A Review of The Factors Affecting Biogas Yield and Their Optimization

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Abstract

Biogas is a renewable energy source which is produced by the anaerobic decomposition of the organic and solid waste. It mainly consists of methane, carbon dioxide and a small amount of hydrogen sulphide and moisture. It is a green energy which has a potential of replacing the conventional fuel to some extent. A number of factors are there which affect the production of the biogas production from anaerobic digestion. Factors affecting biogas yields are divided into two main categories, primary and secondary factors. Primary factors mainly comprise of temperature, pH of the slurry, C/N ratio of the composition, organic loading rate, moisture content, Hydraulic Retention Time (HRT) etc whereas secondary factors are design & construction of digester and operation & management. This review is based on the study of the factors affecting the biogas production and their optimization.

Keywords*:* C/N Ratio, biogas, Hydraulic Retention Time (HRT), renewable energy.

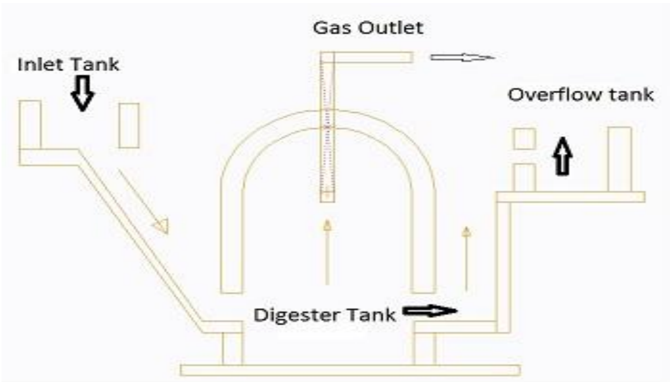
1. Introduction

Biogas is a green fuel which founds a variety of use in developing countries like Nigeria and Uganda. Biogas is produced by the anaerobic digestion of organic waste like the animal and human waste. Biogas generation will help the cities and the slum in the countries like Nigeria and Uganda in proper sanitation. Due to income conditions, several parts of the countries don't have proper sanitation or waste management systems. These wastes further caused several hazardous health conditions. People will get proper clean fuel for their daily household uses. Biogas generation has social as well as economic impact. It is the best option for the people of the developing countries as a source of fuel and energy.

1.1Working of the biogas plant

Biogas production process comprises of several steps. First organic waste undergoes a pre-treatment process where it is mixed with some chemicals like maceration to increase the gas yield. After the pre-treatment process, it is mixed with water in proper proportion to form a slurry in the mixing chamber (tank). This slurry is mixed with some enzymes and inserted in the digester for decomposition. In the absence of oxygen micro bacteria produces in the slurry which further initiates anaerobic decomposition of the slurry. Biogas is produced as a result of the decomposition.A traditional biogas plant mainly consists of three Components, inlet tank, digester and the overflow tank. Component of the biogas plant where decomposition takes place is known as the digester. Overflow tank is used to manage the flow of excess slurry in the digester. The arrows in the figure show the path of slurry flow in the biogas plant. Digestion chamber is further fitted with an outlet valve and gas hose on the top of the drum in order to extract the produced biogas.

Fig. 1: Biogas plant



2. Literature survey

I.S. Ogiehor et al**.**[1]performed the experimentwith solid agriculture and animal waste to study the effect of primary factors such as temperature, pH of the slurry and the solid concentration on biogas production. They used a 2ltr plastic container fitted with a gas hose in the cap of the container as experimental setup. They performed the experiments in the batch form a matrix setup of the containers was made with 5 rows and 4 columns of the digesters. Slurry of 10%, 15%, 20%and 25% solid concentration is taken under experiment. Slurry samples of different pH 5, 6, 7, 8, and 9 are taken, understudy. Biogas production commenced within 24 hrs of the recharging of the digester. The experiment was performed at two different mesophilic temperatures 30degree and 35 degree Celsius. Highest cumulative gas yield for 14 days was in a case of slurry with SC 25%, pH 7 and temperature 35degree Celsius.

