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METHANE GENERATION FROM ORGANIC WASTES

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Abstract
Biogas is one of the reliable alternative fuels. Nowadays, it is widely used in all over the world. It is a renewable type of energy. The biogas can be produced by anaerobic digestion of biodegradable elements. Many research works focused on the biogas preparation from the bio wastes. Vegetable wastes, food wastes are some of the bio wastes. Mostly, in urban areas, the cooking has been carried out by the use of biogas. Biogas can be used as the alternative fuel for the following sectors in industries for boilers and power plants, in transports for buses. Water hyacinths are naturally available in ponds and lakes. Since, Plants such as Milkweed are of no use can be used for the extraction of biogas. Food wastes also a good biogas producers. This paper investigates the possibility of producing biogas from a mixture of water hyacinth and cow dung, milk weed, food waste and analyzing the methane concentration. The biogas consists of methane as a major constituents and traces of other gases which includes CO, H_2S, and NH_3.To increase the yield of methane gas cow dung is mixed with water hyacinths.

Key word: Biogas, vegetable wastes, food wastes, water hyacinth, milkweed

1. INTRODUCTION

Biogas, is a renewable energy source which is also environmentally friendly, is generated via anaerobic digestion of biomass wastes (animal dung, municipal solid wastes, plant residues, waste waters, agro and human industrial wastes etc.). Biogas production is a three stage biochemical process comprising of hydrolysis, acetogenesis/acidogenesis and methanogenesis. The discharge of this process is a residue that is rich in essential inorganic elements needed for healthy plant growth known as bio fertilizer which when applied to the soil enriches it with no detrimental effects on the environment.

Since the plant has plentiful nitrogen content, it can also be used as a substrate for biogas production. Biomass experiments involving the use of water hyacinth and milkweed for the biogas productions for cooking appeared to present a feasible option. Biogas is a green fuel that may substitute firewood. Water hyacinth's plentiful biomass can be used to yield renewable energy simply, locally by fermenting it in a digester. The fermentation process takes a longer time period in the case of milkweed, water hyacinth and food wastes. Water hyacinth often occupies bodies of water that have been stuck by human activities.

Biogas is categorized based on its physical characteristics chemical composition which result from it. It is mainly a combination of methane (CH_4) and inert carbonic gas (CO_2). However the name "biogas" collects a huge variety of gases causing from precise treatment processes, beginning from various organic waste - animal or domestic, industries origin waste etc.

Various sources of production lead to various specific compositions. The existence of H_2S, water and CO_2 make biogas much corrosive and need the use of modified materials. The composition of a gas delivered from a digester rely on the substrate, of their organic matter load, and the digester feeding rate.

The alterations of a conventional diesel engine to run on the dual-fuel system by carbureted biogas and injected diesel fuel as suggested by Vangelica Jovanovska [1]. The biogas can prepared from the Dung (pig waste) and distiller's grains. Also, it is concluded that while there is no availability of biogas, the engine can be substituted over to diesel oil alone easily. The engines running on either biogas alone or diesel/biogas dual-fuel can do well at a wide range of load. Jayesh D.Vaghmashi [2] studied the possibility of biogas as fuel for vehicle and automobile engines. It has been noted that the biogas can be prepared from the agricultural, industrial and community based feed stocks. Agricultural feed stock includes algal biomass, animal manure, crop residues etc. Industrial feed stocks may include food processing wastes, dairy, sugar industry etc. In the case of community based feed stocks food remains, sewage sludge were included.

R. Ilaboya et al. [3] conducted the experiment to examine the effect of Alkaline [NaoH] on the entire volume of a biogas prepared by using the agricultural wastes such a mixture of plantain, pineapple, and cassava peelings. Results found tells a high amount of gas produced while the operating conditions inside the digester is kept at moderately alkaline condition. Further results also expose that the digester temperature keep on within the range of 27 to 35.5°C during the course of the period of experimentation.Earnest Vinay Prakash et al. [4] examined that the biogas generated from the waste (vegetable and fruit waste) for different ratios with cow dung yields high amount of biogas.

