© 2018 IJSRSET | Volume 4 | Issue 4 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Anaerobic Digestion of Biomass Waste : A Comprehensive Review

P. C. Roy* and S. Paul
Department of Mechanical Engineering, Jadavpur University, Kolkata, West Bengal, India

ABSTRACT

Biogas is obtained through Anaerobic digestion process of biomass waste. The present work aims to discuss the different factors affecting the digestion process. A comprehensive review of some biogas plants have been presented to show the techno-economic feasibility of different plants based on the different locally biomasses. But most of the cases plants are installed with adequate financial supports as subsidy but plants affects from the technical knowhow. Effect of different process parameter such as temperature, pH, C/N ratio on biogas generation, need to be taken care of to run the biogas plant to have maximum biogas generation rate with highest yield.

Keywords: Biomass, Biogas, Anaerobic Digestion, Digester Performance.

I. INTRODUCTION

Energy consumption in the world is mostly dependent on fossils fuel reserve. Due to rapid growth of industrialization and urbanization, there is a severe shortfall of electricity generation specifically in the developing countries like India and China. The electricity generation increased 5.1 billion units in 1950 to 1107 billion units in 2015-16. The quantity of fossils fuel are limited in the earth, hence the crisis of this type of fuel are increasing and the price also. Emission coming out by burning of the fossils fuel polluted the environment because of the presence of hydrocarbon, carbon monoxide, oxide of nitrogen and particulate matters in their exhaust gas. The emitted gas polluted the environment as well as causes for the climate changes. Global warming is a major problem at present due to greenhouse gases. To overcome these problems researcher were looking for as alternative fuels those are renewable. Different types of alternative sources are used such as solar, hydel, wind, biomass etc. Harnessing renewable energies are mainly site specific and per unit costs are high. Biomass is the one type of renewable energy which is easily available throughout the India, as a tropical country. Gaseous fuel can be extracted through gasification or anaerobic digestion. Gasification is fast process compared to anaerobic digestion. But methane is obtained from anaerobic digestion is more clean fuel compared to producer gas obtained from gasification. Methane can be used as a cooking fuel or can be used as a engine fuel or for power generation. In the present paper, some case studies have been presented to justly the fact that anaerobic digestion of waste biomass may be viable option for sustainable development of rural India.

II. ENERGY FROM BIOMASS

Biomass are easily available organic material as agriculture waste like animal manure, energy crops, crop residues; industrial waste like waste from dairy industry, food processing industry, sugar industry, wood waste, paper mill waste; municipal solid waste like kitchen waste, food waste, green waste etc. There are two types of conversion technology for conversion

of biomass to bio fuel. One is the thermochemical conversion and another is biochemical conversion. In thermochemical conversion there are three process combustion, gasification, pyrolysis and in biochemical conversion there are two process fermentation and anaerobic digestion which convert biomass to bio energy. The conversion of biomass to biogas are depends upon certain factors like environmental condition, feedstock, quality of the biomass, economic condition, type of digester etc.

III. BIOGAS THROUGH ANAEROBIC DIGESTION

Generally dry biomass are used for gasification and wet or biomass contain moisture are used for anaerobic digestion process. There are two type of digestion process one is aerobic digestion and another is anaerobic digestion process. The aerobic digestion happens in presence of oxygen and due to the presence of oxygen there is no combustible product left after digestion. Whereas the anaerobic digestion (Bio-methanation) happens in the absence of oxygen and the product comes out from this process is known as biogas. The end products from anaerobic digestion are mostly methane 50- 70%, carbon dioxide 30-50% and little portion of nitrogen, hydrogen sulphide, oxygen, ammonia, hydrogen [1]. There are four steps by which the conversion from biomass to biogas in bio-methanation

3.1 Hydrolysis

In hydrolysis the complex compound which are insoluble like carbohydrate, protein are brake down to soluble compound like amino acid, sugar, fatty acid, amino acid with the help of cellulose enzyme like proteases, amylases, cellulases and lipases. Carbohydrates becomes sugar or alcohol, cellulose becomes glucose or cellobiose, proteins becomes amino acid or peptides, fat becomes fatty acid or glycerol.

3.2 Acidogenesis

It is the next step of the digession process where acidogenesis bacteria converted the product from hydrolysis to alcohol (methanol, ethanol), hydrogen, carbondioxide, acid (propionic acid, butyric acid, acetic acid, lactic acid, formic acid). This is generally the faster process and the growth rate of acdogenesis bacteria is higher than the methanogenesis bacteria [2]. In this process sugar is converted to fatty acid, glycerol converted to acetate, carbondioxide.

