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Development of small scale biogas digester and analysis of the effect of Chicken manure additive on the biogas yield

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ABSTRACT

Due to the rapid industrialization and urbanization, there is a scarcity of conventional energy resources and a need to look out for alternative energy sources. Biogas is a potential energy source which can be easily produced by using agricultural and domestic house hold wastes like animal wastes and foods wastes. So produced biogas can be used for house hold applications, electricity generation and to run the vehicles. In this research work, an attempt is made to design and develop a fixed dome biogas digester with minimum expenditure to produce biogas from food wastes that is generated at homes and hotels. A fixed dome biogas reactor of 25 liter capacity was designed and fabricated with a gas collecting dome, an inlet and outlet options. Chicken manure was added as an additive to increase the biogas production. The quantity of biogas obtained with and without the additive was compared and tested as fuel for household cooking application. Chemical composition of biogas was determined by using gas chromatography and the same was compared with natural gas composition. It was observed that methane obtained from kitchen wastes in presence of chicken manure was significantly higher than that from kitchen wastes alone.

Key words : *Biogas, Chicken manure, Digester, Fermentation, Kitchen waste*

Introduction

Biogas is a renewable source of energy that can replace fossil fuels which is depleting very fast and contribute in abating global warming. It is can be a replacement to natural gas in power production, household heating applications, and automobiles (Omer, 2017).

Biogas is obtained from renewable sources, is cost effective, can be produced locally, is free from harmful combustion products and can contribute in reducing environmental pollution and greenhouse effect. It also contributes in bio-waste management (*Ruan et al.,* 2019). Biogas is a mixture of various gases mainly consisting of methane and carbon dioxide along with small amounts of nitrogen, ammonia and hydrogen sulphide, synthesised economically from raw materials like agricultural biomass, animal wastes, manure, municipal waste and sewage by the aerobic/anaerobic degradation of organic matter in a closed system called as digester (Bhatiya, 2014). Anaerobic degradation is preferred over aerobic degradation even though the later requires less time for gas production. The main reasons are, aerobic degradation is associated with bad odour, require more energy, produce excess sludge and more greenhouse gases compared to anaerobic degradation (Baldasano and Soriano, 2000;

Hartman and Ahring 2006; Fricke *et al.,* 2005). Biogas produced need to be purified before being used for transportation or electricity generation which is not economical. However, biogas can be used for small scale heating and cooking purposes without purification (Awe *et al.,* 2017).

During anaerobic digestion complex molecules will be hydrolyzed to simple ones and finally converted to biogas by enzymes and bacteria. Hydrolysis process convert lipid to fatty acid, polysaccharides into monosaccharaides and also protein to amino acid (Yebo *et al.,* 2011). Design of bio digester depends on biochemical reactions, type and amount of feedstock, climate conditions and process duration (Nkoi *et al.,* 2018). There are three different type of biogas digesters first is a floating dome digester, second a fixed dome digester and third is a balloon type digester. Fixed dome and balloon type digesters are preferred over floating drum digesters as it is corrosion free and has long cycle life (Kaoma and Yamba, 2013). Maintaining optimum pH and temperature becomes very important in order to achieve maximum methanogenesis and hydrolysis of the feed stock. Maintaining optimum pH conditions for acid generation and its conversion to methane are crucial because the pH decreases due to production of acid and also methane producing bacteria requires pH 6-8.5 (Chua *et al.,* 2013). Temperature has remarkable influence in enhancing the microbiological growth and chemical reaction rate (Khalid *et al.,* 2011). The temperature range varies from 15 ^{o}C to 65 ^{o}C. Very high temperatures cause decrease in biogas production due to generation of volatile gases which reduce methanogenesis process (Vahid *et al.,* 2020). Mixing of the feedstock is also one more important parameter to get higher yield of methane, as it decreases the particle size and increase biogas production (Satoto *et al.,* 2010). Improper and excess mixing may also lead to decrease in gas yield (Shuler and Kargi, 2002). Many researchers have reported the synthesis of biogas from municipal wastes, cow dung, food wastes, cassava peels etc., (Islam *et al.,* 2009; Anand Kumar *et al.,* 2018; Shivani and Bashir, 2018; Hamna Abdul *et al.,* 2019). It is also reported that co-digestion of sewage wastes and cattle wastes, with food wastes yield higher biogas than that produced by individual wastes (Kim *et al.,* 2007; Kim *et al.,* 2006; Maranon *et al.,* 2017). Addition of 1% glycerol as an additive is found to increase the methane production (Fountoulakis *et al.,* 2010) remarkably.