Pramod k. Pandey etal.[2]performed an experiment on ambient (25 degree Celsius), mesophilic (37degree celsius) and thermophilic temperature(52.5dgree Celsius) to determine the effect of temperature on biogas yield. They performed the experiment with dairy manure.

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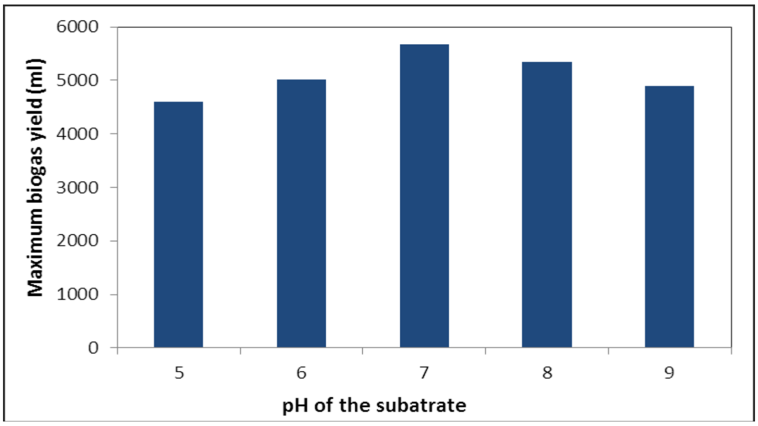
Temperature and solid reduction were measured on the daily basis. Biogas yield at 52.5degree Celsius is 49times higher than that of 25degree Celsius and biogas yield at 37degree Celsius is 17times of the amount of gas yield at 17degree Celsius. Percentages of total solid reduction are 5.6, 57 and 34 at 25degree, 37 degree and 52.5 degree Celsius respectively. Percentage reductions in volatile solid are 127, 58.4 and 42.50 at 25degree, 37degree and 52.5 degree Celsius respectively. pH value of the slurry decreases at ambient and mesophilic digestion whereas increases in case of thermophilic digestion. Methane composition in the biogas produced is very small in the case of ambient temperature, 55% in mesophilic decomposition and 70% in case of thermophilic decomposition.

S. Jayaraj et al.[3] experimented to determine the effect of pH value on the anaerobic decomposition of the food waste. They collected the food waste from the NIT Calicut mesh and substrate was prepared with 1N sodium bicarbonate solution. The substrate was stored at 5degree Celsius before the experiment. Batch reactors of 2ltr volume were used as the digester for the study. 7.5% SC of the total solid substrate were taken in each reactor for decomposition. Hydraulic retention time (HRT) period of 30days was taken for the study. Cumulative biogas yield values for the substrate of pH 5, 6, 7, 8 and 9 were 4594, 5021, 5673, 5347 and 4889 respectively. Methane concentrations in the biogas produced during the study were 56.7, 58.6, 60.8, 60.1 and 59.4% for substrate pH value of 5, 6, 7, 8 and 9 respectively.

Fig.2 : Effect of pH of substrate on the biogas yield[3]



The highest gas yield was in the case of a substrate with pH value 7 and lowest in the case of a substrate with pH 5. Total and volatile solid reduction values for the substrate with pH 7 were 49.44 and 50.91% respectively. Chemical oxygen demand for the degradation was 38.93, hence pH of the substrate is an important factor for the biogas yield.

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P. Vindis et al.[4]conducted an experiment on anaerobic digestion of maize silage to study the effect of temperature. They performed the experiment in a specially designed mini digester for durations of 5weeks. A mixture of a 15gm substrate with 385 gm of inoculums was prepared for the digestion. The experiment was conducted at two temperatures mesophilic(35degree Celsius) and thermophilic(55degree Celsius). Biogas yield at mesophilic temperature came out from 315 to 409 NI kg VS^-1 where yield at thermophilic temperature is from 494 to 611 NI kg VS^-1. Thermophilic digestion is approximately 4times intense and has higher VSS removal efficiency. Methane composition in biogas was 50-70% (v/v) and that of carbon dioxide was 10-40% (v/v).

