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Review Article – Bioenergy

A review on biogas production as the alternative source of fuel

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Abstract

Challenges related to energy shortages are increasingly frequent both at the local and global scale due to population growth and the desire for a higher standard of living. The growing demand for oil and natural gas caused by high consumption levels is one of the current major problems faced by the world population. Therefore, new forms of energy generation must be investigated that would eventually allow the diversification of the present energy matrix, which has an almost 90% dependence on fossil fuels the world over. This coupled with long-term economic and environmental concerns have resulted in a great amount of research in the past decades on renewable sources of liquid fuels to replace fossil fuels. Burning fossil fuels such as coal and oil releases carbon dioxide (CO_2), which is a major cause of global warming. It is anticipated that not a single source of alternative energy but a mix of various energy sources and carriers will contribute to the energy system of the future. Among the various sources that has been explored, biogas offer one of the best alternative options as they present a viable option for improving sustainable development through energy security and reducing the emission of greenhouse gases. This paper elaborates on Biogas production as the alternative source of fuel. The paper also outlines the importance of Biogas production as a means of reducing problem of power energy, environmental vandalism, loss of resources, climate change and also reduce environmental pollution caused by cars, motorcycle and industrial activities as also burning of woods.

Keywords: biogas, biogas production, biomass energy, biofuel, petroleum, pollution

Introduction

In Nigeria, the scarcity of petroleum supply particularly kerosene has become a national concern and the problem became career to the nation. So biogas technology has gained a national interest. The power energy become a problem, the Niger Delta people became obstacle in petroleum supplied, Boko haram insurgency also a problem in our resources, lack of electricity no more new company are exist, majority of Nigerian are jobless, problem of fertilizer in our field, global warming, climate change and pollution to our environment as a result of burning of woods, cars, motorcycle and industrial activities. Biogastechnology will surely solve all the above mentioned (Sambo, 2009). A major factor effecting Nigerian economic progressing is power supply and it has been a major discourse in the country. However, in rural areas, assistance programs are emphasizing on the need to employ technology that is within

of petroleum products in the country coupled with exhaustible petroleum reserve and fluctuation in their prizes have caused uncertainly in the feature availability and supply of petroleum products as the major source of raw materials available for domestic and industrial uses. Thus, there has been a renewed interest in the research and development of renewable resources that would serve as viable alternative source of fuels.

An alternative source of energy known as "biomass energy" can help alleviate the energy needs of the country and the African continent. Biomass can however be seen as a shooting star among the most discussed options of the development of sustainable energy and resource system. However, developing countries generally rely on wood, dung, plant, agricultural, animal and human power to meet most of their basic energy needs. It is estimated that more than two third of the households in the world live in developing countries and about three quarters of these are in rural areas where biomass (wood and agricultural wastes) is the principal fuel and where both income and energy consumption are among the lowest in the world (Deckoning *et al*., 1985). Waste generation is a natural consequence of human activities, and is increasing along with population growth, urbanization and industrialization. Continued open dumping and unsophisticated land filling of solid waste in major cities of developing world result in significant health and environmental consequences because the uncontrolled decomposition of waste could lead to spread of epidemic diseases, proliferation of foul odors and climate change (Anderson *et al*., 2012).

strategic priority in all
nts for a large share of Nigeria's energy use. More than 85% of the population of sub-Saharan Africa currently uses solid fuels (predominantly firewood) for cooking, of which the collection of this energy source becomes increasingly cumbersome (ECOWAS Renewable Energy and Energy Efficiency [ECREEE] Status Report, 2014). Women and children predominantly spend time and energy on providing traditional energy service, and they are the usual victims of smoke-related respiratory illnesses such as pneumonia, lung cancer and chronic obstructive pulmonary disease. According to World Health Organization, household air pollution from cooking smoke kills over 4 million people every year and sickens millions more. Over 95,000 Nigerians, mostly women and children, die annually from cooking smoke. Indoor air pollution from

burning of fuels ranked as the Nigerian's third highest killer after malaria and HIV/AIDS (Garcia and Angenent, 2009).One of the main environmental problems of today's society is the continuously increasing production of organic wastes. In many countries, sustainable waste management as well as waste prevention and reduction have become major political priorities, representing an important share of the common efforts to reduce pollution and greenhouse gas emissions and to mitigate global climate changes. Uncontrolled waste dumping is no longer acceptable today and even controlled landfill disposal and incineration of organic wastes are not considered optimal practices, as environmental standards hereof are increasingly stricter and energy recovery and recycling of nutrients and organic matter is aimed (Al Seadi and Holm, 2004).

