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# Fundamental Principles of Biogas Product

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**Abstract:** ***Biogas is a mixture of gases (containing 50-75% Methane, and 25-50% Carbon dioxide while 0-10% Nitrogen, 0-3% Hydrogen disulphide and 0-2% Hydrogen may be present as impurities) produced by anaerobic digestion (fermentation). The sequential enzymatic breakdown of biodegradable organic material (Biomass) in the biodigester occurs in four major steps i.e. hydrolysis, acidogenesis, acetogenesis and methanogenesis. The micro organism and enzymes plays a vital role in the biogas production which is usually not taking advantage of in other to increase the yield per digester thereby commercializing the production and sale of biogas. This paper highlighted the sequential role played by each micro organism and enzymes in the biodigester in other to identify each by the role it plays which is a way of enhancing further research in the field of biogas production where the isolation of these enzymes and micro organism and their artificial production will help in more output per digester when introduce into it artificially.***

**Keywords:** fermentation, biodigester, hydrolysis, acidogenesis, acetogenesis, methanogenesis

## 1. Introduction

Biogas is a mixture of gasses produce by anaerobic digestion (fermentation) of biodegradable organic materials such as manure from animals like cows, pigs, humans etc. It is often known as "marsh gas" or "swamp gas" because it is produce by the same anaerobic process that occurs during the underwater decomposition of organic matter in wet land.[(1)(19)]

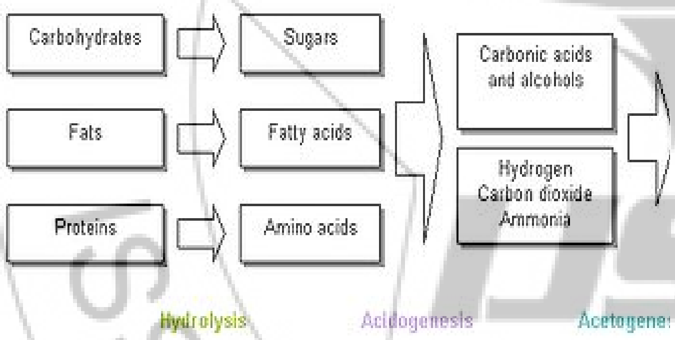


**Table 1:** Biogas Composition [(19)]

| Matter | % |
|---|---|
| Methane ($CH_4$) | 50-75 |
| Carbon dioxide ($CO_2$) | 25-50 |
| Nitrogen ($N_2$) | 0-10 |
| Hydrogen ($H_2$) | 0-2 |
| Hydrogen sulfide ($H_2S$) | 0-3 |
| Oxygen ($O_2$) | 0-2 |

As seen in table 1, the important component of the biogas is methane (50-75%) and carbon dioxide (25-50%) while other gasses especially hydrogen sulfide ($H_2S$) serves as impurities in the biogas thus for crude biogas to be used as fuel, it need purification or upgrading using the following methods; [(3)]

- ✓ Water washing
- ✓ Pressure swing absorption
- ✓ Selexol adsorption
- ✓ Amines gas treatment.

**Figure 1:** Biogas used as cooking gas

The role played by micro organism and enzymes is highlighted in this paper with view to identify each by the role it plays which is a way of enhancing further research in the field of biogas production where the isolation of these enzymes and micro organism and their artificial production will help in more output per digester when introduce into it artificially.

### 1.1 History

Historically, biogas production from the decomposition of organic matter was first reported in the 17$^{th}$ century by Robert Boyle and Stephen Hale who noted that flammable gas was release by disturbing the sediments of streams and lakes. [(5)] In 1808, Sir Humphry Davy determines that methane was present in the gas produce by decomposition of cattle manure. However, the first anaerobic digester was billed at Bombay, India in 1859 and through scientific research, anaerobic digestion gained academic recognition in 1930's. [(8)(9)]

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### 1.2 Biodigester

A biodigester is a tank used in processing the organic material into biogas. It usually comes in different shape and size depending on the need of its user and the local possibility of building it. It is usually design to be air tithe as the process in biogas production is anaerobic (absence of oxygen). The production capacity of a biogas depend generally on [6][7][19]

- ✓ The type of material (manure) used in the biodigester.
- ✓ Temperature of the mixture inside the digester.
- ✓ Accuracy in constructing the digester.
- ✓ The PH in the digester.