In the present research work, an attempt is made to design and fabricate a small scale biogas digester to generate biogas from kitchen wastes as raw material. The effect of small quantity of chicken manure supplement on the production of biogas was studied and the results were compared.

Materials and Methods

Materials

Kitchen wastes was collected from the local hotel and was grinded to reduce the size. Chicken manure was collected from the nearby poultry. It was dried and crushed to fine powder before mixing with kitchen waste for fermentation. In order to fabricate the biogas digester stainless steel (Chromium-Nickel steel), rubber tunings,pressure gauges and gas collecting tubes were used.

Methods

A 25 L capacity biogas digester was fabricated using stainless steel material. Inside of the digester was coated with a rubber lining to prevent corrosion.

About 8kg of the grinded kitchen waste was mixed with 8L of water to prepare a slurry to which 10% of chicken manure was added with continuous agitation. The slurry was transferred to the fabricated biogas digester and kept under anaerobic condition at pH 7, for a period of 25-35 days for the production of biogas. Biogas collected in the gas collection unit was taken out in to tyre tubes and sent for composition analysis.

Chemical Oxygen Demand (COD) of the sample before and after fermentation was determined by standard iodometric method using acidified Potassium dichromate as oxidizing agent, FAS as titrant and Ferrion as indicator (Dedkov *et al.,* 2000). Determination of Biological Oxygen Demand (BOD) of the sample before and after fermentation was carried out byWinkler's method using standard Sodium thiosulphate and freshly prepared starch indicator (Carpenter, 1965).

The composition of the biogas obtained was determined by gas chromatographic method.

Results and Discussion

Design and fabrication of Biogas digester

Figure 1 shows the 3-dimensional view of biogas reactor design. With reference to Figure 1, a 25L ca-

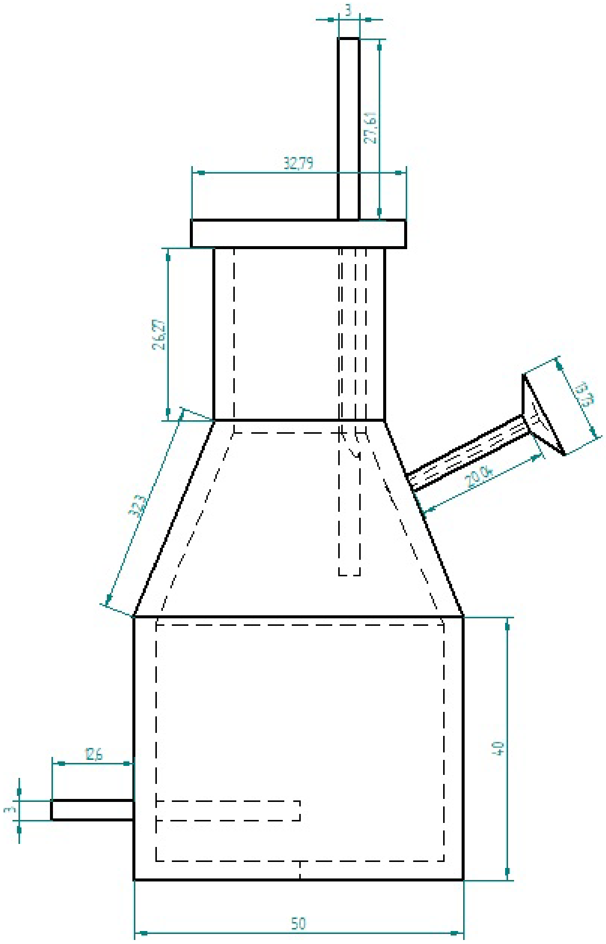

Fig. 1. Biogas digester design in 3-Dimension

pacity biogas digester was designed. Figure 2 shows the fabricated simple air tight biogas digester with 5cm width slurry inlet and 2 cm width gas outlet. It is known that the density of bio methane is very less compared to air and it can escape into the atmosphere even if the digester has a very small opening. Hence, at most care is taken to fabricate an air tight digester.