Biogas Production

Biogas refers to a mixture of different gases produced by the breakdown of waste, such as human and animal excretory product, plant material or any other organic waste in the absent of oxygen to produce natural gas, used for cooking, lightening, machineries and other energy purposes (Persson*,* 2007*)*. Biogas can be produced by anaerobic digestion with anaerobic organisms which digest material inside a closed system, or fermentation of biodegradable materials (NNFCC, 2011). Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have a small amount of hydrogen sulfide (H_2S), Moisture, and Siloxanes.

Production of biogas through anaerobic digestion (AD) of animal manure and slurries, plant material as well as of a wide range of digestible organic wastes, converts these substrates into renewable energy and offers a natural fertilizer for agriculture. At the same time, it removes the organic fraction from the overall waste streams, increasing this way the efficiency of energy conversion by incineration of the remaining wastes and the biochemical stability of landfill sites (Moller ,2004*)*.Interest in biogas technology is increasing around the world due to the requirements for renewable energy production, reuse of materials and reduction of harmful emissions. Biogas technology offers versatile and case-specific options for tackling all of the above mentioned targets with simultaneous controlled treatment of various organic materials. It produces methane-rich biogas which can be utilized as renewable energy in various ways. The residual material, digestate, contains all the nutrients of the original raw materials and offers a way to recycle them. Along the process steps, also emissions directly from the raw materials (storage, use, and disposal) or from the replaced products (fossil fuels, inorganic fertilizers) can be reduced (Hjort-Gregersen, 1998).

Biogas technology is currently the most sustainable way to utilize the energy content of manure while also recycling the nutrients and minimizing the emissions. As it was reported in other research which particularly emphasis on anaerobic digestion of manure, and with co-substrates. The benefits generated by the model projects have been estimated for two cases. The first case assumes that biogas will be used in gas stoves with maximum efficiency of 60%, replacing energy from burning wood. Economic benefits generated by these projects include:

- Reduction of uncontrolled forest cutting, and thereby mitigation of risks such as avalanches, landslides, etc. (Over the last decade, especially in rural areas of the world, people have been using mainly firewood for cooking, heating and hot water.)
- Contribution to the value of the standing forest saved. This "show price" of afforestation/reforestation is estimated on the basis of analysis of different projects developed in world.
- Improved living conditions for the population (*e.g.* people will spend less, or no, time, energy and finance on wood collection).
- Indoor pollution will be reduced.
- Electricity generation (especially in the case of thermophilic bioreactors, which produce more biogas than necessary for generating heat).
- Higher education levels (*e.g.* during short winter days, schoolchildren will be able to study by electric light powered by biogas).
- Better access to information: with electricity from biogas, the rural population can watch TV, which is a vital source of information, especially in wintertime, when access roads to mountainous regions are closed.
- Reduced greenhouse gas (GHG) emissions by avoiding methane emissions and using wood in heat production and electricity.

Component of biogas

The composition of biogas varies depending upon the substrate composition, as well as the conditions within the anaerobic reactor (temperature, pH, and substrate concentration). Landfill gas typically has methane concentrations around 50%. Advanced waste treatment technologies can produce biogas with 55%–75% methane, which for reactors with free liquids can be increased to 80%-90% methane using in-situ gas purification techniques. As produced, biogas contains water vapor. The fractional volume of water vapor is a function of biogas temperature; correction of measured gas volume for water vapor content and thermal expansion is easily done via simple mathematics which yields the standardized volume of dry biogas.