Debabrata Barik [5] studied the potential biogas production and its application. It was resulted that the exhaust emissions from the biogas-fuelled vehicles are comparatively short in particulates and nitrogen oxides and hence subsidize to increase local air and climate quality. Patil V.S [6] reviewed that the biogas generation from anaerobic digestion of vegetable wastes. It has been noted that vegetable wastes may have high moisture content, high carbohydrate and thus are a suitable substrate for the generation of biogas with biomethanation process. N.H.S.Ray et al. [7] revised that the characteristics of biogas and its application in diesel engines. The study concluded the biogas preparation and its properties, for the application of diesel engines.

The biogas preparation from cow dung, water hyacinth, waste paper was proposed by MOMOH et al. [8]. The results revealed that waste paper concentration of 17.5g is the extreme quantity of waste paper required to combine with 5g of water hyacinth and 5g of cow dung for maximum preparation of biogas. This can be converted to kilograms or tones for large volume biogas production.

Many research works focused on the biogas production from various work. In this paper, focuses on the production of biogas production from cow dung, water hyacinth, food wastes, and milkweed.

2. SOURCE MATERIALS FOR BIOGAS PRODUCTION

2.1 Water Hyacinth

Water hyacinth is a free-floating perpetual aquatic plant (or hydrophyte) native to tropical and sub-tropical South America.They have long, spongy and bulbous stalks. The feathery, easily floppy roots are purple-black. An erect stalk supports a particular spike of 8-15 noticeably attractive flowers, typically lavender to pink in with six petals. One of the wildest growing plants known, water hyacinth replicates chiefly by the way of stolon or runners, which finally form daughter plants. Every plant can yield thousands of seeds each year, and these seeds can remain viable for more than 28 years. The common water hyacinth are energetic growers recognized to double its population in two weeks.

Fig 1. Water hyacinth

Water Hyacinth as a Fuel:

Water hyacinths have great cellulose content, building them a possible renewable energy source. Plant materials are further hard to biodegrade than animal manures. This is due to hydrolysis of cellulose materials of crop residues is a gentle process and can be a foremost rate examining step in anaerobic digestion process. Addition of small amount of activated carbon to sludge digesters increases gas production by 10 to 15%. Biogas is a clean burning fuel; its domestic use can reduce the incidence of eye and lung problems that are commonly encountered with such2 smoke producing fuels as fire wood, agricultural residues, and coal. Biogas is considered as better fuel than natural gas and liquefied petroleum gas, because it does not contain sulphur. Sulphur on burning, gets changed to sulphur dioxide which is answerable for various lung diseases. The slurry which derives out of a biogas unit establishes good quality manure free from weed seeds, foul smell and pathogens.

The benefits of water hyacinth as a source of fuel are:

- It is richly and freely available
- Its cultivation takes up no extra land
- The technology is well-proven
- Overall, it does not improve atmospheric carbon dioxide levels.
- Use in this way can be a considerable contribution to its control.

2.2 Milk Weed:

It is a huge shrub growing to 4 m (13 feet) height. It has bunches of waxy flowers which are either lavender or white in color. Each flower may consists of a five pointed petals and a lesser, elegant "crown" rising from the centre, which holds the stamens. The aestivation found in Calotropis is valvate i.e. sepals or petals in a whorl just touch one another at the margin, devoid of overlapping. The plant has light green leaves which is in oval shape, and milky stem. The latex of *Calotropis gigantea* may comprises cardiac glycosides, fatty acids.

Fig 2. Milkweed

2.3 Cow Dung:

Conventionally cow dung has been used as a fertilizer, although today dung is gathered and used to yield biogas. This gas is high in methane and is used in rural areas of India and elsewhere to deliver a renewable and stable foundation of electricity. According to the International Energy Agency, bioenergy (biogas and biomass) have the potential to meet more than a quarter of world demand for transportation fuels by 2050. Today, biomass accounts for approximately 12% of world energy consumption. Yet the probable of using biogas has so extreme been unexploited, especially in the system of livestock manure. Helping reduce carbon emissions, provide clean green energy and enable local farmers to maintain current herds, with potential for future cattle increases.