3.3 Acetogenesis

The product from acidogenesis is converted by acetogenesis bacteria to carbon dioxide, hydrogen, acetic acid. This process is very much dependent on the pressure, temperature and other condition of the digester. This process is good when the partial pressure of hydrogen is less.

3.4 Methanogenesis

This is the last step of digestion process which occurs in anaerobic condition only where carbon dioxide, hydrogen are converted to methane and carbon dioxide by methanogens bacteria. Generally 70% of total methane are formed from acetate and rest 30% are carbon dioxide and hydrogen. Two types of bacteria affecting the reaction –hydrogenotrophic (known as hydrogenophilic genera) and the acetoclastic species (known by acetotrophic).

IV. FACTOR AFFECTS BIO-METHANATION

Several factors that affects on methane production through biomethanation are temperature, pH value, C/N ratio, volatile fatty acid etc.

4.1 Temperature

Generally there are three temperature range psychrophilic (0-20 ºC), mesophilic (20-45 ºC) and thermophilic (45-65 ºC). There is a fourth temperature range between 70- 95 ºC known as hyperthermophilic.

Mesophilic condition is the ideal condition for biogas production but the bacteria are more active in themophilic condition and producton of biogas is increased. But it is required some energy consumption to maintain the high temparature. Hence the retention time is larger in mesophilic temperature than thermophilic condition.

4.2 pH value

Digester can be performed at different pH value but according to literature the production of methane is more in neutral pH value which is 7. Hydrolysis and acidogenesis occurs efficiently at pH 5.5-6.5 and methanogenesis occurs efficiently at pH 6.5-8.5. The optimum range of ph is 6.8 to 7.2 [3]. There is no biogas production if the pH value is less than 4.

4.3 C/N ratio

The C/N ratio represents the ratio of carbon and nitrogen in the organic matter which affect the biogas production. High C/N ratio decreases the N percentage than C hence the nitrogen consumption is more and the nutrients deficiency whereas the low C/N ration increase the production of ammonia in the digester which reduces the methane production. The C/N ratio varies from 20-30 for optimum biogas production [4].

4.4 Volatile Fatty Acids (VFA)

Volatile fatty acids are the product after acidigenesis. If the production of VFA is more, the acid is more in the process which reduce the pH value of the digester and the substance become toxic. For maximum of VFA removal and biogas production rate the optimum concentration for propionate, butyrate and acetate are 1.93 g.L -1 , 2.15 g.L -1 and 2.50 g.L -1. pH and the total VFA concentration are the two key parameters for digestion process. The optimum level for VFA degradation is in the pH range of 6.5 to 7.2 [5].

4.5 Organic loading rate

Organic loading rate is an important parameter because if the organic loading rate lower, which gives less production of biogas and also uneconomical because the digester cannot run on full load. As the loading rate increases the production of biogas also increases. But there is a chance of over loading which gives more VFA in the system which makes the process toxic, which causes failure of the digester.

4.6 Nutrients

Nutrients helped to increase the rate of reaction in anaerobic condition. There are two types of nutrients presents- macronutrients and micronutrients. The macronutrients are mainly carbon , nitrogen, phosphorus and sulphur and the other nutrients such as hydrogen which is required for methane production.

V. REVIEW OF BIOGAS PLANTS

A compressive review of few biogas plants have been presented to show the techno economic feasibility of energy conversion technique from biomass to biogas and also its benefits on social environment and economic aspects.

5.1. Case Study 1. Biogas Power Plant at Surat:

This is a biggest plant producing biogas spread over two hector land located at Dumbhal in Surat by partnership of Agricultural Produce Market Committee and Didask Bioenergy Pvt Ltd. Vegetable and fruit wastes are used as a feedstock. This plant handles 110 MT of waste in daily basis and produces 11,000 cubic metres of biogas, 4,000 kg of bio-CNG every day. It is a zero discharge plant and the CNG is stored in pressurized form and sold as a vehicle fuel [7].

5.2. Case Study 2. A 30 kw biogas plant in Kerala:

A biogas plant of capacity 30 kW electricity is located at Connemara market in Palayam, Thiruvananthapuram. The feedstock of the plant is

the leftovers from the fish and vegetable market along with the household wastes of approximately 1,500 residences. The processing capacity of the plant is two tonnes of garbage a day. Electricity generated from the plant is utilised to light energy-efficient lamps in the fish market and open areas of the market [9].

5.3. Case Study 3. A biogas bottling project in Punjab:

A biogas bottling project was setting up at Kalatibba village, Tehsil Abohar, Ferozepur district by Anand Energy. Cattle dung, poultry waste and kitchen waste are used as a feedstock material. The capacity of the project is to produce biogas 600m^3 per day. Government aprove 45.50 lakhs for this project in 2009-10. The biogas containing 98% of methane after upgrading and filling in the cylinder at 150bar pressure which is supply as a cooking fuel for school students[10].