Table 1. Typical Composition of Biogas

Compound	Formula	%
Methane	CH_4	50–75
Carbon dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen sulfide	H_2S	0–3
Oxygen	O_2	0–0.5

Substrate/feedstock for biogas production

A wide range of biomass types can be used as substrates (feedstock) for the production of biogas from anaerobic digester. Different raw materials will produce different amounts of biogas and methane depending on their content of carbohydrates, fats and proteins (Buswell, 1930). In theory, all biodegradable materials with reasonable lignin content (i.e. not wood) are suitable raw materials for biogas processes. In agriculture, manure and most plant biomass can be directed to biogas plants, while from municipalities, food waste and sewage sludge are the most important material flows to biogas processes. Moreover, different industries produce biodegradable by-products which can be used in biogas plants.

The most common biomass categories used in biogas production are listed below

- o Animal manure and slurry
- o Agricultural residues and by-products
- o Digestible organic wastes from food and agro industries (vegetable and animal origin)
- o Organic fraction of municipal waste and from catering (vegetable and animal origin)
- o Sewage sludge
- o Dedicated energy crops (e.g. maize, miscanthus, sorghum, clover).

- Sewage sludge
- Food waste
- Waste from food industry
- Residues from agriculture
- "Energy" herbs and plant like grass
- Kitchens waste etc.

Alternative feed stocks

Animal waste are generally used as feed stocks in biogas production, these include;

- Cattle waste
- Buffalo waste
- Piggery waste
- Human excreta
- Camel waste
- Horse waste etc. (Al Seadi *et al.,* 2001).

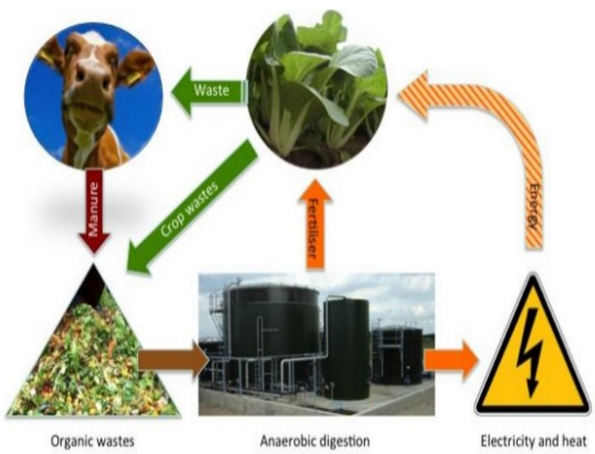

Fig.1. Different feedstock

How to choose a substrate for a biogas process

Many different organic materials can be decomposed to biogas in a digestion chamber (Gunaseelan, 1997). Some materials are more appropriate than others, and some general guidelines can be applied. However, process parameters such as load, temperature and retention time have a great influence on how efficiently a given substrate is broken down. How well a particular material works in a biogas process can also depend on what pre-treatment is applied and whether it is the sole substrate or if it is co-digested with other materials. The presence of toxic substances or lignin, which is not at all broken down in a biogas process, also plays a role. Below follows a discussion of the importance of substrate composition for the microorganisms and gas production, and how to evaluate materials to be used for biogas production.

The importance of substrates for microorganisms and gas production

The composition of a substrate is very important for the microorganisms in the biogas process and thus also for process stability and gas production. The substrate must meet the nutritional requirements of the microorganisms, in terms of energy sources and various components needed to build new cells. The substrate also needs to include various components needed for the activity of microbial enzyme systems, such as trace elements and vitamins. In the case of decomposition of organic material in a biogas process, the ratio of carbon to nitrogen (C/N ratio) is also considered to be of great importance. It is important that the ratio is not too low, in other words, that there is not too much nitrogen relative to carbon. If so, the process can easily suffer from ammonia inhibition. The ratio should also not be too high, since the bacteria in the process may then experience nitrogen deficiency (Yen and Brune 2007). It is hard to say exactly what ratio is optimal because it varies with different substrates and also with the process conditions

