Experimental study of biogas production using starch-rich food waste at pilot scale

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Abstract. An experimental study was conducted to study of biogas production potential from starch rich food waste of NIT Manipur boys hostel mess, NIT Manipur, Manipur, India (24.8320°N Latitude and 93.9128°E Longitude). Three (3) different plastic bio-digesters coated with black paint were proposed. Variation in ratio of water and substrate, variation in temperature of the digester was performed. The feed materials were grounded before feeding into the digesters. Biogas production and pH of the outlet manure were measured. It was observed that digester with higher temperature have produced more gas than the other digesters analysed at room temperature.

1. Introduction
Biogas is produced by anaerobic digestion of organic matter e.g. municipal solid waste, food waste, cow dung, poultry waste etc. in a sealed biogas digester. Anaerobic digestion is a biological process which occurs in the absence of oxygen. It helps in the breakdown of organic matter by the microorganisms which convert into biogas whose main composition is methane (CH₄), carbon dioxide (CO₂) and other gases in traces. The digestion of organic materials produces biogas. Sahu N et al. (2017) [1] have investigated the effect of presence of spices on the kitchen waste on the potential of biogas production. They have analyzed the effects of presence of garlic, red chilli, cinnamon, coriander, clove, turmeric, cardamom and black pepper on the anaerobic digestion of the kitchen waste. In the study the authors have concluded that there is significant reduction due to the presence of the species on the kitchen waste during biogas production. Presence of clove, cardamom and cinnamon have resulted in more than 85% reduction in biogas production potential, while black pepper by 75% and turmeric, garlic, coriander and chilli by 55-70% respectively. They have also noticed the reduction of the population of the microbes inside the digester due to the presence of spices.

Additions of co-substrates in small amount with sewage sludge have been found to increase biogas production by Maragkaki A.E. et al. (2018) [2]. They have found that addition of 5% food waste, grape residue, manure of sheep and glycerol (crude) increases the methane content of the biogas sample by almost 8.5%. It was observed that addition of glycerol (crude) enhances the production of biogas and proved to produce the maximum gas, amongst all the co-substrates. R.
toruloides with other co-substrates were fed on a bio-digester for biogas production. It was observed that co-digestion of thee wastes reduces the toxicity of the wastes. Highest biogas production was observed during co-digestion of biomass residue and supernatant with glucose [3]. Hydrolysis and acidogenesis of waste activated sludge & food waste have resulted in increase of methane yield in the biogas by upto 25%. Hence the authors recommended the pretreatment of wastes as it can also reduce solids inside the digester by 10.1% [4].

The biogas production was also proved to have been improved by almost 170% upon addition of food waste, cheese whey and olive mill wastewater as co-substrates in the anaerobic digestion of sewage sludge at operating conditions of 37°C, with hydraulic retention time of 24 days. The authors also emphasized the increase in gas production due to co-digestion of wastes [5]. Singh T.S et al. (2015) [6-7] have performed analysis of biogas production using kitchen waste from locally sourced food waste of Tiruchirapalli, Tamilnadu, India. They have also found that the food waste generated from kitchen have a huge potential in using as raw materials for biogas production.

In this paper, the authors have estimated the production of biogas from the food waste which is starch-rich and sugary material using pilot scale digesters. The effect of temperature and substrate water ratio (including moisture content) is studied. The biogas potential of kitchen waste at environment temperature was also estimated.

2. Methods
The general methodology of the study consists of digester set-up, measurements and discussion. They steps are given in details in the following paragraphs. The main source raw material is obtained from the leftover and food waste from the kitchen of NIT Manipur Boys hostel, NIT Manipur, India (24.8320°N Latitude and 93.9128°E Longitude).

