Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Nature Environment and Pollution Technology An International Quarterly Scientific Journal	ISSN: 0972-6268	Vol. 15	No. 2	pp. 437-442	2016

Original Research Paper

Synthesis of Biogas as a Renewable Energy from Organic Waste Mixture by Anaerobic Fermentation

A. Kumar*, K. Rasappan and P. Santhosh***†**
*Karpagam University, Coimbatore - 641021, Tamil Nadu, India
**Coimbatore Institute of Technology, Coimbatore-641014, Tamil Nadu, India
***Department of Chemical Engineering, Kongu Engineering College, Perundurai, Erode - 638052, Tamil Nadu, India
†Corresponding author: P. Santhosh

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 20-02-2015
Accepted: 25-09-2015

Key Words:
Animal waste
Vegetable waste
Anaerobic fermentation
Biogas

ABSTRACT

An alternative method of obtaining gaseous fuel is through the anaerobic fermentation of wet livestock (animal and vegetable) wastes to produce biogas which is a mixture of methane (45-75%) and carbon dioxide. The process occurs in two stages. In the first stage, the complex organic substance contained in the waste is acted upon by a certain kind of bacteria called acid formers and are broken into small chain simple acids. The second stage produces methane and carbon dioxide by another kind of bacteria. The calorific value of this biogas ranges from 16000-25000 kj/m^3. It is an excellent fuel for cooking and lighting as well. When blended with diesel, it is a very good alternate fuel for compression ignition engines and can yield diesel savings of 72 to 80%. Thus, by means of suitable apparatus, biogas is produced from animal waste and vegetable waste with high calorific value (more than 16000-25000 kj/m^3).

INTRODUCTION

Due to the increase in the price of petroleum and its demand, the environmental concerns about pollution from burning gases, biogas is becoming a booming area of high concern. The attractive features of biogas are (1) it is plant derived, not a fossil fuel and as such, its combustion does not increase current net atmospheric levels of carbon dioxide, a greenhouse gas, additionally. (2) It can be domestically produced, offering the possibility of reducing petroleum import. (3) It is biodegradable and relative to convectional gas fuel (Selvamurugan et al. 2013).

Biogas is distinct from other renewable energies because of its characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply. Biogas is a gas mixture and obtained by disintegration of organic materials in anaerobic conditions. 1m^3 biogas has 5000-5500 kcal energy, according to methane rate. It is an uncoloured and odourless and weaker than air. Its density rate, according to air is 83% and the octane number is 110. Subject of waste management, legislated and selling of electricity obtained from biogas is given an incentive bonus for increasing speed of this development. Nowadays, one of the most important problems of the world is environmental pollution. Increase of CO_2 emission because of using fossil energy sources cause global warming and climate change, which affects human life negatively. Biogas process can help reduce CO_2 emission born of using fossil energy sources, and also it reduces demand of fossil energy resources (Aremu & Agarry 2013).

Anaerobic digestion has been found a very good method to reduce organic matter and odours, destroy pathogens and produce energy (methane). Furthermore, anaerobic digestion is a good option to reduce mass volume of animal and vegetable wastes in the present environment. The objective of this study is to analyse, in terms of quantity and quality, the release of biogas and methane from animal waste and biodegradable vegetable waste and select the optimum ratio of the mixture as 60:40 for the study.

MATERIALS AND METHODS

Collection of Raw Materials

The vegetable waste was collected from Anna market, and animal waste from rural areas of Coimbatore, Tamilnadu. The mass of raw material for the mixture in the ratio of 60:40 as given in Table 1.

Preparation of Raw Materials

It was ensured that foreign materials like earth, sand, gravel, sawdust, etc., did not enter the digester. The slurry was prepared and later poured into a 20 litre bioreactor. Three litre tap water was added to the waste inside the reactor. The slurry was fully stirred manually.