Water and the manure are major component feed into the biodigester in a ratio that depends on the type of manure being used e.g. using caw manure, the manure to water ratio is 2:1 while using pig droppings, it is 1:1. This variation is so because water plays a vital role of initializing the hydrolysis of manure and some manure e.g. caw manure requires more water for this hydrolysis because the feed more on grasses which makes there manure more fibrous. The mixture of water and manure known as slurry is then feed into the biodigester for onward digestion. [12][17]

**Figure 2:** Two-stage, low solids, UASB digestion component of a mechanical biological treatment system near Tel Aviv

## 2. Biogas Formation Principles

The basic principle by which biogas is produce in the digester is the principle of anaerobic digestion. Anaerobic digestion is a series of enzymatic processes by which microorganism breakdown biodegradable organic materials in the absence of oxygen ($O_2$) [17]. The process occurs in four concurrent stages.

i. Hydrolysis
ii. Acidogenesis
iii. Acetogenesisge
iv. Mathanogenesis

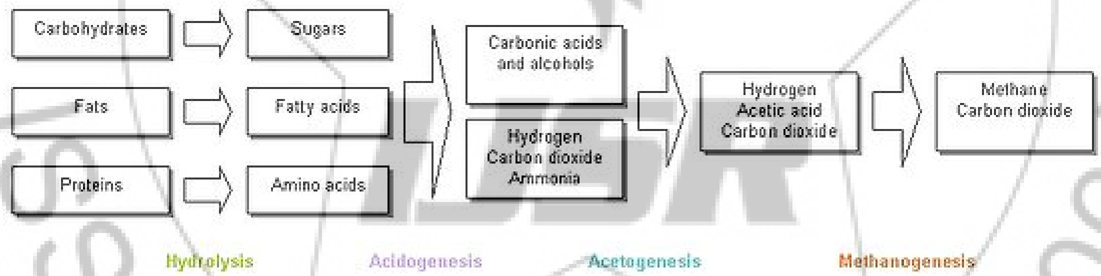


**Figure 3:** Summary of anaerobic digestion [13][16][19]

### 2.1 Hydrolysis

Hydrolysis simply means "rupture of chemical bond using water". The word comes from a Greek root. "Hydro," means water while "lyses" means rupture [19]. In the process, large organic polymers in the biomass (carbohydrates, fats and proteins) are broken down to release simple monomers (starch, fatty acid and amino acid). [21] On hydrolysis, polysaccharide yield mono, di, and oligosaccharide (simple sugars), Protein yield amino acid while fats yield fatty acids. As the slurry is formed, hydrolytic enzymes become active. The hydrolytic enzymes glycoside hydrolases or glycosidases in a polysaccharide chain, target the glycosidic bond which is the bond linking the monomers together e.g. the bond between glucose and fructose units (sucrose or table sugar) is a glycosidic bond represented by an oxygen atom. The hydrolysis of polysaccharide to soluble sugers involve the following enzymes [6].

- Glycosidases acting on glycosidic bond.
- Amylases acting on starch to glucose or oligosaccharide
- Cellulases acting on cellulose to glucose or other disaccharide. (cellulase is also found in the stomach of ruminant animals)

Proteins consist of a long chain of amino acids linked by a peptide bond (polypeptide). On hydrolysis, the peptide bonds are broken to release the amino acids. The reaction is catalyzed by protease. The amide on hydrolysis yield carboxylic acid and an amine. The carboxylic acid gains the $OH^-$ group from the water while the amine gains the $H^+$ to form ammonia [11].