3. FACTORS AFFECTING BIO-GASIFICATION

3.1 Digestion Period

Digestion period for organic waste strongly depends upon the temperature. In the beginning, the obtainable gas quantity increase rapidly with the digestion period after which it approaches its maximum value asymptotically. No appreciable gains in the gas production are expected after a definite time period. The optimal digestion period is between 20 and 30 days at 30°C. Gas production depends on the amount and nature of the fermentation slurry, digester temperature and retention time. An increase in the ambient temperature generally increases the rate reaction and therefore rate of biogas production. All bacteria involved in the biogas reaction (production) are active only within a limited temperature range. Since the bacteria respond sensitively to temperature fluctuations, one should maintain a particular constant temperature. The maximum rates of reaction in anaerobic digestion occur at around 35°C (mesophilic) and 55°C (thermophilic).

3.2 Retention Period

The retention time is the theoretical time that a particle or volume of liquid added to a digester would remain in the digester. There is a minimum retention time which allows the slowest growing bacteria to regenerate. Long retention time lead to low efficiency of the process. The retention times of different substrates are influenced by their rate of bio degradability, exposure to bacterial enzymes, physicochemical properties of the substrates, etc. Longer the digestion process, higher the methane content and hence its calorific value. The methane content falls to as little as 50% if the retention time is short. If the methane content is considerably lower than 50%, biogas no longer becomes combustible. Digestion at higher temperature continues more quickly than at lower temperature through gas produce rates doubling at about every 5ºC increase. The temperature ranges are

- Psycrophilic, about 10-20ºC, retention time over 100 days.
- Mesophilic, about 20-35ºC, retention time over 20 days.
- Thermophilic, about 50-60ºC, retention time over 8 days.

3.3 Effect of C/N Ratio

Carbon and nitrogen are the main nutrients for anaerobic bacteria. While carbon supplies energy, nitrogen is needed for building up the cell structure. Plants may have to be shredded and dried to certify proper dilution, mixing and digestion. It may often by necessary to add urine to maintain a proper carbon to nitrogen ratio. The carbon to Nitrogen (C/N) ratio in a substrate is important because high nitrogen (greater than 80 mg/l as undissociated ammonia) with low C/N ratios can cause toxicity and low levels (high C/N ratios) can inhibit the rate of digestion. A C/N ratio of 30:1 is considered to be optimal. A low C/N ratio of the slurry leads to high concentration of ammonia. High concentration of ammonia is toxic to the microorganisms involved in biogas production.

3.4 Effect of Water Content on Bio Gas Production Rate

Water is essential for the survival and activity of micro-organisms. Optimum moisture content has to be maintained within the digester. In case of water hyacinth, the water content is already high i.e. Solid content is low. Hence attempts have to be made to increase the solid content to an optimum level before digestion. The production rates decrease with increasing concentration of total solids. When solid wastes like water hyacinth are put into digesters, due to their low density in the dry state or due to buoyancy attained by the adhering gas bubbles will float above the liquid surface and become unavailable for digestion. Thus, it necessitates their digestion in the absence of a large liquid phase. When the water content is too high, the main slurry temperature and hence the net biogas gain drops. If the water content is too low, active acids accumulate and hinder fermentation process. For most of the biogas systems, the ideal feed to water ratio is 1:1. The optimum total solid concentration is 7 to 9%.

3.5 pH

A digester operates well at a pH of 7.0 or just above, i.e. slightly under alkaline conditions. The methanogens that convert the wastes to gas are pH sensitive, consequently effective biogas production requires a pH range of 6.5 to 8.5.

3.6 Bio gas properties

Biogas consists of 50 to 65% CH_4, 35 to 50% CO_2, 30-160 g/m^3 of water and 4-6 g/m^3 of H_2S. It has a calorific value of about 5.96 KWh/m^3, and a density of 0.94 kg/m^3. The danger of explosion of biogas is less as it contains carbon dioxide which acts as a fire extinguisher. Table 1 shows the calorific value of various gaseous fuels.