Anaerobic Digestion

Anaerobic Digestion (AD) is the preferred stabilization process for the treatment of wastewater sludge's and organic wastes. Anaerobic digestors also function waste disposal process that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. The process provides volume and mass reduction and delivers valuable renewable energy with biogas production (Aluydas Zagorskis et al. 2012). Anaerobic digestion is a naturally occurring biological process consisting of four stages

Enzymic hydrolysis: In the first stage the organic matter is enzymolysed externally by extracellular enzymes, cellulose, amylase, protease and lipase of microorganisms. Bacteria decompose long chains of complex carbohydrates, proteins and lipids into small chains. For example, polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids.

Acidogenesis: Acid-producing bacteria, involved this stage, convert the intermediates of fermenting bacteria into acetic acid, hydrogen and carbon dioxide. These bacteria are anaerobic and can grow under acidic conditions. To produce acetic acid, they need oxygen and carbon. For this, they use dissolved O_2 or bound-oxygen. Hereby, the acid-producing bacteria create anaerobic condition which is essential for the methane producing microorganisms.

Also, they reduce the compounds with low molecular weights into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical point, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction.

Acetogenesis: The third stage anaerobic digestion is acetogenesis. Here simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acid as well as carbon dioxide and hydrogen.

Methanogenesis: Methanogenesis is a microbial process involving many complexes and differently interacting species, but most notably the methane-producing bacteria. In the final stage, the obligatory anaerobes that are involved in methane formation decompose compounds with a low molecular weight. They utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, CH_4 producing microorganisms occur to the extent that anaerobic conditions are provided. The methanogenic bacteria belong to the archaebacter genus, i.e. to a group of bacteria with heterogeneous morphology and a lot of common biochemical and molecular-biological properties that distinguish them from other bacteria.

Symbiotic of bacteria: Symbiotic groups of bacteria perform different functions at different stages of the digestion process. There are four basic types of microorganisms involved. They are hydrolytic, fermentative, acidogenic and methanogenic bacteria. Hydrolytic bacteria break down complex organic wastes into sugars and amino acids. Fermentative bacteria then convert those products into organic acids. Acidogenic microorganisms convert the acids into hydrogen, carbon dioxide and acetate. Finally, the methanogenic bacteria produce biogas from acetic acid, hydrogen and carbon dioxide.

Biogas

Biogas is produced by bacteria through the biodegradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of biogeochemical carbon cycle (Ukpai & Nnabuchi 2012). It can be used both in rural and urban areas. The composition of biogas is given in Table 2.

Factors Affecting the Generation of Biogas

Acidity: Anaerobic digestion will occur at an optimum pH range of 6.8 to 8.0. More acidic or basic mixtures will ferment at a lower speed. The introduction of raw material will often lower pH (make the mixture more acidic). Digestion will stop or slow dramatically until the bacteria have absorbed the acids. A high pH will encourage the production of acidic carbon dioxide to neutralize the mixture again.

C/N ratio: The bacteria responsible for the anaerobic process require both elements, as do all living organisms, but they consume carbon roughly 30 times faster than nitrogen. Assuming all other conditions are favourable for biogas production, a carbon/nitrogen ratio of 30:1 is ideal for the raw material fed into a biogas plant. A higher ratio will leave carbon still available after the nitrogen has been consumed, starving some of the bacteria of this element. These will in turn die, returning nitrogen to the mixture, but slowing the process. Too much nitrogen will cause this to be left over at end of digestion (which stops when the carbon has been consumed) and reduce the quality of the fertilizer produced by the biogas plant. The correct ratio of carbon to nitrogen will prevent loss of either fertilizer quality or methane content.

Temperature: Anaerobic breakdown of waste occurs at temperatures lying between 0°C and 69°C, but the action of the digesting bacteria will decrease sharply below 16°C. Production of biogas is most rapid between 29°C and 41°C or between 49°C and 60°C.

This is due to the fact that two different types of bacteria (acetogens and methanogens) multiply best in these two different ranges, but the high temperature between 32°C and 35°C has proven most efficient for stable and continuous production of methane. Biogas produced outside this range will have a higher percentage of carbon dioxide and other gases than within this range.

