http://dx.doi.org/10.22161/ijeab/2.2.18 *ISSN: 2456-1878*

Biogas Production Potential of Food Waste

P. Manonmani[1], Lurwan Muazu[2], M. C. Kamaraj[3], Mukesh Goel[4], R.Elangomathavan[5]

[1, 2,3 ,5] Department of Biotechnology, Centre for Research and Development, PRIST University, Vallam, Thanjavur, India
[4]Centre for Environmental Engineering, PRIST University, Vallam, Thanjavur, India

Abstract—*At present our country is facing various problems, among that energy crisis has become more serious in next coming years. Both energy crisis and pollution problems could be controlled by adopting an alternative method of biogas production form waste products. Food waste is the best alternative for biogas production in a community level biogas plant. Hence in the present study, an attempt has been made to study the rate of biogas production in a lab scale biogas digester model for the efficient conversion of the food waste (starch –rich materials) generated from PRIST University Campus. The biogas production depends on the maximum biogas yield, the concentration of volatile solids of the input, the density of the effluent, the density of the biogas and the reaction rate constant, which are all substrate - or process - specific. The experiments were carried out for 40 days and the rate of gas production was measured by water displacement method. The pH value of the cow dung and food waste was initially measured and adjusted to nearer to neutral and gradually increased to acidic and again it got stabilised to the neutral pH which favoured the production of biogas. The percentage of total solids was 69.86, 93.56 and 25.67 for cow dung, food waste and digested slurry respectively. The percentage of volatile solids was 52.5, 86.3 and 18.9 for cow dung, food waste and digested slurry respectively. The percentage of volatile fatty acid was 285, 356 and 365 for cow dung, food waste and digested slurry respectively. Observations on daily basis were made on the constituent of biogas, pH, volume and rate of biogas production. The rate of biogas production continuously increased as days progressed and there was maximum yield in biogas after 20 days. Thus continuous feeding helps in daily biogas production and can be used at a small as well as larger scale to manage the organic waste and energy production for various applications.*

Keywords— Anaerobic digestion Continuous fermenter, Digester, Food waste, Slurry.

I. INTRODUCTION

The prime challenge for the country is to provide the minimum energy services to allow the rural people to achieve decent standard of living. The biogas plant is a boon to the Indian farmers. The two main products of the biogas plants are enriched compost manure and methane, where as the compost manure helps to meet the fertilizer requirements of the farmers in a more economical and efficient manner that boost ups the agricultural production [1].

Due to industrial revolution and population explosion there has been an increase in the energy demand. To fulfil this energy demand non-renewable energy resource such as fossil fuels are the key energy generators. These non-renewable energy resources are limited and have various environmental impacts. This has resulted in researching heavily on alternatives forms of renewable sources of energy such as biogas production from biomass.

Biogas can be produced by anaerobic digestion from nearly all kind of biological feedstock types. They are from the primary agricultural sectors and from various organic waste streams. The largest resource is represented by animal manure and slurries from cattle and pig production units as well as from poultry, fish etc. In India million tones of animal manure are produced every year. When untreated or poorly managed, animal manure becomes a major source of air and water pollution. The animal production sector is responsible for 18 % of the overall green house gas emissions, measured in CO_2 [2]. It is smokeless, hygienic and more convenient to use than other solid fuels [3].

Biogas is used for cooking and lighting purposes and in larger plants, as motive power for driving small engines. It is produced when bacteria degrade organic matter in the absence of air. Biogas contains around 55-65 % of methane, 30-40% of carbon dioxide. The calorific value of biogas is appreciably high (around 4700 kcal or 20 MJ at around 55 % methane content). The gas can effectively be utilized for generation of power through a biogas based power-generation system after dewatering and cleaning of the gas. In addition, the slurry produced in the process provides valuable organic manure for farming and sustaining the soil fertility.

The bio-gas produced from food waste and decomposable organic material consisting of methane and a little amount of carbon dioxide is an alternative fuel for cooking gas (LPG). Also, the waste materials can be disposed off efficiently without any odour or flies and the digested slurry from the bio-gas unit can be used as organic manure in the garden.