2.1. Digester set-up
Figure 1 shows the pictorial view experimental setup. In this apparatus, the authors have used U-tube setup for measuring biogas produced by using water displacement method. Three (3) bio digesters each with a capacity of 2.68 litres is taken. In two (2) digesters, sample 1 & 2 have substrate to water ratio of 1:1 and 2:1 was filled and the third digester (3) was filled with slurry which is having substrate to water ratio of 1:1. The substrate itself has 60.67% moisture. The fabricated digesters were airtight to ensure non-contamination with oxygen. A coat of black paint is made on the digesters to ensure accumulation of heat. A stirrer is used during feeding to facilitate proper mixing and the feed materials were grounded before feeding. Sample 1 is fed at normal room temperature with 1:1 substrate to water ratio. Sample 3 is kept at 36°C (using a 100W bulb) with the same ratio. Sample 2 is fed with 2:1 substrate to water ratio at room temperature.
2.2. Feed materials
The typical composition of kitchen waste from the NIT Manipur Boys Hostel mess is shown in figure 2. The major component is boiled rice (85%) which is rich in carbohydrates and other components are pulse (5%), potato (2%), wheat flour (2%), tomato (1%) and gram flour (5%) etc. The feed materials obtained from the mess were grounded using an electric grinder such that smaller particles have more tendency to produce gas at a lesser time [11]. The feed were then fed to the corresponding digesters are respective ratios with water. The grounded feed materials and feeding of the feed into the digesters were shown in figure 3.
2.3. Instrumentation and measurement
A pH meter with accuracy of ±0.1 was used to determine the pH of the outlet. Thermometer with ±0.5 °C was taken for continuous monitoring of temperature change in the digester during the course of the study. The initial moisture content of the samples was calculated using a convection oven at about 85°C. The initial and final moisture content of the samples are tabulated in table. A Bunsen burner is used to check the flammability of the gas.

3. Results and discussion
After the digester is fed and rested, the retention time is noted. The temperature and gas production was given special attention during the course of the study. Broad parameters were taken into account, such as gas production and pH of the outlet from the digesters.

![Graph showing biogas production](image)

Figure. 4 Biogas productions from the samples on daily basis

The volume of gas produced versus digestion time has been plotted for the samples with digester maintaining at 25 °C and 36 °C, shown in figure 4. We can observe that, sample maintaining at optimum mesophilic temperature (36 °C) can produced higher amount of biogas also it shows lower hydraulic retention time compare to the counterpart. The biogas production is much higher at sample 3, as compared to sample 1 of equal ratio. It has a hydraulic retention time of 9 days in which day 3-4 producing the highest amount approximately of 9750 ml of biogas.
Figure 5 Cumulative biogas production from the sample (1), (2) and (3)

Figure 5 shows variation of biogas cumulative volume versus digestion time for various substrate water ratios for different samples. Sample 3 was able to produce much higher amount of biogas than the other duo. By maintaining optimum mesophilic temperature, it enhances the production of biogas and reduces the hydraulic retention time through increase in rate of decomposition.

Figure 6 pH of the samples at the outlet after gas production.

The variation of pH of the slurry with respect to retention time is shown in figure 6. The pH decreases in the early phases of the anaerobic digestion process due to formation of various volatile fatty acids (VFA) such as propionic, acetic, butyric etc. However in the methanogenesis process, VFA acids were consumed by the methanogens bacteria resulting in increases of the pH causing higher production of biogas.

4. Conclusion
The authors have conducted an experiment to check the effect of temperature and water to substrate ratio in the production of biogas from starch rich food waste obtained from NIT Manipur boys hostel mess, NIT Manipur, Manipur, India (24.832°N Latitude and 93.9128°E Longitude). Plastic bio digesters coated with black paint were used for the study. The feed materials were grounded before feeding into the digester. The samples were feed with either 1:1 or 2:1 substrate to water ratio. Two (2) samples were kept at room temperature while the other is maintained at 36°C using light bulb. It was concluded that the digester with higher temperature (maintained at 36°C) have the highest gas production potential, as compared to the other two digesters. The pH of the feed was found to range from 6.9-7.1 at the end of the retention time. Thus, starch rich food waste from
the kitchen which were properly grounded and kept at mesophilic conditions have a good potential for waste to energy recovery.

References

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