### 2.2 Acidogenesis

This is a biological reaction where an acidogenic (fermentative) bacterium acts on the products of hydrolysis (amino acids, sugars, and fatty acids) from the first stage to produce the following:

- Volatile fatty acid (acetate, butyrate, propionate, and lactate)
- Ammonia ($NH_3$)
- Carbon dioxide($CO_2$)
- Hydrogen sulphite ($H_2S$)

Due to the formation of these compounds, the content of the digester becomes slightly acidic. A bacteria known as thermaanaerobium brockii is a thermophilic hydrolytic bacteria which ferment glucose via the Embden-Meyerhof pathway. The bacteria being a typical heterolactic acid bacterium forms lactate, ethanol, and hydrogen from glucose. The glucose is first glycolytically reduced to pyruvate after which reduced end products are formed enzymatically from the pyruvate as follows [18][19].

Pyruvate ---------→ lactate (using fructose-1, 6-bisphosphate)
---------→$H_2$ (by pyruvate ferrodoxin, oxidoreductase, hydroginase
----------→ethanol (via NADH-NADPH linked alcohol dehydrogenase)

Iin this stage, the products of hydrolysis are fermented to yield $NH_3$, VFA, $CO_2$ and H. Bacteria is involved in acetate formation are; [15][16]

- Clostridium aceticum
- Acetobacter woodii
- Clostridium termoautotrophicum

Winter Y. wolfe, in 1973 demonstrated that acetobacter woodii in syntrophic association with methanogens (methanocercina spp) produce methane and carbon dioxide from fructose instead of three molecules of acetic acids, [6] while Clostridium termoacetacum and Clostridium fermiacetacum are able to reduce carbonic gas to acetate but since they do not have hydrogenase which inhibits hydrogen use, they produce three molecules of acetic acids from fructose [19].

### 2.3 Acetogenesis

This is a process through which acetic acid (acetate) is produce by anaerobic bacteria (acetogens) from the acedogenic products ($CO_2$ and $H_2$). The acetogens acts on the $CO_2$ and $H_2$ produce in acidogenesis to produce acetic acid ($CH_3COOH$).

#### 2.3.1 Biochemistry of acetogenesis

In the acetogenic pathway, the precursor of acetate is the thioester acetyl Co A. The key aspect of this pathway involves several reactions that reduce $CO_2$ to CO and the attachment of a methyl group ($-CH_3$) to the CO. The reduction of $CO_2$ to CO is catalyzed by carbon monoxide dehydrogenase while the attachment of the methyl group (provided by methyl cobalamin, a co factor) to CO is catalyzed by acetyl Co A synthetase [14]

$$2CO_2 + 4H_2 \text{---------}\rightarrow CH_3COOH + 2H_2O$$

The acetic acid ($CH_3COOH$) produce are then utilized by the methanogens for methane formation.

### 2.4 Methanogenesis

This is also known as biomethanation i.e. the formation of methane by microbes (methanogens) from $O_2$ and $H_2$ and or $CH_3COOH$. Methanogens are microbes capable of producing methane as a byproduct in the absence of oxygen (anaerobically). They belong to a domain known as archaea which were initially thought to be bacteria but are later discovered to be polygenetically distinct from both eukaryotes and bacteria however they live in close association with bacteria. The methanogens are commonly found in wet land where they are responsible for marsh gas, in the guts of ruminant animals such as cows where they are responsible for the methane content of belching in the ruminants. While in humans, they are responsible for flatulence [10].

A strain of the archaea known as Mathanosercina berken is an exceptional strain that posses an enzyme superoxide dismutase which enables it to survive longer than others in the presence of oxygen.[4][5]. Recently, some research suggested that leave tissue of living plants emits methane [1] while others indicated that plants are not actually generating methane but are just absorbing methane from the soil and emitting it through the leaf tissue [2][10].

