A Review Study on Biogas Production

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Abstract- *This paper shows, feasibility of utilizing energy crops , different parameters which regulates and effect the production of biogas by the method of anaerobic digestion. A comparative study of biogas production from Different experimental setup results, production of methane-rich biogas through anaerobic digestion of organic materials provides a versatile carrier of renewable energy.*

Keywords- Anaerobic digestion, biogas yield, substrate, HRT, BMP, organic waste.

I. INTRODUCTION

Due the increasing demand of energy use, has induced a active search for alternative energy source. Especially renewable resources, such as biomass, have been, under constant examination ,so that green house gases can be reduced to some extent. Therefore use of renewable resources will account lesser contribution to climate change (1). Biomass represents a sustainable source of renewable energy. It is characterised by its abundance and offers a secure energy supply. Several organic substances have been used for anaerobic digestion. Anaerobic digestion of biomass is a multi-stage microbial process, which produces biogas and digestion residues as the final products. Biogas is an energy-rich mixture of primarily methane and carbon dioxide and can be used for energetic purposes. Digestion residues are characterized by high nutrient content and can be efficiently applied for soil fertilization (1). The production of biogas has been evaluated as one of the most energy-efficient and environmentally beneficial technology for bioenergy production (11). Typical substrates for anaerobic digestion include animal manure, sewage sludge from wastewater treatment and energy crops . Co-digestion of several substrates increases biogas yield and improves process efficiency. Additionally, the utilization of organic waste as a substrate for biogas production accounts for waste stabilization and a reduced amount of land filled waste.

This paper shows that grass is a crop with significant yield and grass biomethane has a good energy balance and does not involve habitat destruction, land use pattern, new farming practices. The grass grown can be numerous species which involves numerous cut. The lignocelluloses content of grass increases with maturity of grass. The first cuts will have more methane contents than that of later cuts. Biogas contains around 55-65% of methane, 30-40% of carbon dioxide. During these periods, the temperature, solar radiation and relative humidity have been measured. The anaerobic digestion is very sensitive to change in pH and it is important to maintain pH of 6.7 – 7.4 for generation of gas. The conditions should be mesospheric, temperature range should be between 32 -37 Celsius. The slurry produced in the process provides valuable organic manure for farming and sustaining the soil fertility.

a) BACK GROUND

Biomass is biological material derived from living or recently living organism. In the context of biomass as a resource for making energy, it most often refers to plant or plant-based materials which are not used for food or feed, and are specifically called lingo cellulosic biomass. As a energy of source, biomass can either be used directly via combustion to produce heat, or indirect after converting it to various forms of bio fuel (9). Biogas is been used for over 3000 year, it is an effective fuel for cooking and lighting. It saves fossil fuels and makes a contribution to heat and electricity production .it is an environmental friendly source of energy because it produces electricity and heat but still keeps carbon dioxide emission neutral. It mainly consists of methane and carbon dioxide and small amount of hydrogen sulphide, moisture and siloxanes. Biogas produced on farm and in bio waste industries is typically converted into electricity and heat energy through the combined heat and power biogas powered generator (2). Biogas is generated from the anaerobic digestion of biomass. Anaerobic digestion is the process which takes place in the absence of molecular oxygen, in a closed container; it is a series of biological process in which micro organism break down biodegradable material in the absence of oxygen.

b) ENERGY CROP

Energy crops are the crops grown at low cost and low maintenance to harvest used for making bio fuels such as bio ethanol or for the generation of heat and electricity. In Kerala, coconuts are dried for making copra (the dried meat or kernel) coconut oil extracted from it has made which is an important agriculture commodity. One of the Important parameter for selecting the energy crop for methane production is the net energy obtained per hector , which is defined by biomass yield and easy convertibility of the biomass into methane. Energy crop should be easy to cultivate , harvest and store , tolerant to weeds, pests, diseases, drought and frost, have good winter hardiness and be able to grow on soil of poor quality with low nutrient input. A very little is known about the methane potentials of crops suitable for biomass production in boreal areas. Furthermore, many studies have only considered the convertibility of the biomass to methane, and methane potentials have rarely been evaluated with regard to the biomass yields of crops and the corresponding methane and energy potentials per hectare. Many conventional forage crops are easy to cultivate and produce large amounts of biomass. Moreover, they have the advantage of being familiar to farmers and suitable for harvesting and storing with the existing methods and machinery. Furthermore, being bred for animal feed these crops are often characterised by good digestibility. Perennial herbaceous grasses (e.g. timothy Phleum pratense and reed canary grass Phalaris arundinacea) are among the most efficient producers of herbaceous biomass in boreal conditions, and many are commonly cultivated as forage in northern countries (11). Leguminous crops (e.g. red clover Trifolium pratense, vetch Vicia sativa and lupine Lupinus polyphyllus) form root nodules with the ability to bind nitrogen from the atmosphere. Thus, they require little fertilisation and contribute to efficient turnover of nitrogen in agriculture (12). In addition to conventional forage crops, several less conventional agricultural species could have potential as energy crops. Examples of crops that are relatively easy to cultivate and produce plenty of biomass are marrow kale Brassica olearacea spp. acephala, Jerusalem artichoke Helianthus tuberosus and rhubarb Rheum rhabarbarum. Other species often identified as weeds (e.g. nettle Urtica dioica L. and giant knotweed Reynoutria sachalinensis) are an interesting alternative as energy crops due to their efficiency in photosynthesis, high competitiveness, ability to grow on soil of poor quality, wide distribution and fewer pests and diseases than with conventional forage crops (13). Furthermore, native weeds are invasive and resilient in nature, making them well suited for repeated harvesting (13). A number of crop residues, such as sugar beet tops and straw, generated in large amounts in agriculture could also be utilised as a substrate in biogas production. Harvesting crop residues for energy use has the advantage that the direct costs of production of these materials are often low, and collecting them from the fields promotes nitrogen recycling and reduces eutrophication due to nitrogen leaching (14).

