

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⁾

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.

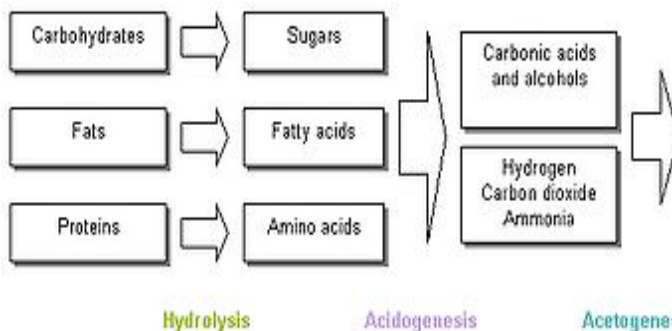


Figure 1: Biogas used as cooking gas

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 ₂ S)	0-3
Oxygen (O ₂)	0-2

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 17th 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⁾

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 (H₂S) serves as

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 cow 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. cow 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 (O₂) ⁽¹⁷⁾. The process occurs in four concurrent stages.

- i. Hydrolysis
- ii. Acidogenesis
- iii. Acetogenesis
- iv. Methanogenesis

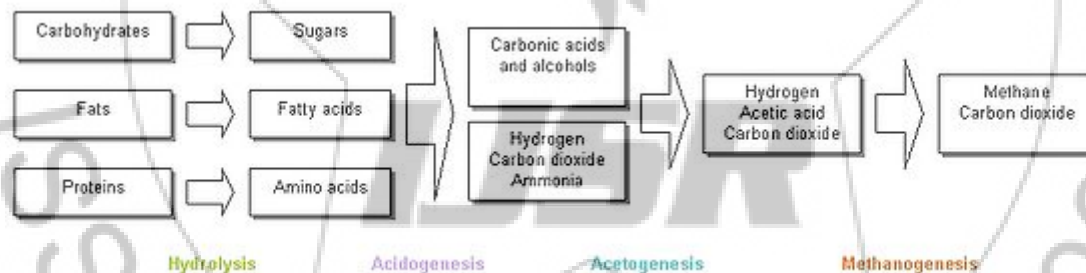


Figure 3: Summary of anaerobic digestion ⁽¹³⁾⁽¹⁶⁾⁽¹⁹⁾

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 sugars 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⁾.

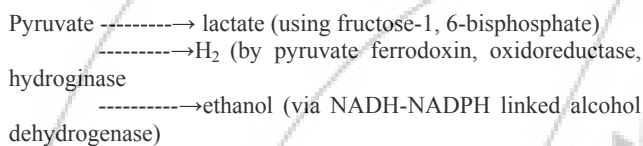
2.2 Acidogenesis

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 (NH₃)
- Carbon dioxide (CO₂)
- Hydrogen sulphite (H₂S)

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⁾.



In this stage, the products of hydrolysis are fermented to yield NH₃, VFA, CO₂ and H₂. Bacteria involved in acetate formation are;⁽¹⁵⁾⁽¹⁶⁾

- *Clostridium acetium*
- *Acetobacter woodii*
- *Clostridium termoautotrophicum*

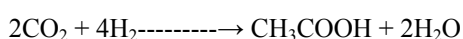
Winter Y. wolfe, in 1973 demonstrated that *acetobacter woodii* in syntrophic association with methanogens (*methanocercina* spp) produce methane and carbon dioxide from fructose instead of three molecules of acetic acids,⁽⁶⁾ while *Clostridium termoacetacum* and *Clostridium fermiacetacum* are able 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 produced by anaerobic bacteria (acetogens) from the acetogenic products (CO₂ and H₂). The acetogens act on the CO₂ and H₂ to produce in acidogenesis to produce acetic acid (CH₃COOH).

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 CO₂ to CO and the attachment of a methyl group (-CH₃) to the CO. The reduction of CO₂ 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⁾



The acetic acid (CH₃COOH) produced are then utilized by the methanogens for methane formation.

2.4 Methanogenesis

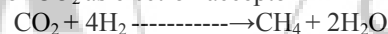
This is also known as biomethanation i.e. the formation of methane by microbes (methanogens) from O₂ and H₂ and or CH₃COOH. Methanogens are microbes capable of producing methane as a byproduct in the absence of oxygen (anaerobically). They belong to a domain known as archaea which were initially thought 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 berkeni* is an exceptional strain that possesses an enzyme superoxide dismutase which enables it to survive longer than others in the presence of oxygen.⁽⁴⁾⁽⁵⁾ Recently, some research suggested that leaf 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⁾.

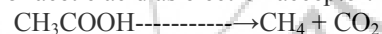
2.4.1 Biochemistry of methanogenesis

During methane formation, carbon is the terminal electron acceptor (instead of oxygen as in respiration) and it comes from organic compounds with small molecular weight. The two methanogenic pathways involve the use of CO₂ and CH₃COOH produced in the early stages.

a. Use of CO₂ as electron acceptor



b. Use of acetic acid as electron acceptor.



Basically the biochemistry of methanogenesis is very complex and involves the following coenzymes and factors; F₄₂₀, CO enzyme B, Coenzyme M, methanofuran and methanopterin⁽¹⁰⁾

3. Conclusion

The activities of enzymes and microorganisms in the biogas digester bring about biogas production. Identifying these enzymes and microorganisms 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 microorganism cultured for artificial use.

4. Recommendation

1. Further research should be carried out on the isolation of these enzymes and the culture of the microorganism 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.

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