

Design, Development and Performance Evaluation of Biogas Digester Filled with Multiple Feed Stocks

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ABSTRACT-In this experimental study, the performance evaluation of biogas digester was investigated with multiple feed stocks. A examine was done to determine the amount of biogas that can be produced from different feed stocks. A high volume of biogas generation was observed with kitchen waste, cow dung and poultry droppings when pH value of slurry is within the range 6.9 to 7.1 and the digester temperature is within the range of 34°C to 39°C. A mixture of 28 kg kitchen waste, 1 kg Ragi powder, 500 grams of Wheat and Juggler powder were added to water in the ratio of 1:2. Similarly, 30kg waste manure was prepared from cow dung and poultry droppings. The volumes of biogas generation were calculated as 1.016 m³, 2.489 m³ and 2.397 m³ from kitchen waste, cow dung and poultry dropping respectively.

KEYWORDS: Kitchen Waste, Cow Dung, Poultry Dropping, pH Value, Volume, Gas Generation.

I. INTRODUCTION

Municipal solid waste (MSW) is a Trash or garbage, consisting of regular matters that are disposed of by human and animal activities [1]. Surveys on MSW have shown that nearly 9500 metric tonne (MT) of MSW is generated in Karnataka state including all urban local bodies. Nearly, 4000 metric tonne per day(MTPD)garbage is generated in Bangalore BruhatBangalore MahanagaraPalike (BBMP) with 80-85% collection efficiency. The rest comes from urban local bodies (ULBs) with 80-90% collection efficiency. Some of ULBs do not even have estimation of MSW generation [2].In Karnataka more than half of the municipal solid waste is created in six municipal corporations. Bangalore city produces nearly 4000 MTPD of solid waste, which is 10 times higher than its next municipal corporation in the state (like Mysore, and Hubli - Dharwad) [2]. The per capita waste production in Bangalore city is 0.4 kg per capita/day. Various innovations are applicable for the potential recovery of energy or products from MSW. There are a many number of factors to be considered for choosing a suitable technology for treating different components of wastes before their final disposal.The innovation options available for preparing the MSW depend on either bio-synthetic conversion or thermal conversion. Bio-Chemical Conversions are Compost,Aerobic, Anaerobic Digester, Vermi-composting.Thermal conversions are Incineration with or without heat recovery, Pyrolysis and gasification, Plasma pyrolysis, Palletisation or Refuse Derived Fuel (RDF) [2].

Hence, many researchers [3] have made attempts to prepare slurry of 1 kg by mixing agricultural waste feed stocks with water in the proportion of 1:1. Examinations were completed by utilizing 10 litre capacity indigenously developed digester. The test was conducted for 50 days and surveyed for proximate substance, biogas generation, natural matter, and mineral substance in the processed and undigested agricultural waste materials. The week by week combined biogas production enhanced from 852.6 cm³ for banana peel/plantain peel (BP/PP) test to 1049.7 cm³ for plantain peel/ rice husk (PP/RH) analysis for the 49 days at the experimental room temperature in the range of 29°C to 35°C. Test Sample for plantain peel/ rice husk (PP/RH) produced the highest volume of gas (biogas, methane, and others). In each

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case, the volume of gas production decreased in week 7 from 271.4 cm³ to 152.0 cm³ (for biogas), 161.4 cm³ to 97.1 cm³ (for methane), and 110.0 cm³ to 54.9 cm³ (for different gasses).

The aggregate amount of MSW generated in the city is roughly 385 tons for every day (TPD) and the points of interest of the same are set out in Table 1 show the total generation of municipal solid waste in Mysore city.

Table 1 Total MSW generated in Mysore City Corporation ^[4]

Sl. no.	Source	Numbers	Unit of generation per day	Estimated quantity (MT)
1	Population	9,38,386	360 gram/capita /day	338
2	Commercial Establishments	20,000	1.0 kg per/ Unit/ day	20
3	Hotels and Restaurants	410	50 kg / unit	21
Total MSW generated per day in MT		385		
4	Street sweepings and silt(TPD)			17
Total MSW generated per day including Street sweepings and silt in MT				402

The table shows the total generation of municipal solid waste in Mysore city. Estimated quantity of municipal solid waste generated 402 Metric tonne per day obtained from the population, commercial establishment's hotel and restaurants and street sweeping etc.