II. ANAEROBIC DIGESTOR

Anaerobic digestion means in the absence of oxygen, organic matter is consumed by the microorganisms and it is broken down to form biogas for energy recovery. Anaerobic digestion occurs in nature, for example, at the bottom of lakes, in slurry and in the rumen of ruminants. [6] Anaerobic digestion includes four key biochemical stages, which are hydrolysis, acidogenesis, acetogenesis and methanation (FIGURE 1). The individual stages are carried out by different groups of microorganisms, which have syntrophic interrelation and have different requirements (for example, pH, and temperature) on the environment for their growths. [7] FIGURE 1 shows anaerobic digestion biochemical conversion pathways.

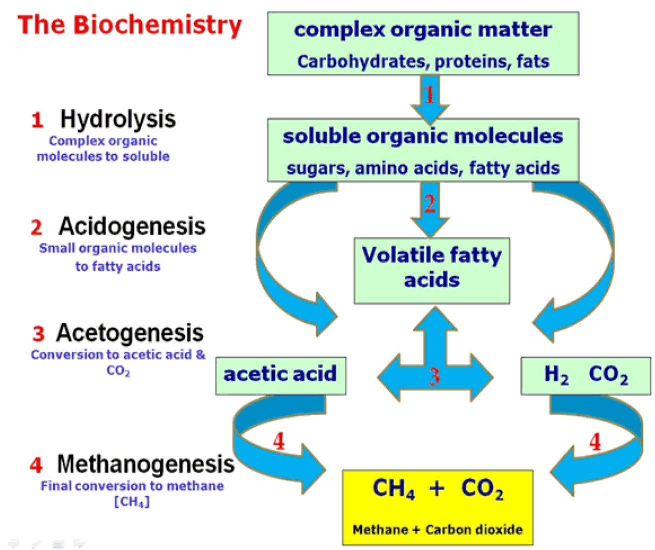

Figure1. Anaerobic digestion biochemical conversion pathways.

Hydrolysis Phase

In the first phase, hydrolysis, the complex high-molecular substances of the starting materials (such as carbohydrates, proteins and fats) are broken down into simpler lowmolecular organic compounds (such as amino acids, sugars and fatty acids) by means of enzymes released from the hydrolytic bacteria. [6]

Long-chain carbohydrates, such as cellulose, hemicellulose and starch, are water- insoluble compounds. They are broken down into short-chain sugars by hydrolases within few hours. Proteases break down proteins into amino acids and lipases break down fats into fatty acids and glycerin within few days. Lignocellulose and lignin can’t be degraded completely and longer time is needed. [7]

Acidogenic Phase

Acid-forming bacteria break down the intermediate products (monomers) formed from hydrolysis further more to form lower fatty acids (acetic, propionic and butyric acids), H2, CO2 and small quantities of lactic acid, alcohol, NO and H2S. At this stage, the concentration of the intermediate hydrogen can affect the nature of fermentation products. [7] The lower the partial pressure of the H2 is, the more acetic acid, H2 and CO2 are produced. The higher partial pressure of H2 is, the more organic acids, lactic acid and ethanol are formed. [8]

Acetogenic Phase

Lower fatty acids (acetic, propionic and butyric acids), alcohols and lactic acids from the previous phase (acidogenesis) are served as substrates for the acetogenic phase. The hydrogen partial pressure is of great importance at this phase. When the partial pressure of H2 is low, acetogenic bacteria form predominantly H2, CO2 and acetate, which are the recourses for the methane formation. [7] When the partial pressure of H2 is high, it prevents the conversion of the intermediate products of acidogenesis, more and more.

