 °C. Then the temperature decrease from the second day to the fourth day from 44 - 40 °C for inside and outside temperature. Thereafter, the temperature varies from 45- 34

°C for grain waste. These temperature ranges signify a mesophilic thermal stage of biogas production in the range of 25 - 45 °C. The maximum methane produced from green waste was attained at day 38, day 39, and day 40 in which the outside temperature for these days was 37, 36, and 36 °C respectively. As well as, the inside temperature for these days was 38, 39, and 36 °C respectively.

C. Production of Methane from Fruit Waste

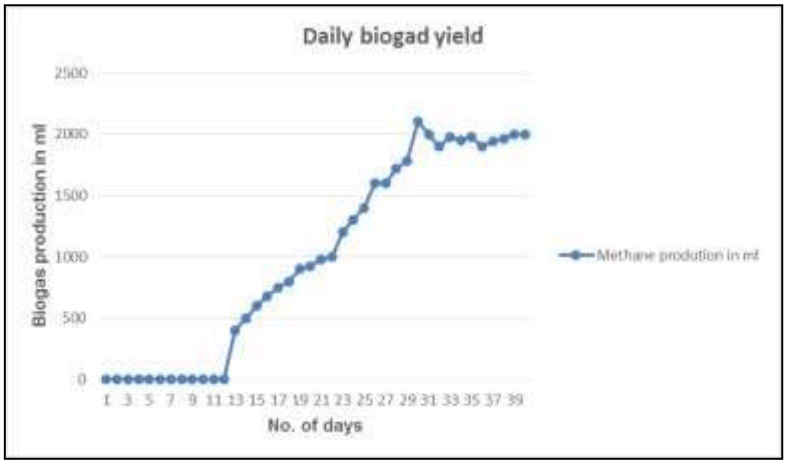

Fig. 7: Biogas Production from Fruit Waste in ml Vs no. of days.

Figure 7 shows the volume methane produced from the digestion of fruit waste. The production of Biogas began on day 13 by producing 400 ml and increases each day until day 31 by producing 2000 ml and after which it production began to fluctuate. However, on day 30, it produces the highest volume of methane, which was 2100 ml and began to decrease for each of the remaining days. As well as, at the last day of retention period the producing of biogas was reached to 2000 ml.

1) Inside and Outside Temperatures during Second Study

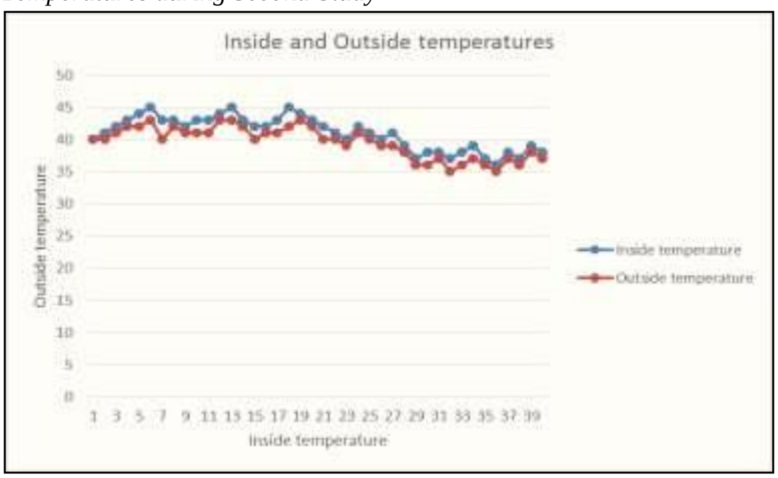

Fig. 8: Variation of temperature outside and inside the digester

Figure 8 shows the relationship between inside and outside temperature of fruit waste within the 40 day retention period. Both temperatures were started with the same temperature on the first day, which was 40 °C. Then the temperature increased until day 6 to 45 °C for inside and 43 °C for outside temperature. Thereafter, the temperature varies from 45- 35 °C for fruit waste. These temperature ranges signify a mesophilic thermal stage of biogas production in the range of 25- 45 °C. The maximum methane produced from fruit waste was attained at day 30, day 31, 39 and day 40 in which the inside temperature for these days was 38 °C, 38 °C, 39 °C, and 38 C respectively. As well as, the outside temperature for these days was 36 °C, 37 °C, 38 °C, and 37 ° C respectively.