Another team of researchers [5] conducted a study to learn the measure of biogas that can be produced from different food stock. This experiment can solve the problem of the kitchen waste management. The digester volume was 20 litre capacities. The solid waste of 9kg was used which comprised of 5kg Cow dung, 2kg Fruit Waste, 2kg garden waste and 100 grams of KOH.

Considerable research [6] was done on to use food waste as a source. It was realized through the observation and experimental test that by using 5 litres of source material with 5 different composition of food waste and cow dung, for example, 100:0, 75:25, 50:50, 25:75, 0:100 for 15 days. It was derived from the test perception to deliver 3100 ml of biogas in the 75:25 proportions. It was found that 75:25 proportion of food waste and cow dung is the best composition, based on this a test ring was manufactured and test was conducted in 120 litre digester and the biogas produced and analysed. The remaining part in the digester was filled with water. The slurry temperature inside digester was maintained in the range 32°C to 35°C all through the time of experimentation. Another team of researchers [7] conducted extensive study on the use of kitchen waste as a source for the generation of biogas. This study comprises of review of work done on MSW, characterization of kitchen waste from a few kitchens and exploring its capability to be utilized for biogas generation. A research [8] was conducted to use water hyacinth and paddy chaff (Paddy waste it contains from paddy husk and undeveloped Rice) with boiled condition as feed stock for producing biogas. This analysis overview of the important parameters like pressure, temperature, carbon to nitrogen proportion (C/N), total solid concentration and hydro retention time (HRT). An attempt [9] has been done to design development and test the performance of volume capacity 0.018 m³ of a floating type biogas plant for open air environment state of New Delhi, India. It has been observed that (i) the biogas generation depends strongly on slurry temperature and (ii) the retention time about 85 days. The range of slurry and ambient temperature of climate recorded during the observation period has been found as 26°C to 42 °C and 30 °C to 40 °C respectively. Chemical and Physical investigation of biogas and slurry has carried out completed. Further, the CO₂ migration and carbon credit has additionally been assessed for the present system. According to Prasad, in Fiji 70% of total primary energy used comes from biomass and petroleum products

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[10]. This, however, contributes to the health issues for women due to inhalation of smoke while cooking. Biogas is one of the alternative energy fuels to use for cooking. Arthur et al. argues that biogas is a clean fuel since it burns without leaving soot or particulate matter and it is lighter in terms of carbon chain length and, hence, less amount of carbon dioxide is released into the atmosphere during combustion [11]. According to Erickson et al., the digester is an airtight tank which sometimes has heating coils and mechanical mixer [12]. Vindis et al. also says that in anaerobic digestion it is important that temperature remains constant [13].

II. MATERIALS AND METHODS

Sample collection: The kitchen waste was collected from collage canteen of VTU PG Studies, Mysore, later cow dung and Poultry droppings were collected from the village near VTU PG Studies Mysore. In order to carry anaerobic digestion, a digester of 90 liters capacity was designed.

Fabrication of biogas digester: The digester was made up of mild steel of 1.6mm thickness (500mm in diameter and 1000mm high) with gas holder, slurry inlet, gas outlet, slurry outlet (Figure 1 and Figure 2). The gas generated (methane) was collected in the gas holder by the upward movement of gas holder.

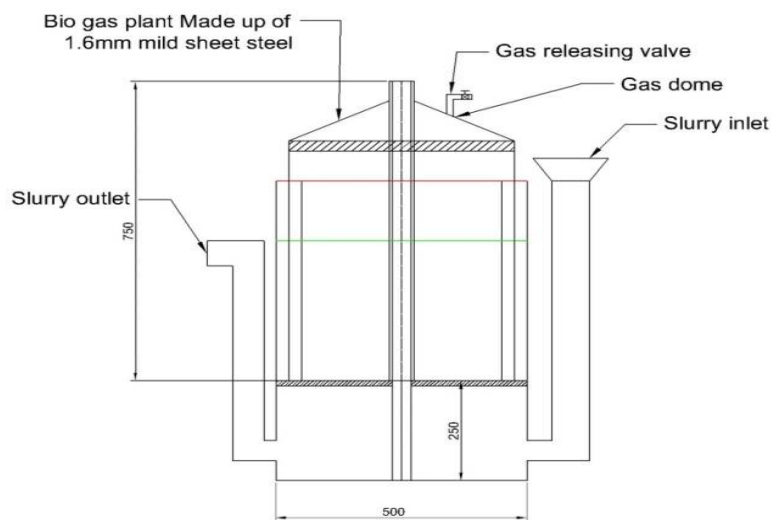


Fig.1 Biogas digester

The figure 1 shows the CAD modeling of compact type biogas plant it is designed to use for the 2 or 3 members family.

