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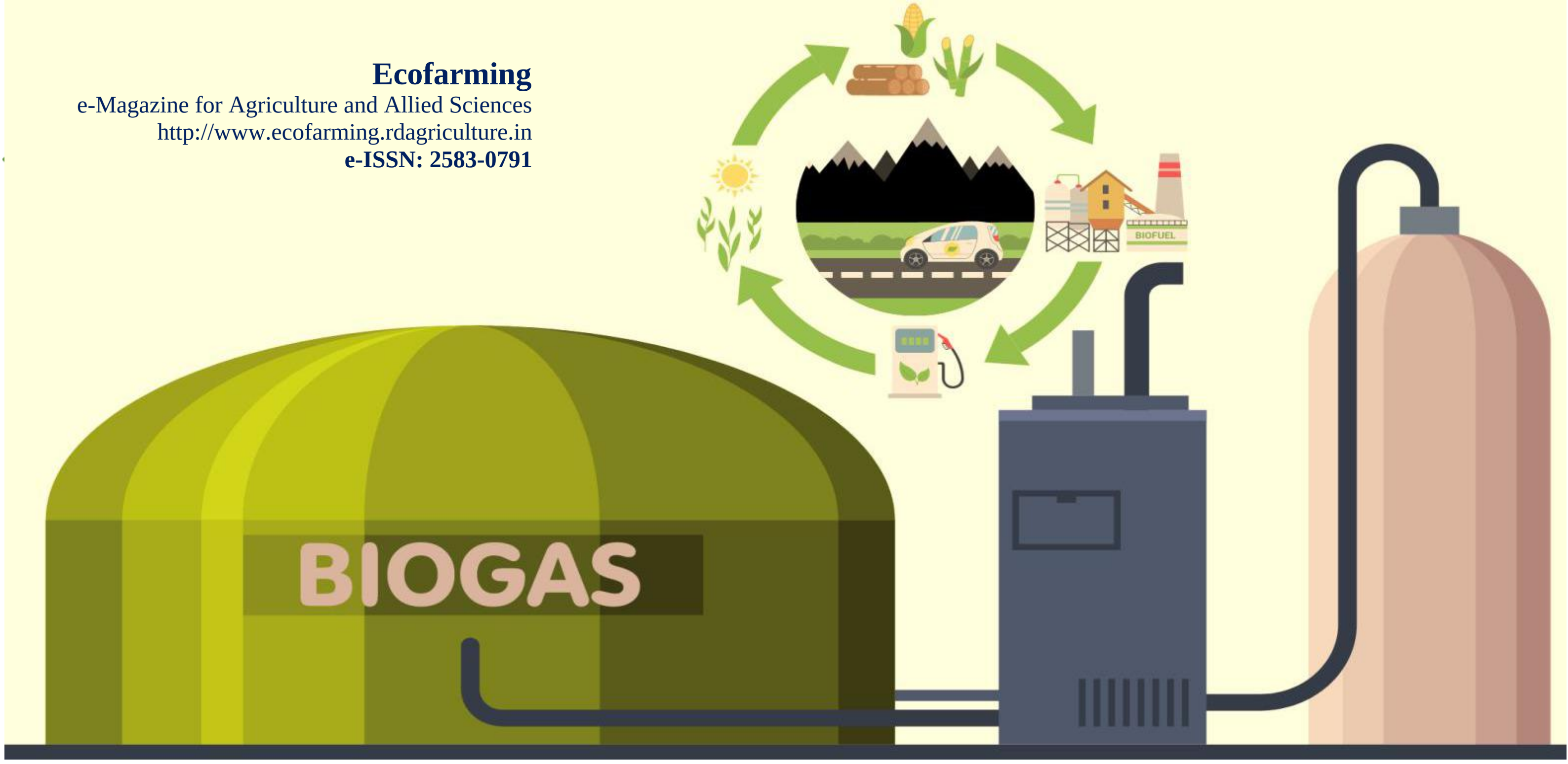

Biochemical changes during Biogas production

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Introduction to biogas

Biogas originates from biogenic material and is a type of biofuels, typically referred to a gas produced by bacteria fermentation of organic material under anaerobic condition. It can be produced from a wide variety of available organic materials and wastes, including sewage sludge, animal manure, and municipal organic waste. The materials like biodegradable waste, straw, manure, sugarcane and by-products from agricultural and industrial processes and specially grown energy crops can also be used for the production of energy. Anaerobic digestion is a simple technology widely used for processing the biodegradable, organic waste for the biogas production. Animal manure (cow dung) is used as inoculum, pre-treatment of substrate. The fermentation of organic waste involves biological and chemical and the process is equally beneficial in waste management. During the process, large organic polymers that make up biomass are broken down into smaller molecules by chemicals and microorganisms. Upon completion of the anaerobic digestion process, the biomass is converted into biogas (methane 55-65%, carbon dioxide 35-40% and traces of other contaminant gases like hydrogen sulphide, nitrogen and ammonia), as well as liquid digestate (nutrient rich fertilizer).

Biochemistry of Biogas production

Anaerobic digestion is a complex process that takes place in four biological and chemical stages namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. These stages are illustrated in Figure 1. The individual degradation steps are carried out by different consortia of microorganisms, which partly stand in syntrophic interrelation and place different requirements on the environment. Hydrolyzing and fermenting microorganisms are responsible for the initial attack on polymers and monomers and produce mainly acetate, hydrogen and varying amounts of volatile fatty acids such as propionate and butyrate. Hydrolytic microorganisms excrete hydrolytic enzymes, e.g., cellulase, cellobiase, xylanase, amylase, lipase, and protease. A complex consortium of microorganisms participates in the hydrolysis and fermentation of organic material.

