ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2,February 2018

# Factors affecting anaerobic digestion of organic waste

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***Abstract:*** **-- This paper gives us an idea of the parameters affecting the anaerobic digestion of food waste on the environment. This will implant seeds of enhanced perception on how biogas can be generated from an inevitable type of waste produced across all cities. Biomass includes organic as well as inorganic waste which may consist of leftovers, kitchen(cooking) waste ,cattle feed ,industrial waste, slaughterhouse waste, mediwaste etc. Due to the high organic content of food waste, and animal manure anaerobic digestion plays a key role as the micro-organisms act as a catalyst in breaking down the complex organic molecules into biodegradable components in the absence of oxygen. The gas is further processed to generate electricity and it is also used as transportation fuel. This paper summarizes all the important factors that are to be considered for the efficient digestion of the waste like the optimum PH range catalyst required and temperature. Important points like loading rate, retention time and also a composition of the waste material are also taken into consideration.**

**Index Terms - Anaerobic digestion (AD), Biogas, Methane, Organic waste**

## 1. INTRODUCTION

Biogas is a mixture of different gases formed by biological degradation of organic waste in the absence of oxygen. It is an ecofriendly fuel which can be used as automotive fuel and used for electricity generation. It protects the earth's natural resources and reduces the pollution rate by significantly lowering greenhouse effect and methane emissions [1]. Anaerobic digestion is regarded as one of the oldest and the most efficient techniques in waste management in the history of mankind. Rapid increase in the amount of wastes involves poor processing and its improper treatment leads to environmental crisis, acidification of oceans affecting marine life and also loss in biodiversity, thereby destroying the ecosystem. It also involves in the contamination of air and soil. Hence it affects human consumption as we depend on marine food like fishes, crabs, lobsters, prawns etc. Anaerobic digestion hence holds the key role in eliminating waste by biodegrading it in the presence of micro-organisms [2].


***Fig 1. Ecofriendly fuel***

***Tab 1. Composition of Biogas***

| Compound | Formula | Percentage (%) |
|---|---|---|
| Methane | $CH_4$ | 50-75 |
| Carbon dioxide | $CO_2$ | 25-50 |
| Nitrogen | $N_2$ | 0-10 |
| Hydrogen | $H_2$ | 0-1 |

Methane and Carbon dioxide plays a major role in causing global warming and more than 85% of waste contains only Methane and carbon dioxide. Methane and Carbon dioxide has the capability of absorbing the heat emitted from the sun and retains it for a longer period of time thereby increasing the surface temperature of the earth. Along with these gases Sulphur dioxide is also produced which should be filtered as it may cause some breathing problems [3].

## II. ANAEROBIC DIGESTION

Anaerobic digestion has contributed a lot in conservation of natural resources which cannot be replenished back. It involves a series of biological processes which takes place naturally when a bacterium breaks down the organic content in the absence of oxygen.

It is a process of microbial decomposition of the biodegradable substance into carbon dioxide – 25-50% and methane gas-50-75%. Decomposition of the organic content i.e. kitchen waste and biomass feed stock takes place in a digester known as anaerobic digester. A huge amount of methane gas is produced through anaerobic digestion of organic waste in the presence of catalyst inoculum and has a greater control over production [4]. Biological activities have been identified as main root for more than 70% of methane

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production in the atmosphere. AD is considered to take place in a series of three to four steps namely.