#### 2.4.1 Biochemistry of mathenogenesis

During methane formation, carbon is the terminal electron acceptor (instead of oxygen as in respiration) and it comes from organic compound with small molecular weight. The two methanogenic pathway involves the use of $CO_2$ and $CH_3COOH$ produced in the early stages.

a. Use of $CO_2$ as electron acceptor

$$CO_2 + 4H_2 \text{-----------}\rightarrow CH_4 + 2H_2O$$

b. Use of acetic acid as electron acceptor.

$$CH_3COOH\text{-----------}\rightarrow CH_4 + CO_2$$

Basically the biochemistry of methanogenesis is very complex and involves the following co enzymes and factors; F420, CO enzyme B, Coenzyme M, methanofuran and methanopterin [10]

## 3. Conclusion

The activities of enzymes and micro organism in the biodigester bring about biogas production. Identifying these enzymes and micro organism and their specific roles, is a way forward in the commercialization of biogas as this makes it easy for such enzymes to be isolated and the micro organism cultured for artificial use.

## 4. Recommendation

1. Further research should be carried out on the isolation of these enzymes and the culture of the micro organism for artificial production.

2. More research should be carried out on more specific roles played by these enzymes and micro organism which might not have been highlighted in this paper.

## Reference


[1] Boone. D, Mah. R. (2006) Transitional bacteria in anaerobic digestion of biomass, p35
[2] Discovering Anaerobic Digestion and Biogas, face-online.org.uk. Retrieved 8.11.07.
[3] Fergusen, T, Mah. R. (2008) Methanogenic bacteria in Anaerobic digestion of biomass, p49
[4] Finstein M. S. (2006) ArrowBio process integrates preprocessing and advanced anaerobic digestion to recover recyclables and generate electricity, oaktech-environmental.com. Retrieved 19.08.07
[5] Gupta S. (2006). "Biogas comes in from the cold". New Scientist (London: Sunita Harrington): pp. 14. Retrieved 2011-02-11.
[6] Humanik, F. (2007) Anaerobic digestion of animal manure, epa.gov. Retrieved 17.08.07.
[7] Jewell. W, Cummings. R, Richards. B. (1993). "Methane fermentation of energy crops: Maximum conversion kinetics and in situ biogas purification". Biomass and Bioenergy 5 (3–4): 261–278. DOI:10.1016/0961-9534(93)90076-G. edit
[8] Lise .A, Jan .B, Jan .D, Raf .D, Principles and potential of anaerobic digestion of waste – activated sludge. Progress in energy and combustion science, 34 (2008) 755 – 781S
[9] Martin A.D, (2011) Understanding Anaerobic Digestion, Presentation to the Environmental Services Association, 16.10.07, esauk.org. Retrieved 22.10.11.
[10] Meisam T. S, Kenji S. Mohammed A. H, 2010. Importance of the methanogenic archaea populations in anaerobic wastewater treatments (Process Biochemistry- 45(8), pp: 1214-1225)
[11] Ochei .J, Kalhatkar D. Medical laboratory science theory and practice. (2007) p565
[12] Richard .B, Cummings .R, White .T, Jewell .W, (1991). "Methods for kinetic analysis of methane fermentation in high solids biomass digesters". Biomass and Bioenergy 1 (2): 65–26. DOI:10.1016/0961-9534(91)90028-B. edit
[13] Sleat .R, .Mah, R. (2006) Hydrolytic Bacteria in Anaerobic digestion of biomass, p15
[14] Song .Y.C, Kwon .S.J, Woo, J.H. (2004) Mesophilic and thermophilic temperature co-phase anaerobic digestion compared with single-stage mesophilic- and thermophilic digestion of sewage sludge, Water Res. 2004 Apr;38(7):1653–62
[15] http://www.biogas-energy.com/site/basics.html
[16] http://www.bios-bioenergy.at/en/electricity-from-biomass/biogas.html
[17] http://www.greenoptimistic.com/2008/02/06/biogas-production-principle/#.U-tVbUB30wY
[18] http://www.iisc.ernet.in/currsci/jul10/articles13.htm
[19] http://en.wikipedia.org/wiki/Biogas