Oghenero W. Orhorhoro et al.[5]conducted an experiment on anaerobic digestion of vegetable waste, sweet potato, cassava peels, animal, and plantain waste to study the effect of carbon to nitrogen (C/N) ratio on biogas production. All the substrates were weighed 10kg individually and then mixed with water in 1:2 ratio. All the substrates were collected separated. Three extra batches were prepared, one with C/N ratio less than 20, other with C/N ratio more than 30 and the third with a combination of high and low C/N ratio substrate. All the substrate batches underwent anaerobic degradation for a duration of 37days. During the study, all the substrate was stirred three times daily. Biogas yield was calculated using the formula given below.

R = (BY/HRT)

R- Rate of biogas production.

BY- Cumulative Biogas yield.

HRT- hydraulic Retention Time.

All the variables are measured periodically. Biogas yield of the substrate with C/N ratio less than 20 was 0.058m^3/kg. Biogas yield for the substrate with C/N ratio more than 30 was 0.081m^3/kg. Biogas of the substrate with the combination of high and low C/N ratio has the highest gas yield, which is 0.108m^3/k. The combination of high and low C/N ratio substrate is required for optimum gas yield.

I.J. Dioha et al.[6]performed an experiment on anaerobic digestion of cow dung to study the effect of C/N ratio on the biogas yield and anaerobic degradation. They used 250ml flat bottom conical flask dried in the oven as a digester. They used inverted tube technique to measure the biogas produced. A sample of various sources with different C/N ratio was also

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taken under the study for comparison. Rice husk produces about 25% of the yield of poultry dropping whereas Neem leaves and sugarcane bagasse gave 10 and 15% of the poultry droppings. Bagasse with highest C/N ratio has the lowest biogas yield whereas poultry dropping with lowest C/N ratio has gas yield more than bagasse but less than cow dung which has C/N ratio in between both. For maximum biogas yield, C/N ratio should be around 25:1 to 30:1.

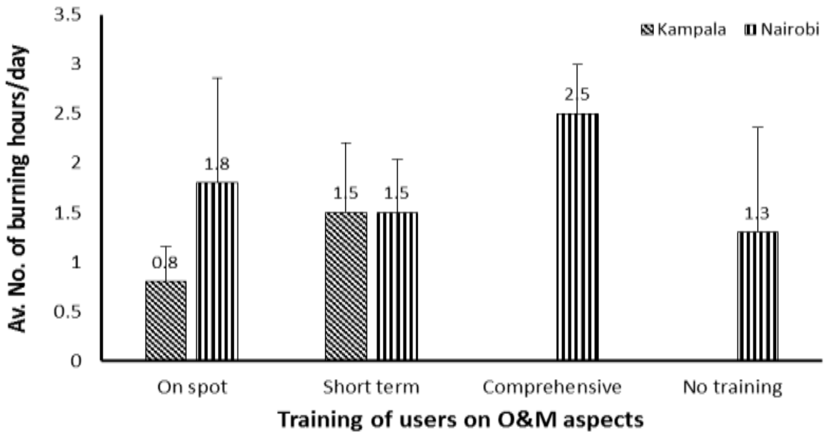
Feng Yongzhong et al.[7]performed an experiment with the various substrate to find out the effect of temperature and addition of substrate combination on biogas yield from human excreta. They used 5ltr plastic pots as a digester, 1ltr Erlenmeyer flask as a gas collector and 2.5ltr plastic pot as discharged water receiver. A mixture of cow dung and human excreta is prepared in 1:1 (DM) and a mixture of wheat powder and human excreta in 1:1 (DM) ratio was prepared for the study at a different temperature. Each digester was filled with 2000gm of digesting materials and 50 gm of inoculums with 8% SC. Each sample is digested at four different temperatures 15degree, 20degree, 25degree ambient temperature and 30degree mesophilic temperature. Biogas production initiation takes a longer time at a lower temperature than at higher temperature. The highest production rate was achieved at 30degree Celsius which is 930ml/day. Biogas yield at mesophilic temperature (30degree) was 284% higher than that at 15degree Celsius and 108% higher to that at 20degree Celsius. The substrate with the mixture of human excreta and wheat powder has highest cumulative yield followed by the mixture of cow dung and human excreta.