Production of Biogas

Initial experiments were conducted with 8kg of crushed raw material mixed with 8L of water to prepare a slurry without any chicken manure. Table 1 shows the characteristics of the sample in terms of COD, BOD and moisture content. The pH of the slurry was adjusted to 7.0. The slurry was mixed thoroughly in a plastic container thentransferred to the fabricated biogas digester and kept under anaerobic condition for a period of 35 days for the production of biogas. The temperature of the slurry

Fig. 2. Fabricated biogas digester for fermentation process

was initially 32 ºC and little rise in temperature was observed after 4 days of fermentation, due to biochemical reactions. The slurry was stirred at regular intervals to initiate the biochemical reaction. Biogas produced was taken out after 10, 15, 20, 25, 30 and 35 days of fermentation in tyre tubes and composition of the biogas was determined by gas chromatography. Figure 3 shows a flowchart diagram of the process.

Table 1. Characteristics of the sample

Characteristic	Sample
BOD mg/L	173,542
COD mg/L	698,232
Moisture %	93.8

In the later stage, the kitchen waste was diluted with water and mixed with 10% of pulverized chicken manure as an additive to get a slurry. The slurry was subjected to anaerobic degradation for 35 days. The biogas collected was tested for biomethane content at regular interval of time in a gas chromatographer. Poultry manure is richer in the nutrients like Calcium, Magnesium, Sulphur, Potassium, Nitrogen, Manganese, Boron, Iron, Zinc and Copper, which enhances the biochemical reactions and the biogas production.

Process flow chart

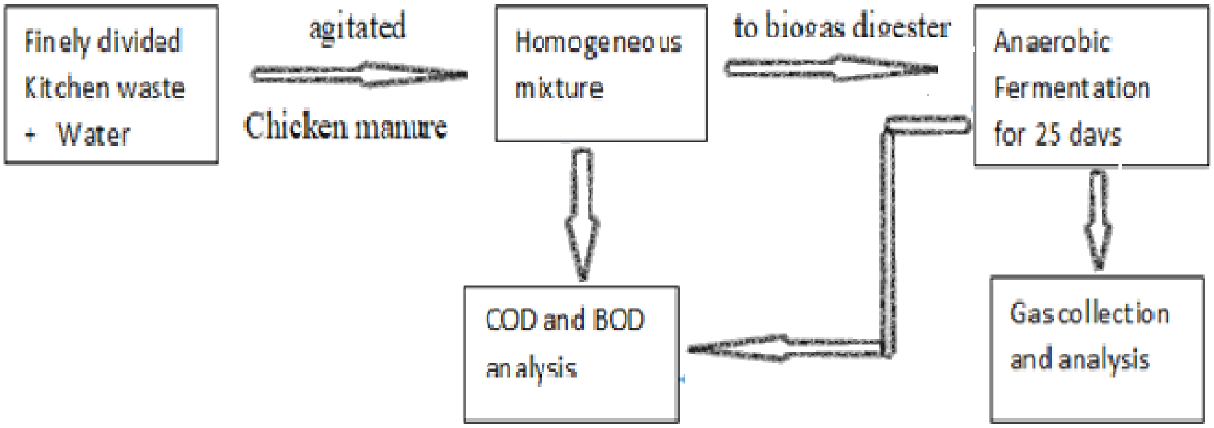

Fig. 3. Flow chart diagram of the process.

Determination of COD and BOD

The COD and BOD of the sample was determined before and after anaerobic degradation process as per the standard procedures (Dedkov *et al.*, 2000; Carpenter, 1965). COD, BOD values and the percentage removal of the same is tabulated in Table 2. Kitchen waste has high biodegradable organic matter and results in higher biochemical reactions. Higher removal of COD and BOD in Table 2 indicates high biochemical reaction and results in good yield of biogas.