4. METHODOLOGY

4.1 Biogas Digester:

Fig 3. Biogas Digester

Specification:

Outer diameter of digester tank: 425 mm
Thickness of digester tank :5 mm
Diameter of valve :78 mm
Height of the digester :1150 mm

Biogas plant Digester, made up of Polyvinyl Chloride plastic is 5 mm thick. Digester consists of an inlet pipe, gas collector valve, digester tank, and an outlet pipe to carry away the slurry. The inlet lid is funnel like projection. The mixture is poured in the funnel of the inlet pipe which is collected in the digester tank. The digester tank is of cylinder in cross section where anaerobic digestion takes place. The gas formed in the tank is collected by a gas balloon via gas collector valve. The slurry formed in the tank is carried away through an outlet pipe.

4.2 Gas Collector:

Fig 4. Gas collecting Balloon

As the result of anaerobic digestion, the gas formed in the tank is collected by using gas collector. The gas collector, made of rubber material is forged with a valve so that it fits with the gas collector valve of the storage tank. The gas is collected and is tested for analysis.

4.3 Gas Chromatography-Mass Spectrometry:

Fig 5. Mass Spectrometer

Gas chromatography–mass spectrometry (**GC-MS**) is a systematic method that combines the structures of mass spectrometry and gas-chromatography to find various substances within a test sample. Usage of GC-MS include fire investigation, drug detection, environmental analysis, identification of unknown samples and explosives investigation. GC-MS can also be used in airport security to notice substances on human beings or in luggage. Additionally, it can find trace elements in materials which were earlier thought to have disintegrated beyond identification. GC-MS is also use to find out the various proportions of a biogas samples with its standard solutions.

5. EXPERIMENTAL PROCEDURE

5.1 Experimental Layout:

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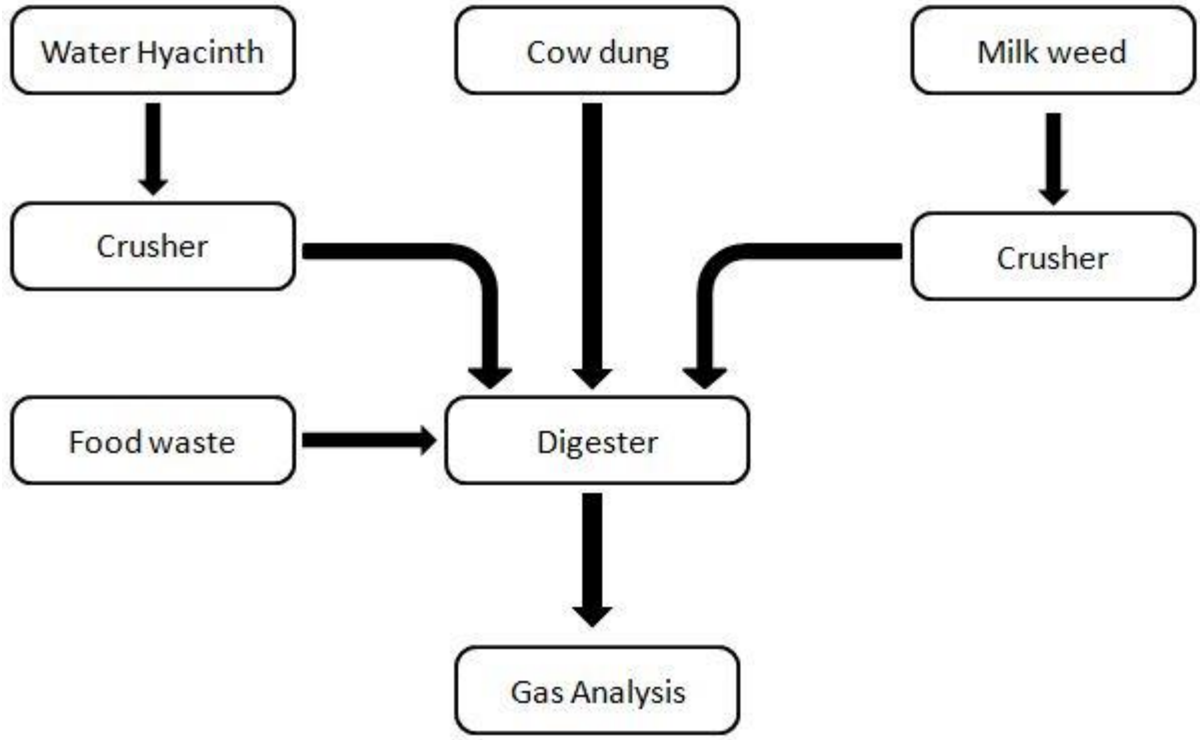
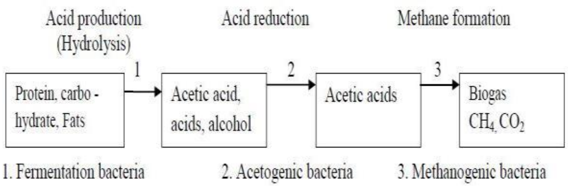