Md. Shariful Islam et al.[8]investigated the effect of design and operation on biogas production. They conducted the study in the capital city of Bangladesh for the duration of 12 months. Their study was concentrated on biogas production from two types of biodigester, local digester (without any controlling scheme) and imported digester (with all type of controlling scheme). The volume of the digesters varies from 6.4m^3 to 4000m^3. As a result, they found biogas yield of imported digester is 75% more than that of a local biogas digester. Methane content of the biogas varies from 60 to 70% in the hotter digester and lower up to 40% in the colder digester. Hence the design of the biodigester and control system play an important role in biogas production.

P. Mutai et al.[9]investigated the effect of structural and operation & management factors on biogas production. He conducted the study in the city of Kampala and Nairobi located in East

Africa. They compared the biogas yield on the basis of skill of mason which constructed the digester, design of dome (fixed and floating), training of users etc. He found out that mason with high skill can construct the digester which can yield almost double of the digester built by skilled and non-skilled masons. The volume of the digester directly affects the biogas yield. Users with comprehensive training when operating the biogas plant biogas yield gets almost twice to that of users with on-spot and short-term training.

Fig.3: Effect of user's training on bio gas yield



ShyamGoswami et al.[10]investigated on the factors affecting biogas production and their optimization. Anaerobic digestion of organic waste and biogas yield depends on a number of factors such as temperature, pH value of substrate, C/N ratio of the substrate design of the digester, operation and management etc. For maximum biogas yield from the anaerobic degradation, substrate should be pre-treated with maceration which increases the yield by 25%, Hartmann (2000)ultrasonic pre-treatment increases the production by 64%. Organic and nonorganic additives like nickel ion increase the biogas production by 54%. Mesophilic temperature digestion is most suitable for anaerobic digestion. An operation like stirring increases the biogas yield. Temperature-phased anaerobic digestion, which initially operates at thermophilic temperature than at mesophilic temperature, is most prominent, Harikrishna and Sung (2003).

3. Conclusion

Primary factors for instance, temperature, pH of the substrate, C/N ratio of the substrate and HRT affect the biogas yield up to a great extent. Secondary factors for instance, the design of the digester, constructional and operation & management are also affect the biogas production up to some extent. For maximum biogas yield, the following points should be kept in a notice.

1. Pre-treatment of the organic waste and substrate before feeding to the digester improves the biogas yield. Ultrasonic pre-treatment of substrates increases the yield by 64% whereas pre-treatment of the substrate with maceration increases the yield by 24%.
2. The addition of organic and non-organic additives like nickel ions, iron, calcium and magnesium salts, intensified the digestion process and increases the biogas production.
3. Highest biogas yield is obtained at thermophilic temperature but thermophilic temperatures are very unstable in nature and require large input hence the most suitable temperature for anaerobic digestion and biogas yield is mesophilic temperature.
4. The most suitable range of pH values for the optimum biogas yield is 6.8 to 7. More or less value of pH will decrease the biogas yield.
5. The most suitable range of Carbon to Nitrogen ratio for the maximum biogas yield is 25:1 to 30:1. C/N ratio value higher or lower to this value results in the decrease of the biogas production.
6. Proper design and construction of the digester from the high skilled persons give the optimum biogas yield.
7. Proper training of the user about the operation and maintenance of the plant is an important factor in increasing the biogas yield.

4. Acknowledgement

The data and studies are helpful for design consideration of an effective biogas plant. The optimized values of the factors will further helpto attain the maximum methane composition in biogas.

5. Future work

Further research focused towards the factors influencing the calorific value of the gas. Study will ensure the implementation of the results derived in the above study ensure the production of biogas of higher quality and quantity for industrial applications.

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