Therefore, this work was carried out to explore the potential of biogas production from co-digestion of cow dung with food waste, along with various organic wastes. Hence, in this study an effort was made to study the cumulative biogas generation during digestion and the relationship of other parameters such as pH, EC, Total Solids (%), Total Dissolved Solids (ppt/l), Volatile Solids (%), Volatile fatty acids (VFA %), Total Khejdhal nitrogen (TKN %), Total organic carbon (TOC) and percentage of methane.

II. MATERIALS AND METHODS

2.1. Components of the Bio-gas Plant

The major components of the bio-gas plant consists of a digester tank, an inlet for feeding the food waste, a gas holder tank, an outlet for the digested slurry, a gas delivery system for taking out and utilizing the produced gas.

The Biogas plant consists of a digester tank, where the organic material was stored and the microorganisms work on them and release gas. The gas thus produced was collected in a tank known as gas collector. In a floating type model, this tank is floating in the slurry and moves up-and-down based on the amount of gas stored in it. It was fitted with a guide pipe that helps the gas collector tank to move up-and-down inside the digester tank. The waste material was fed through feed pipe inside the digester tank. The fully digested slurry drained out through the outlet pipe. This was collected, diluted and used as fertilizer for plants. A gas pipe line from the Gas collector tank helps in utilizing the gas for cooking and lighting.

2.2. Sample Collection and Processing

Cow dung sample were collected from the animal farm house at Vallam, Thanjavur and they were homogenized using through mixing. Food waste was brought from boy's hostel and canteen of PRIST University in a plastic container. Fresh feed material (food waste) was collected every three days and was stored at 4ºC. The preparation included homogenization in a kitchen blender, diluting with water (1:1 ratio).

All the samples brought to the laboratory and further processed for experimental analysis. Cow dung and food waste in combinations were used as a substrate to find out the efficient conversion of biogas.

Fig.1: Collection of food waste from PRIST University Hostel

2.3. Preparation of Inoculum

The inoculum was prepared from just one day old cow dung. 25 kg of cow dung were mixed with 25 litre of water. The samples were taken from the homogenized slurry for further physico - chemical analysis. About 25 kg of inoculums were fed into the digester through inlet chamber. The purpose of inoculums is to make a culture of the microorganisms so that when fresh food waste is added to it, the biogas production is enhanced.

2.4. Feeding of waste into the digester tank

After the acclitimization period, the gas formation was noted after 5 days of the inoculation of cow dung slurry. At this stage, the digester is ready for feeding the waste material. About 100 kg of waste material was fed to the digester (food waste from canteen/hostel) through inlet pipe fitted to the bottom of the digester. The dilution was kept less than 1:1 because food waste had already enough water content in it. The preparation of slurry was made by homogenization in a kitchen blender, diluting with water. The samples were taken from the homogenized slurry for further analysis.

2.5. Physico – chemical analysis of Cow dung and food waste

The physico- chemical analyses of the substrates were carried out and are shown in Table 1 and 2. pH, EC, salinity, Total solids (TS) and Total Dissolved Solids (TDS) were measured by potentiometeric method. TOC [4] and TKN were determined according to standard procedures as outlined in APHA [5]. Volatile solids

(VS), Volatile fatty acids (VFA), were analyzed for fresh substrates and then for the digested slurry according to method of [6].

The bio gas composition was also analyzed. The biogas was collected and measured in a graduated beaker by means of water displacement method. The amount of gas produced is equal to the amount of water displaced in the beaker.

III. RESULTS AND DISCUSSION

3.1. Components of the Bio-gas Plant

The major components of the bio-gas plant consists of

- A digester tank, an inlet for feeding the food waste
- A gas holder tank, an outlet for the digested slurry
- A gas delivery system for taking out and utilizing the produced gas.

The volume of the digester tank constructed for lab scale was 200 litres capacity of PVC material. The volume of the gas collector tank was 150 litres capacity this acts a reservoir of gas collection. The produced biogas was collected in a gas collector tank and is shown in fig.2.