Fig 6. Layout of biogas production

The figure shows the experimental layout for the biogas production setups. The formation of biogas is discussed below.

5.2 Biogas production steps:

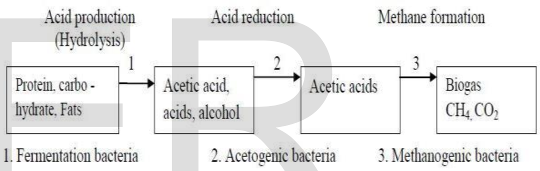
The biogas production in this process is based on anaerobic digestion of water hyacinth, milkweed, and cow dung and food waste. The anaerobic digestion consist of three stages (**Hydrolysis, Acid formation, Methane formation**).



1. Hydrolysis
2. Acid formation
3. Methane formation.

The processes are carried out by two set of bacteria namely acid forming bacteria and methane formers. pH values of less than 6.2 are toxic to the bacteria needed for digestion. Temperatures below 15oC significantly reduce gas production. Acid production Acid reduction Methane formation.

Methane production steps:



Methane Formation

Thus the figure 1 shows the methane production steps. For successful digester operation is to maintain constant conditions of temperature and suitable input material. The influent to a biogas plant is slurry of biomass and water, generally in the ratio of 1:1. The slurry is composed of total solids (7-9%) and water [91-93%]. The total solids are composed of fixed solids and volatile solids. Fixed solids are those that cannot be broken down during the digestion process, while volatile solids are those that are attacked by microorganisms to yield biogas. Regular stirring increases gas production. The water makes the feed material capable of flowing. This is important for the process of a biogas plant. It is informal for the methane bacteria to arise to contact with feed material which is quiet fresh when the slurry is in liquid state. Discontinuous digesters (batch), which are used in this case, use solid organic substrates (lignocellulosic) submerged in slurry of bacteria and are then hermetically sealed until the production of biogas ceases.

5.3 Collection of Water Hyacinth and Milk Weed:

Water hyacinth, a free floating aquatic plants is widely available in lake. Then it is collected of 5 kg near the shore. Later we collected 5 kg of Milk weed which is available at the raw lands.

Fig 7. Collection of Water Hyacinth

5.4 Crushing:

Fig 8. Crushing of Water hyacinth

The crusher is used to crush the water hyacinth with water at a proportionate of 40:60 i.e.

Water – 40%

Water hyacinth – 60%

The crushed paste is collected and poured into the digester.

5.5 Mixing:

The collected water hyacinth is crushed by the crusher then it is poured into the digester.Later we added 5 kg of crushed milkweed and 5 kg of food waste which is collected from the hostel at a ratio of 1:1 i.e.