- Hydrolysis
- Acidogenesis (acid forming)
- Acetogenesis
- Methanogenesis


*Fig 2. Conversion of waste to electricity*

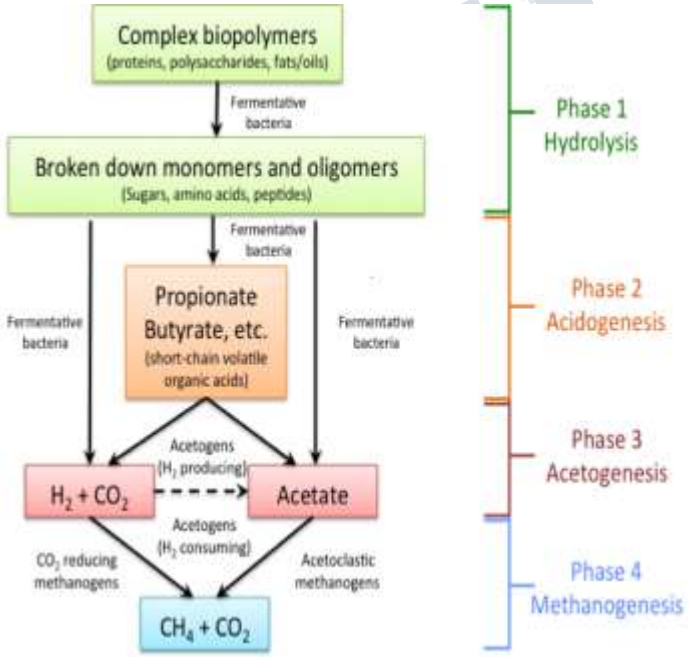


*Fig 3. Stages of Anaerobic digestion*

***1) Hydrolysis***

Hydrolysis is a process simply defined as reaction with water. It is a process in which complex organic molecules are broken down into their respective constituents i.e. soluble monomers. The chemical bonds of these complex organic molecules are weakened and broken by addition of water. It represents the unbinding of chemical bonds by water molecules [5]. When it is used to break down carbohydrates into its sugar components, hydrolysis is termed as saccharification. The reaction mainly takes place between an anion and cation proceeding with the alteration of pH and the formation of cleavage in H-O bond.

This particular reaction takes place with the help of promoters which are the enzymes excreted from fermentative bacteria. The reactions results in end products such as amino acids, soluble sugars and typically long chained carboxylic acids. Hydrolysis is also considered as a reversal of condensation reactions because condensation reactions involve joining of two molecules in order to form a larger molecule by eliminating a water molecule [6]. Whereas hydrolysis proceeds with the addition of a water molecule. Chemical formula for organic solid wastes is C4H10O4. So the hydrolysis reaction considering this fraction of municipal solid waste or organic waste is -

$$C_4H_{10}O_4 + 2O_2 \longrightarrow C_6H_{12}O_6 + 2H_2 \qquad -(1)$$

***2) Acid forming stage***

This stage is known as the acid forming stage which mainly comprises of two reactions facilitated by micro-organisms which help in converting the end products of hydrolysis into simple organic acid like acetic acid, butyric acid with ethanol, hydrogen and carbon dioxide. The two reactions involved here are fermentation reactions and acetogenesis reactions. Fermentation reaction takes place when the organic products of hydrolysis are converted into organic compounds mostly short fatty acid chains such as formic, butyric, propionic with alcohols and ethanol's. Firstly the conversion of glucose to ethanol takes place along with the conversion of glucose to propionate.

Acetogenesis is a process in which carbohydrate fermentation takes place and it leads to the formation of H2 compounds, acetate and CO2 that is further utilized by micro-organisms that produce methane [7]. These micro-organisms are methanogens which belong to the archaea class of domain. They generally dwell in wetlands, marsh gas and the inner lining of the digestive tracts of ruminants and human beings. The amount of hydrogen present during the acid forming stage is of utter importance and the reactions can only proceed if the hydrogen content is very low. It is important to know the thermodynamic feasibility of the reaction.

Reactions involved in the following stage are -
1) conversion of glucose to acetate
2) conversion of ethanol to acetate
3) conversion of propionate to acetate

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4) Conversion of bicarbonate to acetate

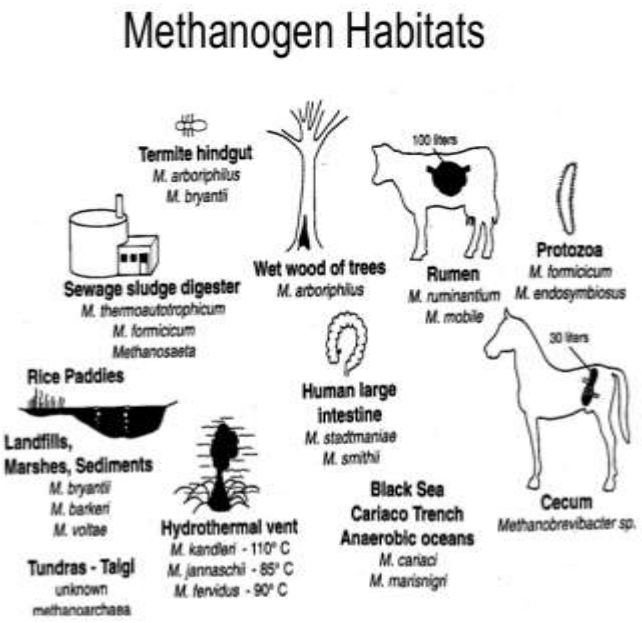


*Fig 4. Habitats of Methanogens*

***3) Methanogenesis***

Methanogenesis is the final stage of anaerobic digestion in which methane forming microorganisms utilizes the intermediate products of the previous stages and transforms them into methane, carbon dioxide and water. Two thirds of the total methane is formed by converting acetic acid or by agitation of alcohol formed in the preceding stage, such as methanol. The other one third of the methane produced is due to the reduction of the carbon dioxide by hydrogen. As the methane has the high potential of climate change the aim is to find an alternative in order to reduce the environmental traces of the organic waste treatment [8]. Therefore instead of methane the production of volatile fatty acids are more preferred.

