



## REVIEW ON BIOGAS PRODUCTION PROCESSES

<sup>1</sup>Ali, M., <sup>2</sup>Bukar, A., <sup>2</sup>Kawo, A. H. and <sup>3</sup>Saleh, A.

<sup>1</sup>National Population Commission, Federal Secretariat Dutse, Jigawa State

<sup>2</sup>Department of Microbiology, Faculty of Life Sciences, Bayero University, Kano

<sup>3</sup>National Root Crops Research Institute, Umudike, Abia State

Correspondence Author: [kanebawa@gmail.com](mailto:kanebawa@gmail.com): 07038019142

### ABSTRACT

*This reviews aims to provide an insight and update of the state of biogas production processes among which are hydrolysis, acidogenesis, acetogenesis and methanogenesis as well as to highlight the resources of biomass used in biogas production, construction of bio-reactor, slurry composition and factors affecting biogas production with emphasis on temperature, pH, nutrients, organic load and antibiotics. Anaerobic digestion is a technology that has been used by humans for centuries. It is considered to be a useful tool that can generate renewable energy and significant research interests have been arise recently. Recent developments in previous research are considered to provide comprehensive summary of accumulated knowledge in the area of anaerobic digestion as well as adequate considerations in the efficient operation of biodigester. Conclusively the review suggest that biogas technology must be encouraged, promoted and invested for implementation and demonstration in order to improve the quality of energy supply.*

**Key words:** Biogas, biomass, anaerobic digestion, bio-reactor.

### INTRODUCTION

These days, air pollution and global warming are the dominant anxieties facing the environment of human. This issue could be attributed to the enormous evolution of greenhouse gases (GHG) like carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and other gases which have been produce from an extensive combustion of fossil fuels. Concurrently with increasing world population. It is well known that GHG act as an important factor for global warming. In global warming the heat reflected from the earth surface to increases temperature of ambient temperature. These global warming major contribution of CO<sub>2</sub> (60%) and less effect of CH<sub>4</sub> (15%) (Jing *et al.*, 2016) as such the used of microorganisms and available agro and other environmental as well as industrial wastes are used in biogas production.

As the name suggests, biogas is produced in a biological process. In the absence of oxygen (anaerobic means without oxygen), organic matter is broken down to form a gas mixture known as biogas. This process is widely found in nature, taking place in moors, for example, or at the bottom of lakes, in slurry pits and in the rumen of ruminants. The organic matter is converted almost entirely to biogas by a range of different microorganisms. Energy (heat) and new biomass are also generated. The resulting gas mixture consists primarily of methane (50-75 vol. %) and carbon dioxide (25-50 vol. %). Biogas also contains small quantities of

hydrogen, hydrogen sulphide, ammonia and other trace gases. The composition of the gas is essentially determined by the substrates, the fermentation (digestion process and the various technical designs of the plants. The process by which biogas is formed involve stages of decomposition (degradation) that must be coordinated and harmonized with each other in the best way possible to ensure that the process as a whole runs smoothly (Peter, 2009). The stages of biogas production are as follows:

#### Hydrolysis

Biomass is normally comprised of large organic polymers proteins, fats and carbohydrates. These are broken down into smaller molecules such as amino acids, fatty acids, and simple sugars. It is the essential first step in anaerobic fermentation; fermentative bacteria hydrolyze the complex organic matter into soluble molecules. Some of the products of hydrolysis, including hydrogen and acetate may be used by methanogens later in the anaerobic digestion process. Majority of the molecules, which are still relatively large, must be further broken down in the process of acidogenesis to create methane (Malico *et al.*, 2016).

#### Acidogenesis

Acidogenesis is the next step of anaerobic digestion where acidogenic microorganisms further break down the biomass and organic products after hydrolysis.

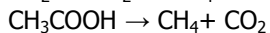
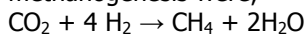
These fermentative bacteria produce an acidic environment in the digestive tank while creating ammonia, H<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>S, shorter volatile fatty acids and organic acids, as well as trace amounts of other byproducts. The principal acids produced are acetic acid, propionic acid, butyric acid etc. (Gumartini, 2009).

#### Acetogenesis

In general, acetogenesis is the creation of acetate, a derivative of acetic acid, from carbon and energy sources by acetogens. These microorganisms catabolize many of the products created in acidogenesis into acetic acid, CO<sub>2</sub> and H<sub>2</sub>. Acetogens break down the biomass to a point to which methanogens can utilize much of the remaining material to create methane (Doggarand 2016).

#### Methanogenesis

There are two general pathways involving the use of acetic acid and carbon dioxide. The two main products of the first three steps of anaerobic digestion, to create methane in methanogenesis were;



While CO<sub>2</sub> can be converted into methane and water through the reaction, the main mechanism to create methane in methanogenesis is the path involving acetic acid. This stage leads to generation of methane and CO<sub>2</sub>, the two main products of anaerobic digestion (Malico *et al.*, 2016).