How biogas produced

During production of biogas using animal dung, plant material, poultry dropping, or any other organic waste the following components must to be considered:

1. *Charging Point:* It is also called Mixing tank, is place where dung, plant material or any other substrates are discharge and mixed with water.
2. *Inlet Chamber:* This is small pipes that are connected between a charging point and digester.
3. *Digester:* This is the most important part during biogas production, is places were anaerobic activities as well as fermentation on the substrate take place, is also places were methane gas are store and collected.
4. *Outlet chamber:* This is also pipes that are connected between digester and effluent tank.
5. *Effluent Tank/Overflow Tank:* From the outlet chamber, the spent slurry overflows into the overflow tank / effluence tank. This is place where aerobic degradation take place and the final sludge in the effluence tank contain 93% water 4.5% organic and 2.5% inorganic matter which is less harmful to the environment, it serves as the good manure for the production of plant.
6. *Demonstration Point:* This is a point where biogas is used for cooking, lightening, machineries, industrial activities and other energy purposes.

Working

1. The various form substrates are mixed with an equal quantity of water in the mixing tank/charging point. This form the slurry.
2. The slurry feed in the digester through the inlet chamber
3. When the digester is partially filled with the slurry, the introduction of slurry is stopped and then left unused about 1 – 2 weeks.

4. During these two weeks, anaerobic bacteria present in the slurry decompose or ferments the bio mass in the present of water. In the digester three steps take place under anaerobic condition which are ;
    - Hydrolyses
    - Acidification and
    - Methylation
5. As result of anaerobic fermentation biogas is formed, this starts collecting in the dome of the digester.
6. As more and more biogas starts collecting the pressure exerted by the biogas forces the spent slurry into the outlet chamber.
7. From the outlet chamber, the spent slurry overflows into the overflow tank / effluence tank. This is the place where aerobic degradation take place and the final sludge in the effluence tank contain 93% water 4.5% organic and 2.5% inorganic matter which are less harmful to the environment; it serves as the good manure for the production of plant.
8. The gas valve connected to a system or pipelines is opened when a supply of biogas is required (Yokoyama *et al*., 2007).

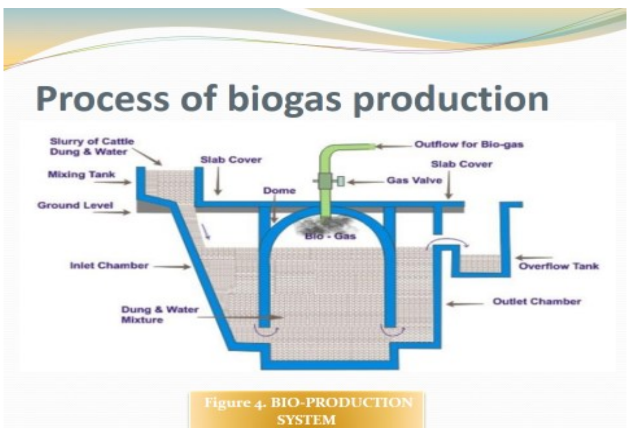

Fig. 2. Process of Biogas Production

Benefits of biogas

1. Renewable energy source

The current global energy supply is highly dependent on fossil sources (crude oil, lignite, hard coal, natural gas). These are fossilized remains of dead plants and animals, which have been exposed to heat and pressure in the Earth's crust over hundreds of millions of years. For this reason, fossil fuels are non-renewable resources which reserves are being depleted much faster than new ones are being formed. The World's economies are dependent today on crude oil. There is some disagreement among scientists on how long this fossil resource will last but according to researchers, the "peak oil production"* has already occurred or it is expected to occur within the next period of time. Unlike fossil fuels, biogas from AD is permanently renewable, as it is produced on biomass, which is actually a living storage of solar energy through photosynthesis. Biogas from AD will not only improve the energy balance of a country but also make an important contribution to the preservation of the natural resources and to environmental protection.