D. Methane Production from Vegetable Waste

Figure 9: Variation Volume of Biogas produced from the digestion of vegetable waste.

The production of biogas began on day 16 by producing150 ml and increases each day until day 21 by producing 500 ml and after which it production began to fluctuate. However, on day 30, it produces the highest volume of biogas, which was 1000 ml and began to decrease for each of the remaining days. As well as, at the last day of the retention period, the producing of biogas was increased again and reached to 1000 ml.

Fig. 9: Graph between biogas production from vegetable waste in ml and no. of days

1) Inside and Outside Temperature during Third Study

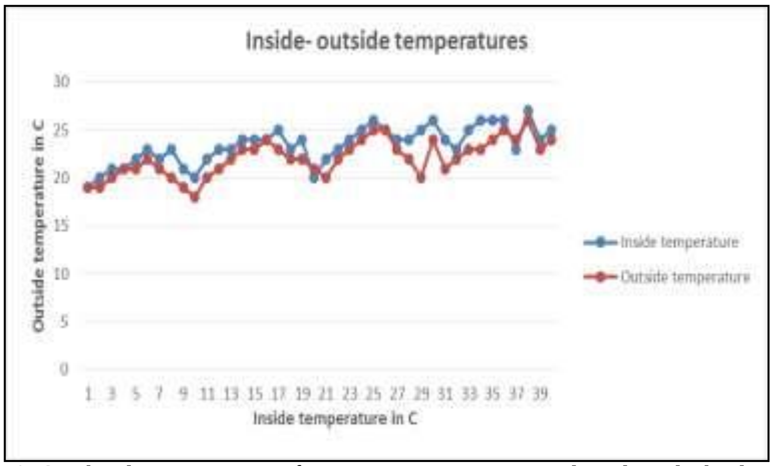

Fig. 10: Graphical representation of temperature variation outside and inside the digester

Figure 10 shows the relationship between inside and outside temperature of vegetable waste within the 40 day retention period. Both temperatures were started with the same temperature on the first day, which was 19 °C. Then the temperature increased until day 6 to 23 C for inside and 22 °C for outside temperature. Thereafter, the temperature varies from 21- 27 °C for vegetable waste. These temperature ranges signify psychrophilic thermal stage of methane production (15 °C to 25 °C). The maximum methane produced from vegetable waste was attained at day 30, day 33, 39 and day 40 in which the inside temperature for these days was 26 °C, 24 °C, 25 °C, and 24 °C respectively. As well as, the outside temperature for these days was 24, 23, 23, and 24 °C respectively.