Stirring: A few methods of stirring the slurry in a digester is always advantageous, if not essential. If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of the biogas. This problem is much greater with vegetable waste than with manure, which will tend to remain in suspension and have better contact with the bacteria as a result. Continuous feeding causes fewer problems in this direction, since the new charge will break up the surface and provide a rudimentary stirring action. If some form of heating is needed for the biodigester, as is generally the case in European winters, this will also provide some circulatory action, which will tend to stir the contents.

Feeding: There are two types of feeding, they are:

Continuous feeding (for liquids): The complete anaerobic digestion of cow manure takes about 8 weeks at normal warm temperature. One third of the total biogas will be produced in the first week, another quarter in the second week and the remainder of the biogas production will be spread over the remaining 6 weeks. Biogas production can be accelerated and made more consistent by continuously feeding the digester with small amounts of waste daily. This will also preserve the nitrogen level in the slurry for use as fertilizer. If such a continuous feeding system is used, then it is essential to ensure that the digester is large enough to contain all the material that will be fed through in a whole digestion cycle. One solution is to use a double digester, consuming the waste in two stages, with the main part of biogas (CH_4) being produced in the first stage and the second stage finishing the digestion at a slower rate, but still producing another 20% or so of the total biogas.

Batch feeding (for solids): This biogas system is designed to digest solid vegetable waste alone. Since solid matter does not flow through pipes, this type of digester is best used as a single batch digester. The tank is opened, old slurry is removed for use as fertilizer and the new charge is added. The tank is then resealed and ready for operation. Depending on the waste material and operating temperature, a batch digester will start producing biogas after two or four weeks. The production slowly increases with time and drop off after three or four months.

Table 1: Mass of raw materials.

Animal and vegetable waste	Weight (kg)
Cow dung	2.5
Goat dung	2.0
Potato	0.235
tomato	0.300
Yarn	0.470
Karunai	0.250
Beet root	0.670
Bitter guard	0.200
Ladies finger	0.250
Brinjal	0.200
Beans	0.400
Guava	0.100
Yeast	0.024
Total weight of solids	7.579
Water	3 Litre

Table 2: Composition of biogas.

Component	Concentration (by volume)
Methane (CH_4)	55-60 %
Carbon dioxide (CO_2)	35-40 %
Water (H_2O)	2-7 %
Hydrogen sulphide (H_2S)	20-20,000 ppm (2%)
Ammonia (NH_3)	0-0.05 %
Nitrogen (N)	0-2 %
Oxygen (O_2)	0-2 %
Hydrogen (H)	0-1 %

Table 3: Flame test.

Sl.No.	No. of days	Flame effect	Gas production
1.	1	Off	CO_2 Produced
2.	2	Off	CO_2 Produced
3.	3	Off	CO_2 Produced
4.	4	Off	CO_2 Produced
5.	5	Off	CO_2 Produced
6.	6	Off	CO_2 Produced
7.	7	Off	CO_2 Produced
8.	8	Off	CO_2 Produced
9.	9	On	CH_4 Produced
10.	10	On	CH_4 Produced
11.	11	On	CH_4 Produced
12.	12	On	CH_4 Produced
13.	13	On	CH_4 Produced
14.	14	On	CH_4 Produced
15.	15	On	CH_4 Produced

Batch digesters are therefore best operated in groups, so that at least one is always producing useful quantities of gas. Most vegetable matter has a much higher C/N ratio than dung has, so some nitrogen producers (preferably organic) must generally be added to the vegetable matter, especially when batch digestion is used. Weight for weight, however, veg-

Table 4: Volume of biogas produced (m^3) within 15 days retention time.

Sl.No.	No. of days	pH	Diameter of balloon (cm)	Volume of biogas (m^3)	Cumulative volume (m^3)
1.	1	6.50	2	0.0	0.0
2.	2	6.52	3	0.00042	0.00042
3.	3	6.74	5	0.00141	0.00183
4.	4	6.51	6	0.00654	0.00837
5.	5	6.50	7	0.01131	0.01968
6.	6	6.70	8	0.01795	0.03763
7.	7	6.90	9	0.02680	0.06443
8.	8	6.40	9	0.03817	0.1026
9.	9	6.54	10	0.03817	0.14077
10.	10	6.50	10	0.05236	0.19313
11.	11	6.33	11	0.05236	0.24549
12.	12	7.02	11	0.06969	0.31518
13.	13	7.25	12	0.06969	0.38487
14.	14	7.52	13	0.09047	0.47534
15.	15	7.50	13	0.11503	0.59037

Table 5: Biogas yield.