Experimental observations have been taken for three different feed stocks, nearly about 3 months 15 days one after the other. The biogas generation has been noted on the daily basis by the observation of upward movement of the gas dome. The volume of the generated gas is calculated by multiplying the height of gas dome by $2\pi r$.

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Fig.2 Photograph of metal made biogas plant

The figure 2 shows the fabricated biogas plant is made from the mild steel sheet metal of thickness 1.6mm i.e., durable, cost effective, corrosion resistance and easy to handle.

Preparation of biogas plant: All three experiments have been performed in 90L batch digesters essentially made of metal. A set of one digester have been used at a time of experimentation. The parameters of biogas production such as pH, temperature, volume of gas, and retention were calculated using various equipments.

Experimental procedure: The feed was prepared from kitchen waste, cow dung and poultry dropping. The water is filled in the ratio 1:2 for effective gas generation; the feed stock was grinded properly so as to increase the surface area of yield of gas in the duration of short time. In this work, biogas production from kitchen waste, cow dung and poultry dropping compared.

III. RESULT AND DISCUSSION

In this batch system, the waste slurry has been added once to the digester for the whole span of time. It has been seen that the generation of biogas depends upon the pH of slurry, temperature and retention time. Figure 3 shows the Volume of biogas generation rate.

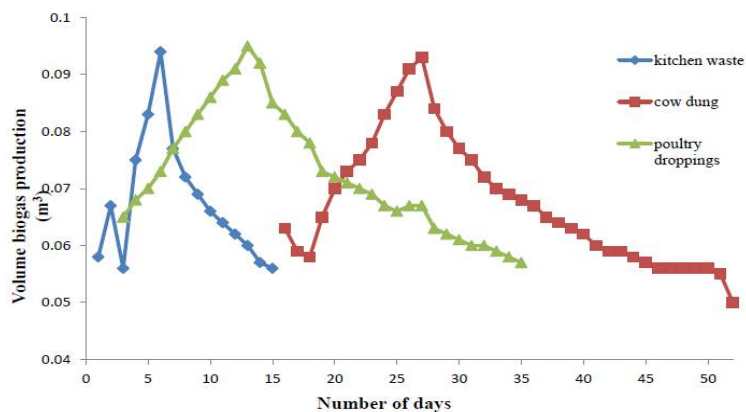


Fig. 3 Volume of biogas generation rate respect to number of days

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The figure 3 shows the Biogas generation rate of different feed stock with respect to number of day's different feed stocks like kitchen waste, cow dung and poultry dropping from these gas generations occurs.

For the kitchen waste, the gas generation started from the 3rd day and the volume of gas is 0.056m³. The volume of gas generation is maximum on the 6th day and volume is 0.094 m³. Day by day, it is gradually decreasing and it is stopped on 15th day. For the cow dung, the generation of carbon dioxide occurred from the 2nd day to the 15th day. Methane production starts from the 16th day and the volume is 0.063 m³ and it is gradually increased and reached a volume of 0.093m³ on 27th day. It is gradually decreased.

For the poultry dropping, the gas is generated from the 3rd day and volume is 0.065m³. It was reached maximum at the 14th day and volume of gas is 0.095m³. It stopped on 35th day. Comparing the kitchen waste and cow dung, volume of gas generation is large for the poultry dropping. Figure 4 and Figure 5 shows the comparison of inlet and outlet slurry pH and temperature. And Table 2 shows the Biogas productions rate from different feed stocks.

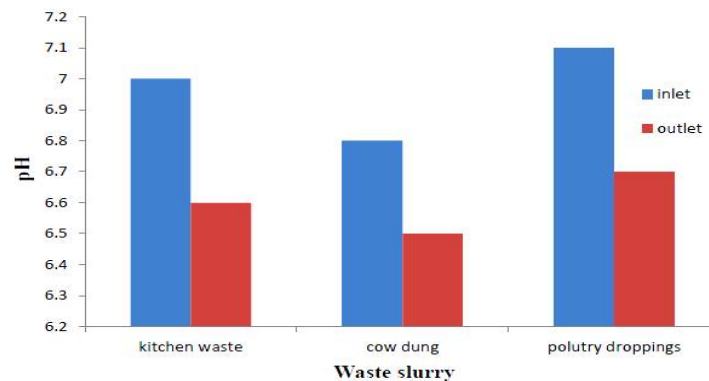


Fig. 4 Comparison of inlet and outlet pH slurry

The figure 4 shows the Comparison of inlet and outlet pH slurry for the different feed stocks like kitchen waste, cow dung and poultry dropping the pH of the slurry is measured from the portable pH meter.