Most of the bacteria are strict anaerobes such as Bacteriocides, Clostridia, and Bifidobacteria. Furthermore, some facultative anaerobes such as Enterobacteriaceae and Streptococci take part. The higher volatile fatty acids are converted into acetate and hydrogen by obligate hydrogen producing acetogenic bacteria. The accumulation of hydrogen can inhibit the metabolism of the acetogenic bacteria. The maintenance of an extremely low partial pressure of hydrogen is essential for the acetogenic and H_2-producing bacteria. Although many microbial details of metabolic networks in a methanogenic consortium are not clear, present knowledge suggests that hydrogen may be a limiting substrate for methanogens. At the end of the degradation chain, two groups of methanogenic bacteria produce methane from acetate or hydrogen and carbon dioxide. The four stages of anaerobic fermentation to accomplish the methane-production process are discussed below:

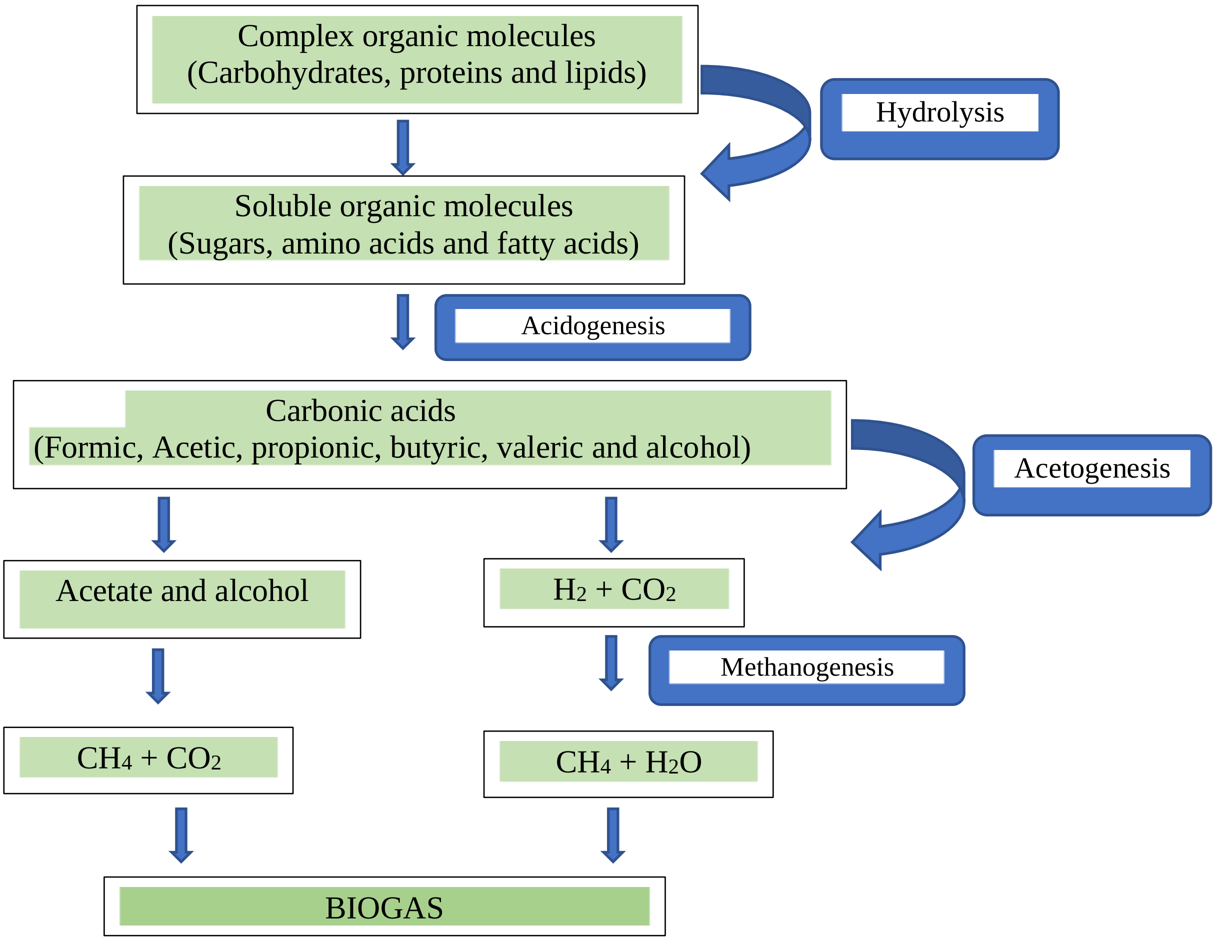

Figure 1. Biochemistry of biogas production

Hydrolysis

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 by proteases, lipase and amylase respectively. 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 so that they may be used to create methane.

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_2, CO_2, H_2S, shorter volatile fatty acids and organic acids, as well as trace amounts of other by-products. The principal acids produced are acetic acid, propionic acid, butyric acid etc.

Acetogenesis

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_2 and H_2. Acetogens break down the biomass to a point to which methanogens can utilize much of the remaining material to create methane.

Methanogenesis

Methanogenesis constitutes the final stage of anaerobic digestion in which methanogens create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis. 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:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2H_2O$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$

While CO_2 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_2, the two main products of anaerobic digestion. Anaerobic digestion is most commonly used to convert organic material into biogas from high moisture content organic wastes like manure (animal and human) and crop residues. The average retention time for animal waste is 20–40 days and for organic waste it is 60–90 days. The resultant biogas contains 55 to 80% methane - depending upon waste type.

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