E. pH Measurement During the Studies

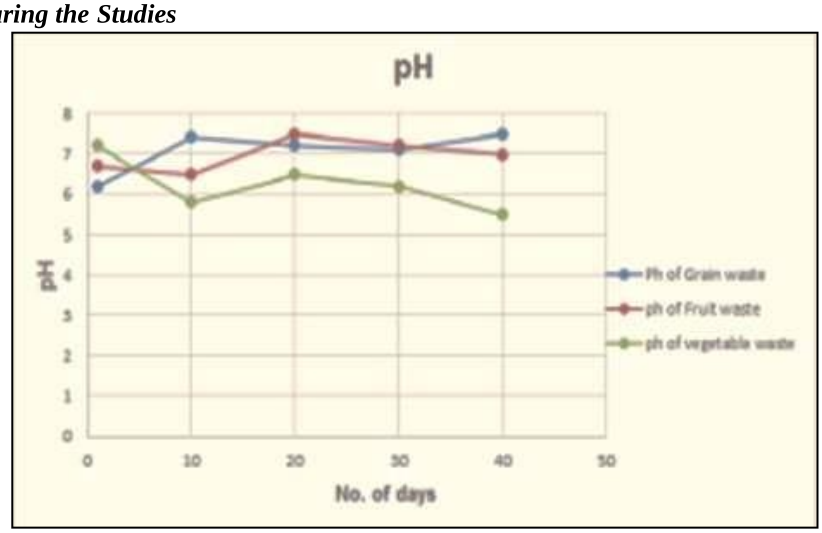

Fig. 11: Graphical Representation of pH Variation of the Digester

From figure 11 shows the pH of the digestion of grain waste, fruit waste, and vegetable waste within the retention period of 40 days. The pH of grain waste, fruit waste, and vegetable waste began in 6.2, 6.7, and 7.2 respectively on the first day. Then the pH continued to increase at grain waste at day 10 and reached to 7.4 in figure 3.10. On the other hand, the pH began decreasing to 6.5, 5.8 at Fruit waste and vegetable waste respectively. On day 20 the pH fluctuates between 7.2, 7.5 and 6.5 for all three wastes respectively, thereafter it began to reduce the pH for all three wastes to 7.1, 7.2, and 6.2 on day 30. The pH increased to 7.5 at the end of the retention period for grain waste, after which it continued to reduce to 7 and 5.5 for fruit and vegetable wastes until the retention period was completed. It is important to maintain the pH of an anaerobic digester between 6 and 8; otherwise, methanogen growth would be seriously inhibited (Gerardi, 2003). In this study, some of the initial pH of grain waste, fruit waste and the vegetable waste of the digestion of the three waste ranges between these standard pH to be maintained given by Gerardi 2003.

IV. CONCLUSIONS

In conclusion, this study showed that the methane gas can produce from food wastes. All the studies of the three wastes that were grain, fruit, and vegetable can be used in the anaerobic digestion process to produce of methane gas. From the result of the first study the Grain waste contributes to the highest methane and the total methane recorded was 2500 ml. And, from the second study of the Fruit waste contributes to second highest of methane production and the vegetable waste was produced the lowest amount from methane gas in the last study. The amount of methane measured from fruit and vegetable wastes were 2000 ml and 1000 ml respectively. The highest amount of methane gas depends upon the height amount of carbohydrates and sugar that show in the food waste. Hence, it can be concluded that anaerobic digestion is the excellent opportunity to produce an alternative fuel, which can be used for the local purposes like cooking, lighting, and generation electricity, managing the waste accumulation and to obtain organic fertilizer. As well as, it is a good way to reduce the waste from our society, hence, reduce the radiation of the harmful gases that affects the atmosphere and cause many environmental problems such as global warming. In addition, the uses of the waste to produce methane gas will help to reduce the many of the diseases that occur due to pollution problems.

REFERENCES

[1] Arsova, L., 2010. Anaerobic digestion of food waste: status problems and an alternative product. WTERT and Earth Engineering Center. 2-77.
[2] Azlina, W., and Idris, A, 2010. Preliminary study on biogas production of biogas from municipal solid waste (MSW) Leachate. Engineering Science and Technology.4.pp. 374-380.
[3] Azlina, W., and Idris, A., 2010. Preliminary study on biogas production of biogas from municipal solid waste (MSW) Leachate. Engineering Science and Technology. 4. pp. 374-380.
[4] Chua, K.H., Yip, C.H., and Nie, W.L.S., 2008. A case study on the anaerobic treatment of food waste and gas formation. International Conference on the Construction and Building Technology (ICCBT). 29. pp. 311-316.
[5] Composition and feature of Biogas, 2011. [Online] Available from: http://ethesis.nitrkl.ac.in/2547/1/THESIS_FINAL_REPORT.pdf [Accessed 29th Dec. 2015].
[6] Elango,D. Pulikesi,M. Baskaralingam,P. Ramamurthi,V. and Sivanesan,S., 2007. Biogas production from municipal solid waste with domestic sewage. Hazardous Materials. 141. pp. 301-304.
[7] David, P. Chynoweth, John M. Owens, Legrand,R., (2001). Renewable methane from anaerobic digestion of biomass. Renewable Energy, (22), pp. 1-8.
[8] Dearman,A and Bentham,F., 2007. Anaerobic digestion of food waste: Comparing leachate exchange rates in sequential batch systems digesting food waste and biosolids. Waste Management. 27. pp. 1792–1799.
[9] Suyog,V., 2011. Biogas production from kitchen waste. [E-book] Rourkela: Department of Biotechnology and Medical Engineering pp.8-13. Available at: http://ethesis.nitrkl.ac.in/2547/1/THESIS_FINAL_REPORT.Pdf [Accessed 25 Dec. 2015].
[10] Thimas, D. & Belenky, L.G., 2009. Life- Cycle Analysis of Energy and Greenhouse Gas Emissions from Anaerobic Biodegradation of Municipal Solid Waste. Journal of Environmental Engineering.135 (11).