Raw material	Vegetable waste	Animal waste	Co-digestion of both
Biogas yield (m^3/kg)	0.36 m^3/kg	0.37 m^3/kg	0.59763 m^3/kg

etable matter produces about eight times as much biogas as manure, so the quantity required is much smaller for the same biogas production. A mixture of dung and vegetable matter is hence ideal in most ways, with a majority of vegetable matter to provide the biogas and the valuable methane contained in it (Sunarso et al. 2010).

Experiment Setup

The size of the reactor was designed based on the weight density of material used for anaerobic digestion. Reactors, which are made of Poly Vinyl Chloride (PVC) drum are single compartment units, and consisted of leak proof outlet pipe joint made on the roof of the reactor. A balloon is fixed at the end of the pipe which acts as a gas holder. All the raw materials are fed in the bioreactor. The raw materials are stirred thoroughly. Tests were carried out in bioreactor of continuous operation, whose volume amounts to 20 litre respectively. Bioreactor was filled with mixture of organic biodegradable vegetable and animal waste and operated in the mesophilic temperature of 35°C ± 1°C. Later, read the pH of slurry in range of 6.5-8.0. The process is continued, for the first nine days CO_2 is produced. After that CH_4 gas is generated. Throughout the experiment, the amount of released biogas and methane were recorded on daily basis, as given in Table 3.

Biogas Production

The biogas in an anaerobic digester is collected in an inverted drum. The walls of the drum extend down into the slurry to provide a seal. It is free to move to accommodate more or less gas as needed. The weight of the drum provides the pressure on the gas system to create flow. Biogas flows through a small hole in the roof of the drum. A non-return valve here is to prevent air being drawn into the digester, which would destroy the activity of the bacteria and provide a potentially explosive mixture inside the drum.

Larger plants may need counterweights of some sort to ensure that the pressure in the system is correct. The drum must obviously be slightly smaller than the tank, but the difference should be as small as possible to prevent loss of gas and tipping of the drum.

RESULTS AND DISCUSSION

One of the key indicators showing the efficiency of the anaerobic treatment of biodegradable waste is the evolved amount of biogas. The larger the biogas yield at a stable amount of methane, the higher is the benefit (more energy) obtained during anaerobic digestion of organic waste. The data observed by us experimentally, are depicted in Table 4. The variation of pH versus retention time and volume of biogas produced versus retention time is shown in Figs. 1 and 2. The Fig. 3 shows the cumulative gas volume.

Table 5 gives the summary of the results for the three wastes for the 15 days retention period. From the table, co-digestion generated the highest total gas volume of 0.59763m^3/kg, followed by animal waste with 0.37m^3/kg of gas and lastly vegetable waste produced 0.36m^3/kg of gas.

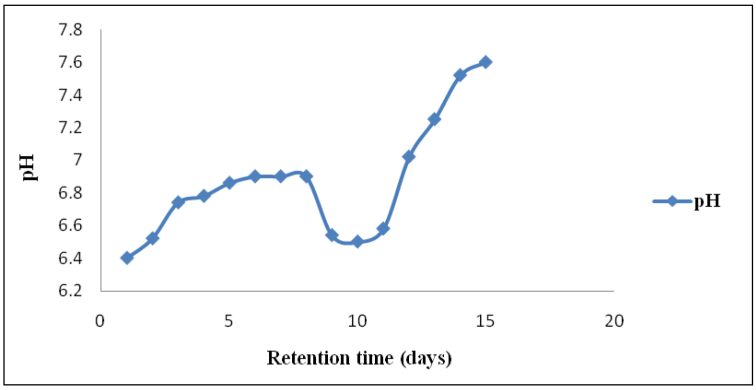

Fig. 1: Varation of pH.