Fig.2: Lab scale model biogas digester and measurement of the biogas using water displacement method

3.2. Analysis of samples

The results of the analysis of physicochemical parameters of the fresh substrates and the digested slurries are shown Table 1 and 2. The pH ranged from 5.89 to 6.8 for the substrates used for the study. The pH was adjusted to neutral (7.0 to 7.2) by adding NaOH to enhance and accelerate the production of biogas in the digester.

Anaerobic digestion depends on several different parameters for an optimum performance. Different groups of microorganisms are involved in the methane production, and suitable conditions have to be established to keep all the microorganisms in balance. Some of these parameters are: pH, temperature, mixing, substrate, C/N ratio, and hydraulic retention time (HRT). Digestion is a slow process and it takes at a minimum of three weeks for the microorganisms to adapt to a new condition when there is a change in substrate or temperature [7].

pH is essentially a measure of the acidity and alkalinity of a solution before feeding to a digester. A pH value of 7 is regarded as neutral, less than 7 as acidic and more than 7 as alkaline. In the present study, the values of pH were ranging from 6.8 and 5.89 for the cow dung and food waste (before digestion process) respectively. The results of the present study correlated with previous workers which favours biogas generation. A symbiotic relationship is necessary between the hydrogen-producing acetogenic microorganisms and the hydrogen-consuming methanogens. Furthermore, a neutral pH is favorable for biogas production, since most of the methanogens grow at the pH range of 6.7 – 7.5.

Augenstein *et al*. [8] suggested that during anaerobic fermentation, micro-organisms require a natural or mildly alkaline environment for efficient gas production. An optimum biogas production is achieved when the pH value of input mixture in the digester is between 6.25 and 7.50 [9,10]. The pH value in a biogas digester is also a function of the retention time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH value inside the digester can decrease below 5. This inhibits or even stops the digestion or fermentation process. Methanogenic bacteria is very sensitive to pH value and do not thrive below a value of 6.5. Later, as the digestion process continues, concentration of NH_4 increases due to the digestion of N_2, which can increase the pH value to above 8. When the CH_4 production level is stabilised, the pH range remains between 7.2 and 8.2. According to studies in China, during the period when ambient temperature varies between 22 and 26°C, it takes approximately 6 days for pH value to acquire a stable value SPOBD [11]. Similarly, during the period when ambient temperature ranges between 18 and 20°C, it takes approximately 14-18 days for pH value to attain a stable value [12].

The C/N ratio of fresh substrates was 19.07, 24.81 for cow dung and food waste respectively. It achieved a ratio of 20.37 after the digestion process completed.

In the present study optimum C/N ratio was obtained, which well correlates with study of Deublein and Steinhauser, [7]. The carbon and nitrogen ratio should be around 16:1 – 25:1. Too much increase or decrease in the carbon/nitrogen ratio affects biogas production. The concentration of solids in the digester should vary between 7 % and 9 %. Particle size is not an important factor compared to other parameters such as pH and temperature. However, the size of the particles used affects the degradation and ultimately the biogas production rate [7,12,13].

The relationship between the amount of carbon and nitrogen present in organic materials is expressed by the carbon/nitrogen (C/N) ratio. A suitable C/N ratio plays an important role for the proper proliferation of the bacteria for the degradation process [14].

Biochemical parameters such as total solids (%), volatile solids (%) and volatile fatty acid (VFA) content of the cow dung admixtures with food waste (before feeding) and slurries (after digestion) were analysed and shown in Table 1 and 2.

Fresh cattle waste consists of approximately 20 % total solid (TS) and 80 % water. TS, in turn, consist of 70 % volatile solids and 30 % fixed solid. For optimum gas yield through anaerobic fermentation, normally, 8-10 % TS in feed is required TERI [15]. This is achieved by making slurry of fresh cattle dung in water in the ratio of 1:1.

The biochemical composition of the substrates mixture during the digestion period showed that there was a gradual decrease in biochemical characteristics such as total solids, volatile solids from the 0^{th} to 40^{th} day. Volatile fatty acid content is represented in the fig. 3. It was increased in the initial stage of digestion and gradually increased up to the 6^{th} day of digestion process and again trending towards decreasing nature up to 14^{th} day. There was a sharp raise in the value in the 16^{th} day and there was a variation in the value thereafter. The decrease of VFA in the middle of digestion process indicated the biogas production yield was better in the reactor. (Fig.3). The organic nitrogen content was subsequently increased during the digestion process and considerable solid removal has been achieved in all the substrates mixtures, which was supported by the reduced rate of total organic carbon (Table 1 & 2).