Methanogenic Phase

Methanogenic phase takes place under strictly anaerobic condition. In this phase, all above acetic acid is converted into methane via acetic acid cleavage by acetoclastic the methane-forming bacteria, whereas H2 and CO2 are converted into methane by the hydrogenotrophic methanogens. Methanogenic bacteria have very low growth rate and are very sensitive regarding to disturbances. When the methane formation works smoothly, the acetogenic phase is also running well. However, when the methane formation is disturbed, over acidification occurs. Furthermore, H2S affects the methanogens toxically.

Types of AD

There are two common types of digesters used for anaerobic treatment:

(i) batch
(ii) continuous

Batch digesters are the simpler of the two because the material is loaded in the digester and then allowed to digest. Once the digestion is complete, the effluent is removed and the process is repeated.

In a **continuous digester**, organic material is regularly fed into the digester with the constant loading and unloading of effluent. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material.

There are three types of continuous digesters: (i)vertical tank systems, (ii)horizontal tank or (iii) plug-flow systems.

Continuous digesters are most common for large-scale operations.(16) Temperature is carefully controlled in anaerobic digestion systems. There are two common environments for anaerobic digesters: thermophilic and mesophilic. The difference between the two environments is the temperature at which the organic material, or sludge, is digested. Thermophilic digestion operates around 50 to 60 °C (120 to 140 °F). The quick breakdown of sludge allows digester volume to be small, relative to mesophilic systems. The average digestion time is approximately three to five days. Thermophilic digestion require more insulation and more heat energy and are more sensitive to incoming materials and temperature changes, compared to the mesophilic digestion system. (17) Mesophilic digestion operates around 35 to 40 degrees °C (95 to 105 °F). The average digestion time is 15 to 20 days. Mesophilic is more common in wastewater treatment plants because thermophilic treatment due to cost and more energy is required to have more sophisticated control & instrumentation, as a thermophilic system would need(18).

There are three common types of anaerobic systems: farm based, food processing and centralized systems. Farm based systems are typically designed for manure from one farm, or the manure from several nearby small farms(19).

Food processing systems are typically on the same scale as farm-based systems. Centralized systems involve materials from many farms and food processing plants. Each type of anaerobic system will have different gas productions due to the difference in the feedstock for the digesters. demonstrates how different waste materials affect biogas production.

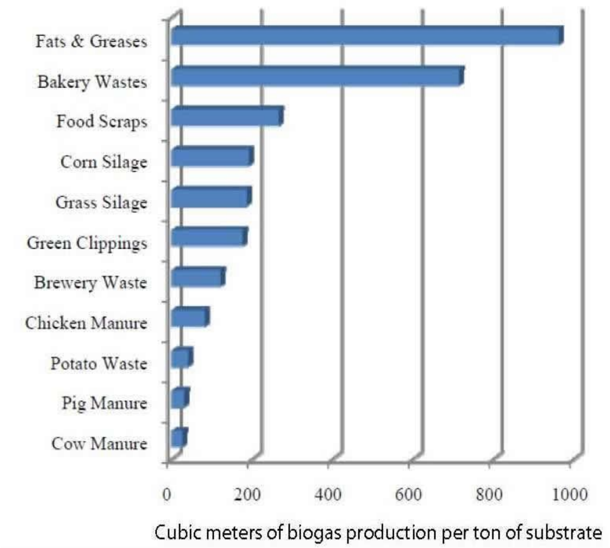

Figure 2-: Biogas Production by Feedstock.

Operational parameters for biogas production

The production of biogas is factored by many operational parameters. Some parameters that affect the production of biogas include temperature, pH, pre-treatment, particle size, agitation, rate of organic load, retention time etc. Any rapid change in these parameters can adversely affect the production of biogas (20).