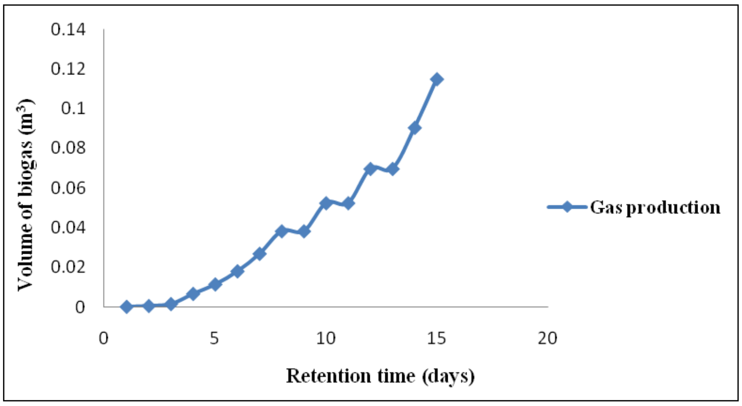

Fig. 2: Volume of biogasproduction.

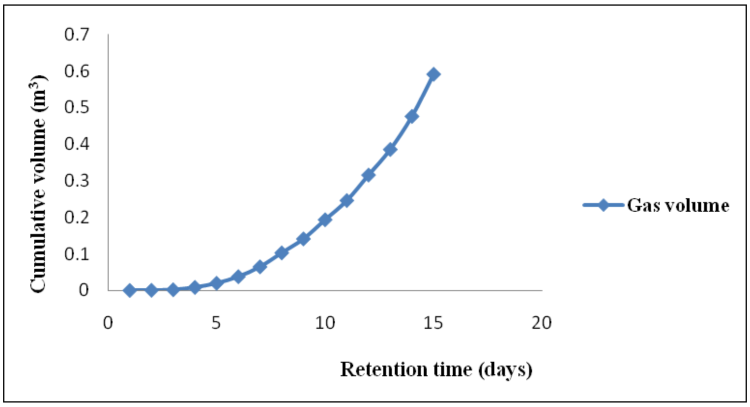

Fig. 3: Cumulative biogas volume.

CONCLUSION

The production of biogas by using anaerobic fermentation process is proposed here, due to its dual advantage. Securing our environment from contamination by using animal and vegetable waste as the raw material and the production of the biogas as a renewable energy source. Reduction of pollution makes biogas much more useful to the present world. The biogas is used to reduce the demand and consumption of LPG and wood fuel. Biogas is considered as an eco-friendly suitable to any non-conventional gaseous fuel. It is cost effective and also it is renewable, since it is produced from animal and vegetable waste. Further, we can do more research on the biogas to increase the production and give more awareness to the people about biogas and its importance in the global issue.

REFERENCES

Aluydas, Zagorskis, Pranas, Baltrenas and Antonas, Misevicius 2012. Experimental biogas research by anaerobic digestion of waste of animal origin and biodegradable garden waste. African Jr. of Biotechnology, 11(100): 16586-16593.

Aremu, M.O. and Agarry, S.E. 2013. Enhanced biogas production from poultry dropping using corn-cob and waste papers as co-substrate. Int. Jr. of Engineering and Science and Technology, 5(02).

Budiyono, B., Sumardiono, S. and Sunarso, S. 2010. Biogas production using anaerobic biodigester from Cassava starch effluent. Int. Jr. of Sci. and Engg., 1(2): 33-37.

Selvamurugan, M., Ramkumar, V.R., Doraisamy, P. and Maheswari, M. 2013. Effluent of biomethanated distillery spent wash and biocompost application on soil quality and crop productivity. Asian Jr. of Science and Technology, 4(10): 124-129.

Sharma, R., Sharma, D., Roa, K.S. and Jain, R.C. 2002. Experimental studies on waste paper pulp biodegradation. Indian Journal of Environmental Health, 44(3): 181-188.

Ukpai, P.A. and Nnabuchi, M.N. 2012. Comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 liters biogas digester. Advances in Applied Science Research, 3(3): 1864-1869.