3.3. Quantitative Analysis of Biogas yield

Cumulative yields of biogas (expressed in litres) from the admixtures of cow dung and food waste are presented in Table 2. The typical set up for the measurement of gas is shown in fig.2 and the rate of gas production at ambient temperature of food waste (FW) admixtures with cow dung (CD) at different hydraulic retention time is presented in fig.4. There was a gradual increase in the production of bio gas as the number days increased i.e. retention time. There was sharp increase in the peak from 26^{th} day to 35^{th} day and there was a decline in the gas production towards the end of the digestion period. The yield of biogas obtained during the study period amounted to about more than 90 percent of the total gas. The CH_4 is to CO_2 ratio was 65: 33 during the end of the digestion process. In the first 20 days of operation, the content of bio gas in the reactor was 65 %, and after 30 days of operation the biogas content was 70 %. The temperature recorded during this process was 35º C to 38º C. The rate of bio gas production was dependent on the temperature and when there was variation in temperature, bio gas production rate was significantly varied.

The major parameters affecting methanogenic reactions in a digester are the C/N ratio, temperature, pH value, presence of volatile substance, biological oxygen demand (BOD), chemical oxygen demand (COD) [16,17]. The rate of biogas production depends on the ambient temperature of a particular region also; it decreases considerably if the ambient temperature falls below 15°C or if it exceeds 45°C. In the present study the ambient temperature of 38°C was recorded which enhances the biogas production rate. Optimum pH, C/N ratio and volatile solids of the present study results favoured the production of biogas in the reactor.

Table.1: Physicochemical parameters in fresh slurry

S. No.	Name of the waste	pH	EC	Salinity (mg/l)	TS (%)	TDS (mg/l)	VS (%)	VFA (mg/l)	Nitrogen (%)	TOC (%)	C/N ratio
1.	Cow dung	6.8	4.6	4.26	69.67	5.32	52.5	285	2.8	53.4	19.07
2.	Food waste	5.9	13.8	12.56	93.56	8.12	86.3	356	1.6	39.7	24.81

Table.2: Physicochemical parameters in digested slurry

S.No	Name of waste	pH	EC	Salinity (mg/l)	TS (%)	TDS (mg/l)	VS (%)	VFA (mg/l)	Nitrogen (%)	TOC (%)	C/N ratio	$CH_4 : CO_2$
1.	Cow dung + Food waste slurry	4.32	8.6	10.56	25.67	5.95	18.9	365	1.9	36.8	20.37	65:33