Table 2. COD and BOD removal percentage after 35 days

Characteristic	Initial value mg/l	After 35 days	% removal
BOD mg/l	173,542	3621.7	97.9
COD mg/l	698,232	284518	59.2

Collection of Biogas and its analysis

Figure 4 shows the biomethane produced at different days of degradation with and without chicken manure additive in percentage. The yield of biomethane produced increased with increase in degradation time up to 25 days and later it remained almost constant upto 35 days. It is also observed that yield of biomethane is more irrespective of the degradation time in the sample with chicken manure additive compared to that without any additive. From the above preliminary experiments the conditions to obtain high biogas yield was optimized and the same is tabulated in Table 3.

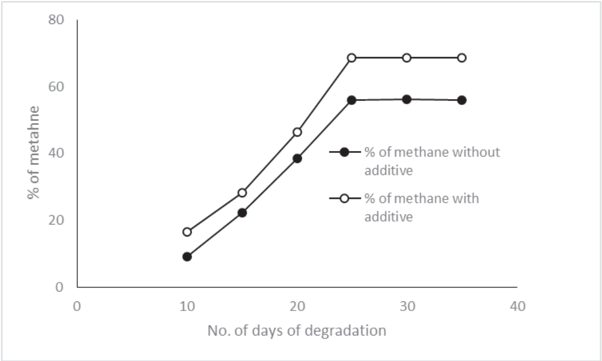

Fig. 4. Percentage of bio methane produced with and without chicken manure additive, by varying fermentation time.

Table 3. Optimum conditions for biogas production

Parameters	Optimized values
Temperature	30-35ºC
pH	6.5-7.5
% of Chicken manure	10
No of days of degradation	25

Table 4 shows the volume of biogas produced at optimum conditions with and without chicken manure. There is a remarkable increase in the production of biogas in presence of chicken manure as an additive.

Figure5 shows the percentagecomposition of biogas, with and without chicken manure as an additive. It is clear that the addition of chicken manure contributed in enhancing the yield of biomethane. The data obtained is tabulated in Table 5.

The collected biogas was tested as a fuel for

Table 4. Volume of biogas produced at optimum conditions with and without chicken manure.

Biogas accumulated in gas collection unit in ml		Biogas collected, ml/kg of the sample	
Without chicken manure	With chicken manure	Without chicken manure	With chicken manure
366	482	45.7	60.25

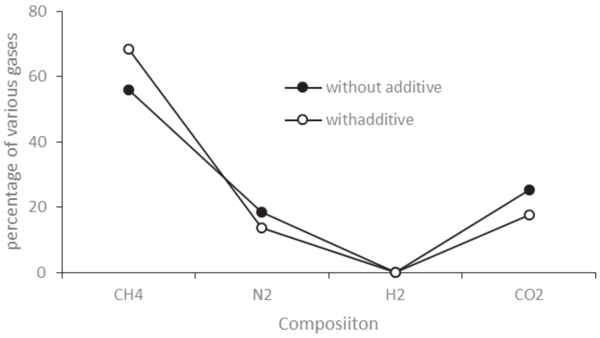

Fig. 5. Composition of biogas with and without chicken manure additive.

Table 5. Percentage composition of biogas with and without chicken manure as an additive.

Sl. No	Composition of biogas	
	Without chicken manure	Withchicken manure
CH_4	56.06	68.55
N_2	18.60	13.63
H_2	0.02	0.02
CO_2	25.32	17.8

household cooking. The biogas was found to undergo complete combustion, burn cleanly without any residues and soot, similar to Liquefied petroleum gas (LPG).

Conclusion

A simple, economical small scale 25L capacity biogas digester was designed and fabricated to process household wastes for biogas production. The biogas produced with and without chicken manure additive was compared. The biogas collected in the gas collection unit in presence of chicken manure additive wascomparatively more than that in the absence of any additive. The produced biogas was tested for its composition using gas chromatography. The methane content in biogas was found to increase with increase in time and was almost constant after 25 days of fermentation at 30±2ºC. Higher removal of COD and BOD with the addition of chicken manure additive indicates higher biological activities leading to the enhanced production of biogas.

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