5.4. Case Study 4. A Biomethanation Plant, Mangalore City:

A biomethanation plant is set up near Urwa Market, Mangalore City by Mangalore City Corporation using the technology developed by Bhabha Atomic Research Centre (BARC), Mumbai. The power generated from the plant is used to achieve self-sufficiency in power supply in operating the plant and supplying power to the market. With this plant, the corporation would achieve the twin objective of saving the cost of transporting the bio-waste to the compost plant and reduce volume of waste being lifted from the market. The plant can produced 261 cubic metres of methane gas and capable of producing more than 200 kW power[10]..

5.5. Case Study 5. A biogas plant at Sundarpur in Anand district of Gujrat:

A biogas plant of capacity 5,000 m^3 per day capacity is operational in 2015 at Sundarpur in Anand district of Gujrat. The capacity of the plant can be expanded upto 10,000 cubic meters. This plant utilizes multi-feed German technology to convert agriculture waste such as banana stems, potato peels, animal dung, sugarcane waste and waste from sugar factories into biogas. The biogas produced is supplied to nearby industries to be used in various ways such as in furnaces, wielding work and melting copper [11].

VI. CHALLENGES OF ANAEROBIC DIGESTION PROCESS

The energy from biomass through bio-methanation is mature technology but its performance and reliability of the plant depends of number of factors temperature, pH value, C/N ratio, volatile fatty acid etc. But plant owners are not aware of these facts. The biomasses are easily available in the local area as a waste product. Initially stakeholders are shown interest to install a plant since they are getting financial subsidies. But most of the plants are run without adequate know how that affects with lower gas production rate. Along with technical issues, there are some issues those are taken care of for the production of the biogas, although the quantity of methane in biogas is dependent on feedstock and other atmospheric conditions.

- ✓ Choice of material as a feedstock.
- ✓ Inexperienced workers and not proper maintenance of the plant.
- ✓ Lack of knowledge on production.
- ✓ Lack of knowledge on biomass potential and financial problems.
- ✓ Lack of planning how to reduce the production cost.
- ✓ Political barrier also be a big problem.
- ✓ Lack of infrastructure.

VII. CHALLENGES OF ANAEROBIC DIGESTION PROCESS

Biogas is obtained through anaerobic digestion of biomass waste. The different factors affect the performance of anaerobic digestion process have been

discussed. Comprehensive review some biogas plant have been discussed. But most of the plants are installed with adequate financial supports as subsidy but plants affects from the technical knowhow. Effect of different process parameter such as temperature, pH, C/N ratio on biogas generation, need to be taken care of to run the biogas plant to have maximum biogas generation rate with highest yield. Biogas can be used as a cooking fuel or engine fuel or for power generation.

VIII. REFERENCES

[1]. T. Bond, and M. Templeton, 2011. History and future of domestic biogas plants in thedeveloping world, Energy for Sustainable Development, 15(4), 347-54.

[2]. V. A. Vavilin, S. V. Rytov, L. Y. Lokshina, J. A. Rintala, G. Lyberatos, 2001. Simplified hydrolysis models for the optimal design of two-stage anaerobic digestion, Water Research, 35(17), 4247-51.

[3]. R. T. Romano, R. Zhang 2011. Anaerobic digestion of onion residuals using a mesophilic Anaerobic Phased Solids Digester. Biomass Bioenergy,35 :4174-4179.

[4]. N.Bardiya, A. C. Gaur, 1997. Effects of carbon and nitrogen ratio on rice straw bio-methanation. Journal Rural Energy 4 (1-4): 1-16.

[5]. Hagelqvist, 2013. Sludge from pulp and paper mills for biogas production - Strategies to improve energy performance in wastewater treatment and sludge management, Dissertation, Faculty of Health, Science and Technology, Karlstad University, 9-18.

[6]. Ministry of new and renewable energy (http://mnre.gov.in/file-manager/UserFiles/SEEIA-Report/index.html)

[7]. The times of India(http://timesofindia.indiatimes.com /city/surat/Surat-to-get- Indias-biggest-biogaslant/articleshow/39666874.cms)

[8]. http://www.indiaprwire.com/pressrelease/ environmental-services/20161117444462.htm

[9]. http://www.newindianexpress.com/cities/thiruvananthapuram/2013/sep/02/Biogas-plant-starts-working-in-full-flow-512724.html

[10]. http://biofueluptodate.com/biogas-plants-in-india-gobar-gas-commercial-production-capacity

[11]. https://timesofindia.indiatimes.com/city/ahmedabad/Doctor-plans-15-more-biogas-plants-across-state/articleshow/46107977.cms