Temperature

The biogas production process is highly influenced by the temperature inside the digester. In nature the formation of methane occurs at different range of temperatures; psychrophlic (<30 °C), mesophilic (30–40 °C), and thermophilic (50–60 °C) . However, mesophilic and thermophilic temperature ranges are more favourable for anaerobes to be active (20). In general, high temperature give a higher methane production rate and allows higher loading rates, thus decreasing the reactor volume needed for a specific material. Anaerobic digestion at thermophilic temperature also gives a better sanitation, i.e. killing of pathogens. However, thermophilic processes are more sensitive to high levels of ammonia, released from protein rich materials (20). Thermophilic processes are also more costly to heat compared to mesophilic processes (21). The digestion period in a mesophilic process usually needs comparably longer time, commonly between 20 and 30 days. In thermophilic temperature, however, gas can be produced in much less time comparing to mesophilic temperature. Digesters which process agricultural waste normally operate at mesophilic temperatures. Today, approximately half of the Swedish co-digestion plants run at thermophlic temperature (21).

pH

The substrate's acidity is measured by pH, which is an important parameter affecting the growth of microbes during anaerobic digestion (20). For optimal performance of the microbes, the pH within the digester should be kept in the range of 6.8 - 8.0. The pH value below or above this interval may restrain the process in the reactor since micro-organisms and their enzymes are sensitive to pH deviation (20). There are also situations in anaerobic fermentation which can highly affect the pH in the digester. These include high amounts of volatile fatty acids, acetic acid, and carbon dioxide produced by the microbes and ammonia. These factors can have an impact on the pH in the reactor and might inhibit the activity of the microbes (23).

Carbon: Nitrogen (C/N) ratio

For efficient biogas plant operation, the C/N ratio of the input substrate should be kept within the desired range since the nutrient composition has an impact on the optimal growth and activity of micro organisms (23). Carbon and nitrogen are the main nutrients for anaerobic bacteria. In anaerobic digestion, the carbon utilization of micro-organisms is 25-30 times higher than nitrogen. Thus, for optimum functioning microbes usually need 25-30:1 ratio of C to N with the largest part of the carbon being easily degradable. Any deviation from this ration gives a less efficient process. Codigestion with different substrate materials can improve the biogas production since a single substrate can be limiting due to its nutrient content. Accordingly, waste materials with low C content can be mixed with other N rich substrates in order to reach the desired C: N ratio (20) and the optimum mix of feed stocks are necessary to get the optimum C/N ratio (23). For this reason the importance of cow manure as a co-digest substrate with other waste materials such as organic industrial waste and household waste have been suggested by different studies in order to optimize the methane yield (24). The C/N ratio of cow dung is around 16 – 25 (23). Manure can also be co digested with different type of plant materials in order to increase the biogas production.

Water Content

Water is the vital element for micro-organisms' life and their activity. The movement of bacteria and activity of extra cellular enzyme etc are highly determined by the water content in the digester (23). Optimum moisture content has to be maintained in the digester and the water content should be kept in the range of 60-95 % (21). However, the optimum water content is likely to differ with different input materials depending up on the substrates chemical characteristics and bio-degradation rate (23).

Ogranic loading rate

The rate at which substrate is supplied to the digester is referred to as organic loading rate and is usually expressed in terms of Kg volatile solids per m3 and day. The gas production rate in the digester is highly dependent on the organic loading rate (20).

Hydraulic retention time (HRT)

The average time spent by the biomass inside a continuous biogas plant before it comes out from the digester is known as the hydraulic retention time, also abbreviated as HRT. The process of degradation requires at least 10-30 days in mesophilic condition, while in thermophilic environment HRT is usually shorter (21).

IV. RESULTS

Total amount of biogas production during 120 days of experimentation in control and test digesters were 147309.82 and 352367.28 mL with their respective average values of 1227.58 and 2936.39 mL d-1 (25). The methane potentials of crops, as determined in laboratory methane potential assays, varied from 0.17 to 0.49 m3CH4kg-1VS added (volatile solids added) and from 25 to 260 m3 CH4 t-1ww (tons of wet weight) (26). Cow dung produced biogas compared to other substarte at ph 6.5 and 7.1 (27). Energy production of 1.7 PJ Animal waste ,organic industrial waste (28). Paper waste ,cow dung in ratio of 1:1, with 45 days retention period at 26-43’c Microbes total viable cont, revealed the progression of the microbes that converted the waste to biogas(29). Coconut oil cake and cashew apple waste, Grass cuttings maximum methane yield was found to be 320ml CH4/gVS(30). Muncipal organic waste sources, primay sludge Methane potential – 568.3 mL-biogas (31).

V. CONCLUSION

The different substrates used for BMP test were producing different composition of gas. Their characteristics and different parameters considered have different influence on biogas production. Substrates with low pH yielded small volumes of biogas while those with a higher pH produced more biogas and higher methane content. The BMP tests are a powerful tool to assess the methane yield from the digestion of organic solids.. The results of the experiments described in this paper show that the BMP tests can be used to assess not only the maximum methane production from an organic substrate, but also the biodegradability of the investigated substrate, the relative specific rate of bio-methnation and the different parameters which may effect during the production of biogas. Furthermore the BMP tests can be used for the calibration of mathematical models suitable to simulate the digestion process and predict the performances of full-scale anaerobic digesters.

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