2. Reduced Greenhouse Gas Emissions and Mitigation of Global Warming

Utilization of fossil fuels such as lignite, hard coal, crude oil and natural gas converts carbon, stored for millions of years in the Earth's crust, and releases it as carbon dioxide (CO_2) into the atmosphere. An increase of the current CO_2 concentration in the atmosphere causes global warming as carbon dioxide is a greenhouse gas (GHG). The combustion of biogas also releases CO_2. However, the main difference, when compared to fossil fuels, is that the carbon in biogas was recently up taken from the atmosphere, by photosynthetic activity of the plants. The carbon cycle of biogas is thus closed within a very short time (between one and several years). Biogas production by AD reduces also emissions of methane (CH_4) and nitrous oxide (N_2O) from storage and utilization of untreated animal manure as fertilizer. The GHG potential of methane is higher than of carbon dioxide by 23 fold and of nitrous oxide by 296 fold. When biogas displaces fossil fuels from energy production and transport, a reduction of emissions of CO_2, CH_4 and N_2O will occur, contributing to mitigate global warming.

3. Reduced Dependency on Imported Fossil Fuels

Fossil fuels are limited resources, concentrated in few geographical areas of our planet. This creates, for the countries outside this area, a permanent and insecure status of dependency on import of energy. Most European countries are strongly dependent on fossil energy imports from regions rich in fossil fuel sources such as Russia and the Middle East. Developing and implementing renewable energy systems such as biogas from AD, based on national and regional biomass resources, will increase security of national energy supply and diminish dependency on imported fuels.

4. Waste Reduction

One of the main advantages of biogas production is the ability to transform waste material into a valuable resource, by using it as substrate for AD. Many European countries are facing enormous problems associated with overproduction of organic wastes from industry, agriculture and households. Biogas production is an excellent way to comply with increasingly restrictive national and European regulations in this area and to utilize organic wastes for energy production, followed by recycling of the digested substrate as fertilizer. AD can also contribute to reducing the volume of waste and of costs for waste disposal.

5. Job creation

Production of biogas from AD requires work power for production, collection and transport of AD feedstock, manufacture of technical equipment, construction, operation and maintenance of biogas plants. This means that the development of a national biogas sector contributes to the establishment of new enterprises, some with significant economic potential, increases the income in rural areas and creates new jobs.

Important and uses of biogas

Biogas is very important in today's world as it is pollution free source of energy at a very low cost. Biogas is energy rich and is well suited as a source of energy within many areas. Some of the uses of biogas include:

1. *Biogas for Heating*

Perhaps the easiest way to use biogas is for heating. This is because, for this purpose, no pre-treatment other than the removal of water is required. Biogas is usually used for heating buildings in conjunction with a biogas plants, but surplus heat can also be directed into the district heating network.

2. *Biogas Power Generation*

Biogas energy can also be used to generate power. Both electricity and heat can be produced with the help of a gas powered generator. The proportions of heat and power generation depend of course on the design of the plant but are usually in the region of 35% electricity and 65% heat.

3. *Biogas as Vehicle Fuel*

Relatively speaking, biogas requires considerable processing if it is to be used as vehicle fuel. The energy value has to be raised by separating carbon dioxide in order to achieve a methane content of between 95 and 99%. Water, impurities and particles must be removed to avoid mechanical as well as environmental damage. Finally, the gas has to be compressed. Although significant work is needed to upgrade methane gas to biogas fuel, the environmental benefit is so great than an increasing number of filling stations are opening through the country. There are at present between 40 and 50 biogas stations are in Sweden.

4. *Biogas in the Gas Network*

Refined biogas can be injected into gas networks. Networks for town gas were perhaps more common before but, in Stockholm for example, there is a functioning network with natural gas being used for gas cookers, heaters, baking ovens, water heaters etc.

5. *Biogas in Industry*

Many industries such as sugar refineries, distilleries, dairies and paper mills generate processing and waste water that can be digested directly on site. Biogas can thus be used for heating premises, district heating power production, heating ovens etc.

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