#### Resources of Biomass

Biomass energy resources are mainly used through conventional technologies, by rural community to meet their basic energy needs, cooking and heating. Meanwhile biomass gasification (biogas) and bio-liquefaction (biodiesel and bioethanol) technologies are gradually being developed (Liu *et al.*, 2011). Among these biogas production technology is simple to install and operate. The technology is cost effective and well taken around the world.

Although almost all biodegradable materials can be used for the production of biogas but there are four major sources of biomass worth to be considered: agricultural and forestry residues, municipal solid waste including kitchen waste, industrial waste, and specifically grown bioenergy crops (Ismail and Talib, 2016)

- **Agricultural and forest residues** - Wood and woody debris left after logging, agriculture waste, crop residues and energy crops, algal biomass, etc.
- **Community based waste** - Municipal solid waste (MSW) much of which is organic including cooked and uncooked kitchen,

sewage sludge, grass clippings and garden waste.

- **Industrial waste** - Large quantity solid and processed liquors is generated by the industries like breweries, sugar mills, distilleries, food-processing industries, tanneries, paper and pulp industries, wood works and furniture.
- **Animal manure and Human Excreta** - Animal dung and human excreta, poultry waste.
- **Marine feedstock** - Seaweeds, fish and shellfish (Luo *et al.*, 2015).

#### Construction of the Bio-reactor (digester)

A hole will be bore on the plastic cover of a 500cm<sup>3</sup> capacity transparent plastic bottle. A polyvinylchloride (PVC) tube of 50cm length and 0.8cm internal diameter will be inserted in to the hole bore on the plastic cover and glue with araldite adhesive (to cover leakages), with one end of the PVC free (i.e. unattached) which will convey the gas from the digester to 1000cm<sup>3</sup> capacity measuring cylinder which are fill with water and inverted into a bowl containing water for gas collection using water displacement method. The digesters will be set up and allow to undergo anaerobic digestion at mesophilic and thermophilic temperature of 31-36°C (ambient) and 40, 45 and 55°C respectively for a retention period of weeks. The amount of gas produce and temperature will be recorded at noon on daily basis (Sabna *et al.*, 2011).

#### Slurry Composition

The slurry is prepared with desired gram of the substrates and specify amount of water such that the substrate will not absorb the water before ending of the experiment. It is important to record the pH of the slurry before and after digestion for each digester using a pH meter. The digester must be made airtight (by screwing the caps tightly) and place in a water bath maintain at 33°C (Sabna *et al.*, 2011).

#### Factors Affecting Gas Production

The potential gas volumes produced from bio resources depends on many factors, some of the factor are given below.

#### Temperature

Although there are no standard rules but for optimum process stability, the temperature should be carefully regulated within a narrow range of the operating temperature. With a mesophilic flora, digestion proceeds best at 30 - 40°C; with thermophiles, the optimum range is 50 – 60°C. The choice of temperature to be used is influenced by climatic considerations. In warm climates digesters may be operated without added heat.

As a safety measure, it is common practice either to bury the digesters in the ground on account of the advantageous insulating properties of the soil, or to use a greenhouse covering. In cold climate where heating of digesting material is required, the costs can be minimized through the use of natural materials such as leaves, sawdust, straw, etc., which are composted in batches in a separate compartment around the digester. For ideal fermentation the temperature should be maintained above 30°C (Alemayehu, 2015).

### **pH**

Low pH inhibits the growth of the methanogenic bacteria and gas generation and is often the result of overloading. Efficient digestion occurs at a pH near neutrality, within a range of 6.0 - 8.0. A slightly alkaline state is an indication that pH fluctuations are not too drastic. Low pH may be relieved by dilution or by the addition of lime (Doggarand, 2016).

### **Nutrients**

The maintenance of optimum microbiological activity in the digester is crucial to gas generation and consequently is related to nutrient availability. Two of the most important nutrients are carbon (C) and nitrogen (N) and overall C/N ratio is a critical factor for raw material choice. Domestic sewage and animal and poultry wastes are examples of N-rich materials that provide nutrients for the growth and multiplication of the anaerobic organisms. On the other hand, N-poor materials like agriculture waste, green grass, etc., are rich in carbohydrate substances that are essential for gas production. Excess of nitrogen leads to the formation of NH<sub>3</sub>, the concentration of which inhibits further growth. Ammonia toxicity can be eased by lower loading or dilution. In practice, it is important to maintain, by weight, a C/N ratio close to 30:1 for achieving an optimum rate of digestion. The C/N ratio can carefully be manipulated by combining materials low in carbon with those that are high in nitrogen, and vice versa (Waziri and Raja, 2016).

### **Acidification – Organic Acids**

Other important endogenous process inhibitors are the organic acids formed during the process. If these are not removed as soon as they are formed – which can happen during an overload – this can lead to an acidification of the process (Peter, 2009).