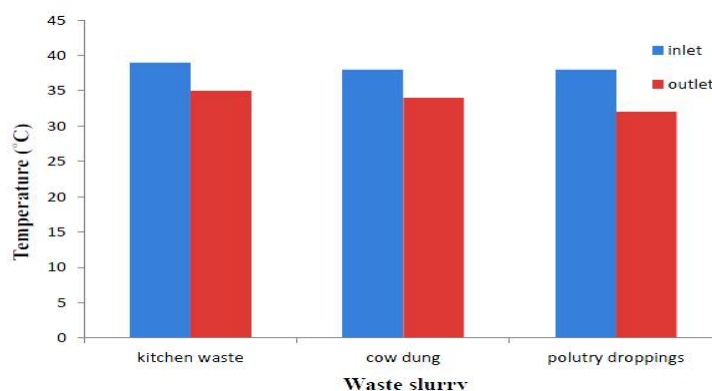


Fig.5 Comparison of inlet and outlet temperature

The figure 5 shows the Comparison of inlet and outlet temperature for the different feed stocks like kitchen waste, cow dung and poultry dropping the inlet and outlet slurry temperature is measured from the thermometer.

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Table 2 Biogas productions rate from different feed stocks

Character	Kitchen waste	Cow dung	Poultry dropping
Capacity of biogas production	0.0954m ³	0.0954m ³	0.0954m ³
Slurry capacity	90 kg (30kg kitchen waste+60 kg water)	90kg (30kg Cow dung+60 kg water)	90kg (30kg Poultry dropping+60 kg water)
Water in ratio	01:02	01:02	01:02
pH	7	6.8	7.1
Average temperature	38 °C	36 °C	36 °C
Biogas production in days (start and stop)	3 to 15	15 to 52	3 to 35
Total biogas production (m ³)	1.016 (15 days)	2.489 (52 days)	2.397 (35 days)

The table 2 shows the comparison of biogas production rate from different feed stocks measured different parameters like capacity of biogas production, slurry capacity, and water in ratio, pH value, temperature, biogas production in days and total biogas production.

The experiment is done for 15 days for kitchen waste; the water is added in the rate of 1:2 with peculiar amount of inoculums. In the experiment analysis it is observed that, better results were obtained from poultry dropping (PD) in respect of biogas generation. For the kitchen waste, Cow dung and Poultry dropping, the generation of gas is 1.016 m³ (15 days), 2.489 m³ (52 days) and 2.397 m³ (35 days) respectively.

In all these experiments, compared with kitchen waste (KW), cow dung (CD) and poultry (PD), the poultry dropping is better in terms of total biogas generation but solid content in the kitchen waste is larger than cow dung and Poultry dropping so that activity of bacteria and micro-organism is very fast in kitchen waste, Generation of biogas in kitchen waste is much faster than the cow dung and poultry dropping. Coming to availability and ease of operation, kitchen waste is much better in urban areas. By utilizing kitchen waste available in apartments, hotels, canteens etc., lot of energy can be generated. This saves the conventional energy source like LPG, kerosene, coal and bio-mass etc. Kitchen waste and poultry wastes will be the best alternatives under a community level biogas production. But availability of poultry waste is less compared to kitchen waste. This biogas plant is sufficient for the 2 or 3 members of 1 to 2 kg waste per day but it varies according to availability of waste and customer's requirement.

IV. CONCLUSION

The following conclusions have been derived based on the work carried out in this research.

1. The activity of bacteria and micro-organism is very fast in kitchen waste. So generation of biogas is much faster than cow dung and poultry dropping.
2. Kitchen waste and poultry wastes will be the best sources for a community level biogas production.
3. This biogas plant is sufficient for the 2 or 3 members of 1 to 2 kg waste per day but it varies according to availability of waste and customer's requirement.

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