Milk weed paste -50%

Food waste -50%

5.6 Storing Up In Digester

Initially the cow dung of 25 kg mixed with a 5 liters of water. The mixer is poured into the digester through inlet. Then it is kept for 25 days. The anaerobic digestion of cow dung is takes place. The water hyacinth paste is added into the digester after 25 days. The mixed raw material is poured into a digester at a closed condition. Later we added 5 kg of crushed milkweed and 5 kg of food waste into the digester.

Fig 9.Pouring into the digester

After few days, the formation of biogas takes place by the anaerobic digestion of mixed contents. The formed gases were accumulated at the top of the digester lid.

5.7 Collection of Biogas:

Fig 10.Before BiogasFormation

The produced combustible biogas is collected in balloons having capacity of 1.5 m^3 and 1 m^3 respectively. The balloon is connected to the reactor through the transparent hose. Fig 4. Indicates that the digester with no formation of biogas when loading to the digester.

Fig 11. After Formation of Biogas

The anaerobic digestion of bio degradable elements took place. The formed gas settled in the top of the digester which is indicated by the Fig 8

The flow of biogas is measured by air flow meter coupled between the reactor and balloon. Every day the drum which is floating in the reactor becomes lifted up due to the rise in pressure in the flammable biogas. Then the biogas is contract out through the hose coupled to the balloon.

Fig 12. Collection of Biogas in a Balloon

At the 45^{th} day the formed biogas is collected in a balloon and took it for analysis

5.8 Analysis of Biogas:

The collected gas is tested for analysis. Chromatography of a gas is carried out. At first the gas is passed through a tube containing silica gel to make the gas moisture free. Then the gas is passed through the analyzer and checked for its proportions.

Fig 13. Analysis of Biogas

6. RESULT AND DISCUSSION

The gas that produced by anaerobic digestion is collected in a Gas collecting balloon. Then the collected gas is taken for analysis. The collected sample is introduced into the mass spectrometer which will react with the reagent gas and the contents present in the produced gas is shown in the monitor. Then the result is saved and printed.

It has been noted that the biogas production of biogas for the composition of cow dung, water hyacinth, milkweed, food wastes is feasible at the room temperature. The concentration of methane has been recorded as 21.395% at the end of 45^{th} day. The constitution of other gases like carbon dioxide, hydrogen were evaluated.

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SHIMADZU LabSolutions Analysis Report

< Sample Information >

Sample Name : BIOGAS
Sample ID : BIOGAS -1
Data Filename : BIOGAS-1.gcd
Method Filename : TCD 1742014-N2-NEW.gcm
Injection Volume : 1 uL
Date Acquired : 4/21/2016 11:51:54 AM
Date Processed : 4/21/2016 12:27:15 PM

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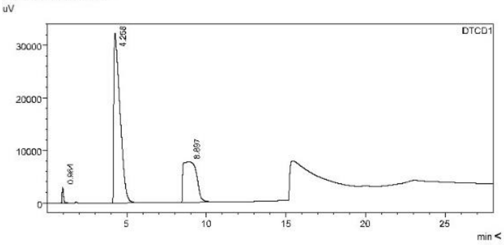

Peak Table >

DTCD1

Peak#	Name	Ret. Time	Conc.	Unit	Area	Height
1 H2		0.964	0.268	%	18186	3019
2 CH4		4.258	21.395	%	875451	32252
3 CO2		8.897	12.191	%	458095	7754
Total					1351732	43026

D:\GC DATA 1\2016\APRIL\RAMAKRISHNA COLLEGE\BIOGAS-1.gcd

Fig 14. Analysis Report

It was found that the concentration of hydrogen and methane is about 0.268 % and 12.191%. The retention time for the methane is 4.258 min and for the CO_2 is 8.897 min occupied by the methane.

7. CONCLUSION

The anaerobic digestion of cow dung, water hyacinth, milkweed, and food waste is feasible at room temperature. However the effect of food waste on fixed amount of cow dung, milkweed and water hyacinth was found to increase biogas production in a parabolic manner. In this research, it was observed that a food waste concentration of 5 kg is the maximum amount of food waste needed to combine with 1:4 of cow dung and water hyacinth for maximum production of biogas. This can be translated to kilograms or tones for large scale production of biogas.

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