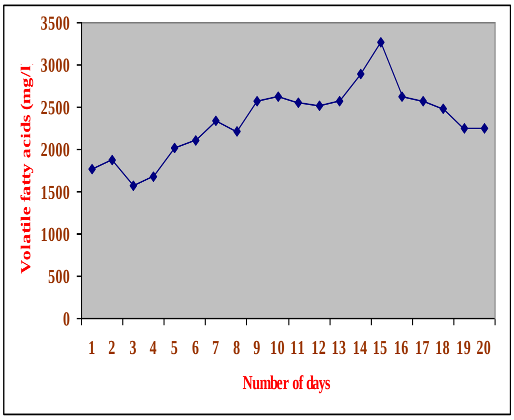

Fig.3: Showing the VFA content of food waste vs number of days

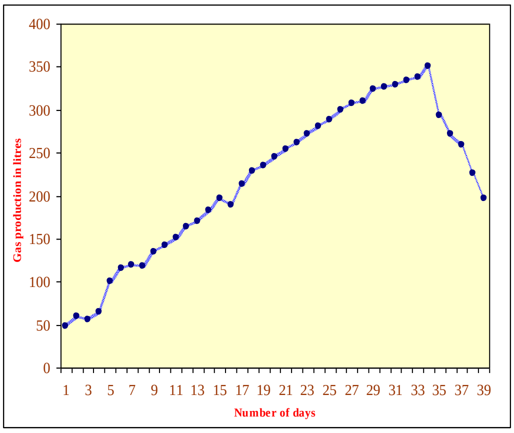

Fig.4: Showing the gas production rate of food waste vs number of days

IV. CONCLUSION

Since food waste is easily biodegradable and is having high volatile solids, it can be potentially used as a feed stock for biogas production. Use of inoculums can significantly reduce the lag phase of bacteria in food waste and hence biogas generation is continuous. Thus continuous feeding helps in daily biogas production and can be used at a small as well as larger scale to manage the organic waste and also produce the energy which can be used for the domestic purpose like cooking, lighting etc.

REFERENCES

[1] **Zhou, Z. Wu, W. Chen, Q. and S. Chen**. 2008. Study on sustainable development of rural household energy in northern China. *Renew. Sustain. Energy Rev.*, **12**: 2227–2239.

[2] **Ranade, D.R., Gore, J.A. and S.A. Godbole**.1980. Methanogenic organisms from fermenting slurry of the gobar gas plant. *Current Science*, **49:** 395 - 397.

[3] **Noykova, N.. Thorsten, G.M., Gyllenberg, M. and J. Timmer.** 2002. Quantitative analyses of anaerobic wastewater treatment process identifiability and parameter estimation. *Biotechnology And Bioengineering.*, 78, 89 - 103.

[4] **Walkley and I.A. Black.** 1985. An estimation of degtjareff method for determining soil organic matter and a proposed modification of the chromic acid –titration method. *Soil Sci*.,, **37**: 29 – 38.

[5] **APHA**, 2005. Standard methods for examination of water and wastewater,19th Ed. *American Public Health Association*, Washighton, DC, USA.

[6] **Lahav, O., B. E. Morgan and R. E. Loewenthal**. 2002. Rapid, simple and accurate method for measurement of VFA and carbonate alkalinity in anaerobic reactors. *Environ. Sci. Technol*. **36**:2736-2741.

[7] **Deublein, D. and Steinhauser, A**. 2008. *Biogas from Waste and Renewable Resources*; Wiley Online Library: Weinheim, Germany.

[8] **Augenstein, D.C., Wise, D.L., Wentworth, R.L. and Cooney, C.L.** 1997. Fuel Gas Recovery from Controlled Landfill of Municipal Wastes, *Resources Recovery Conserve*, 2, pp. 10.

[9] **Mahanta, P., Dewan, A., Saha, U.K. and Kalita, P**. 2004. Influence of Temperature and Total Solid Concentration on the Gas Production Rate of Biogas Digester, *Journal of Energy in Southern Africa*, 15 (4), pp. 112-117.

[10] **Wise, D.L**. 1987. *Global Bioconversions*, CRC Press, Florida, Vol. IV, pp. 178-189.

[11] **SPOBD**.1979. Biogas Technology and Utilization. Chengdu Seminar, Sichuan Provincial Office of Biogas Development, Sichuan, P.R. China.

[12] **Gerardi, M. H**. 2003. *The Microbiology of Anaerobic Digesters*; John Wiley & Sons: Chichester, UK, Vol. **3.**

[13] **Yadvika, Santosh, Sreekrishnan, T.R. Kohli, S. and V. Rana**. 2004. Enhancement of biogas production from solid substrates using different techniques - A review. *Bioresour. Technol.*, **95**, 1–10.

[14] **Y. Hong-Wie and E. B. David**. 2007, .“Anaerobic co-digestion of algal sludge and waste paper to produce methane,” *Bioresource Technology*, **98**(1):130-134.

[15] **TERI**. 1987. *Fixed Dome Biogas Plants: A Design*, Construction and Operation Manual, TERI, New Delhi, p. 3.

[16] **Raju, K. and Ramaligaiah**. 1997. Methane production from orange processing waste. *Indian J. Environ. Health*, **39**(1): 20–22.

[17] **Pachaiyappan, S., Priya Elavinvazhuthi, Dhamodharan, M. and S.Sundram**. 2014. Biogas production from water hyacinth blended with cowdung. *Indian Journal of Energy*, **3**(1):13 -139.