### **Antibiotics**

Among the exogenous causes, antibiotics and disinfection agents are obvious inhibitors of the

process, because both – by definition – are toxic to and are used to kill microorganisms. Both substances are used in livestock production to treat sick animals and to keep animal houses and milking parlours clean and can therefore also be found in the slurry, but apparently only at concentrations so low that they do not have a negative impact on the biogas plant. A slow adaptation to these substances can also take place if the supply is fed in continuously. Other substances such as heavy metals, salts and micronutrients can also inhibit the process at high concentrations. But as previously mentioned, some of them are essential for the process at low concentrations, in the same way that vitamins are for humans (Peter, 2009).

### **Gas purification**

Besides methane and carbon dioxide, the gas also contains a smaller amount of hydrogen sulphide. The amount proportional to the protein content of the biomass. The higher the protein level, the higher the H<sub>2</sub>S production. If the biogas is intended to be used in a combustion engine, the H<sub>2</sub>S-content has to be removed from the gas, as it is corrosive in combination with CO<sub>2</sub> and water vapour. This can be done in a biological process, where the ability of sulphur bacteria to degrade hydrogen sulphide to pure sulphur or sulphuric acid is utilised. This sulphur in an aqueous solution is pumped to the secondary storage tank and therefore recycled to the field and crops (Peter, 2009).

### **CONCLUSION**

Anaerobic digestion is a technology that has long been used for the production of biogas. The technology is simple with tested and finds ready use in domestic and farming applications. The technology can contribute substantially to the sustainable energy recovery from organic waste particularly agriculture and municipal. The amount of agricultural and municipal organic wastes currently available for energy production is very large. Apart from significant energy source, it is important for comprehensive utilization of biomass, agricultural, animal husbandry, forestry and fishery residues, thus controlling the pollution and protecting the environment. Waste management particularly in developing countries like Nigeria is one of the most serious environmental problems. The biogas technology provides two important benefits: environmentally safe waste management as well as the generation of clean renewable energy. Coordinating the factors like waste management, organic fertilizer, the biogas production and use may further optimize the promotion and development of agricultural and

animal husbandry in rural areas, as well as improve the living conditions of rural communities. It may be one of the important

options, which might gradually reduce the fossil fuels use.

## REFERENCES

- Alemayehu, Y.A. (2015). Enhancement and Optimization Mechanisms of Biogas Production for Rural Household Energy in Developing Countries: A review, *Int'l Journal of Renewable Energy Development*, 4(3), **189-196**, 2015.
- Arkadius., MaciejD., and Janusz., (2016). "Agricultural biogas plants in Poland – selected technological, market and environment aspects" *Renewable and Sustainable Energy Review* 58(2016)**69–74**, *journal homepage: www.elsevier.com/locate/rser*
- Doggarand M. G. and Aja I A, (2016). Biogas: An Energy Options for 1000 Acre Agriculture Farm, ESdev VI, Conference, COMSATS Institute of Information Technology, Abbottabad, Pakistan.pp; 56-60
- Gumartini, T(2009). Biomass Energy in the Asia-Pacific Region: Current Status, Trends and Future Setting, FAO Regional Office, Bangkok pp;87-904
- Ismail Z. Z. and Talib A. R., (2016). Recycled medical cotton industry waste as a source of biogas recovery *Journal of Cleaner Production*, Volume 112, Part 5, 20, 4413–4418,
- Jing W., Zohaib Ur RehmanA., Zhi P. C., Zhong Z., Souhila P.,HuaiZ. L., Jian E. Z., and Kai J. W., (2016). "Size effect of anaerobic granular sludge on biogas production: A micro scale study" *Bioresource Technology* 202 (2016) 165–171 *journal homepage: www.elsevier.com/locate/biortech*
- Luo, X., Wang J.D., M. and Clarke, J.(2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation, *Applied Energy*, 137 (1), **511–536**, 2015.
- Liu, W., Lund, H. and Mathiesen, B.V. (2011). Potential of renewable energy systems in China, *Applied Energy* 88(2):518-525, 2011.
- Malico I, J. Carrajola, C. Pinto Gomes, and J.C. Lima. (2016). Biomass residues for energy production and habitat preservation. Case study in a montado area in Southwestern Europe, *Journal of Cleaner Production*, 112(5), **3676–3683**, 2016
- Peter,J.J.(2009),Biogas-Green Energy, Second edition. Digisource Denmark.pp;304-307
- Sabna, S. Pramod, S. and Potty, V.P. (2011): Isolation, identification and methanogenesis of CNSL Degrading bacterial and immobilized bioremediation Institute of Information Technology, Abbottabad Pp. **325**.
- Wazir, S. and Rajai.A, (2016). Simple design and installation of biogas plant in KPK Pakistan, ESdev-VI, COMSATS Institute of Information Technology, Abbottabad, Pakistan, pp;424.