Reactions involved during the following stage are-

$$2CH_3CH_2OH + CO_2 \longrightarrow 2CH_3COOH + CH_4 \text{ (conversion of acetate)} \quad -(2)$$

$$CH_3OH + H_2 \longrightarrow CH_4 + H_2O \text{ (conversion of methanol)} \quad -(3)$$

$$CO_2 + 4H_2 \longrightarrow CH_4 + H_2O \text{ (reduction of carbon dioxide by hydrogen)} \quad -(4)$$

## III. PARAMETERS AFFECTING ANAEROBIC DIGESTION (CONSIDERING FOOD WASTE)


*Fig 5. Summation of all parameters affecting AD*

***1) pH value range***

For anaerobic digestion to take place profoundly, pH value of the composition of food waste (taken into consideration) is of huge importance. It is a pivotal factor in the digestion. The modern world, post its urbanization has resulted in an excessive release of food waste which contains a large amount of organic matter which can be decomposed, hence leading to the harnessing of biogas from it.

The biogas generation is highly affected by the parameters like its pH value range, optimum operating temperature, retention time, loading capacity and the composition of the food waste used [9].

It has been experimentally proved that the biogas production yield and the degradation efficiency is said to be higher for the substrates having an optimum range value of pH7 comparing with other pH range values. The pH value plays an important part as the micro-organism i.e. the methanogens are highly sensitive to acidic environmental conditions. As an acidic environment inhibits their growth and methane production [1].

On the other hand increasing the pH value more than 7.5 and towards 8 can lead to proliferation of methanogens which inhibits acetogenesis process. In order to keep the pH value in an equilibrium condition, a certain amount of buffer solution is added to the system such as CaCo3 or lime. Although the optimum PH value should be maintained between 7.5 to 8, in order to obtain higher yield of biogas.

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***2) Operating temperature***

Operating temperature is a pivotal factor which determines the performances of the AD reactors because it is an important condition for the survival and optimum flourishing of the microbial association. Bacteria have two optimum ranges of temperature, termed as mesophilic and thermophilic temperature optimum [6-7]. Mesophilic digesters have a very good output efficiency while operated in the temperature range of 25-40 degree Celsius and thermophilic digesters have a range of 50-65 degree Celsius.

Thermophilic digesters permit higher loading rates and generate higher methane production, substrate decomposition and pathogen destruction. The higher temperature squeezes the required retention time by speeding up the reactions of degradation of organic material. The thermophilic anaerobic bacteria are easily influenced by toxins and small changes in environment and need some time to undergo redox population [5]. The systems are less suitable for commercial application because they need subsidiary energy input for self-heating purpose.

Mesophilic AD reactors employ powerful microbial consortia which have high tolerance towards environmental changes and have better stability and easy to maintain. These systems don't need any additional energy input for heating. But they have disadvantage of longer retention time and low rate of biogas formation. However, these are more suitable for commercial scale plants as they are easy to operate and maintain and have lower investment cost [3].

***3) Loading rate***

Loading rate is another essential parameter in the anaerobic digestion process. It is determined by the measure of the amount of volatile solids in a biological AD system which can be feasible as an input in the system. The loading rate of a system should never be high as it may result in a low or average biogas production. The overloading of a system usually happens due to the presence of degrading or inhibiting substances in the system such as insoluble fatty acids which can cause hindrances in the path of biogas production [9].

High loading in simple words causes increase in the amount of acidogenic bacteria which stimulates PH fall and hence results in the elimination of methanogenic bacteria or methane producing micro-organisms hence causing the system to crash.

***4) Retention time***

Retention time or "residence time" in the AD systems is the amount of time a feedstock resides in an anaerobic digester. It is calculated in terms of no. of days (n) as in the case of the following equation.

n (No. Of days) = Operating volume V / Flow rate Q -(5)

It is the average time required for the organic material residing in a digester to decompose considering the COD or chemical oxygen demand of the influent or the particles residing in and also the BOD or biological oxygen demand of the liquid waste materials. The longer is the retention time period, the better is the degradation of the organic matter [6]. Retention time also depends on the operating temperature and content of the solid waste material of an AD system. The retention time for dry systems or highly solid wastes are usually more than that of wet system or liquid type waste.

The residence time for a digester is designed in a way keeping in mind the microbial communities present in the digester that operate at different rates and at different times.

***5) Composition of the food waste***

This is another parameter considering the content of the food waste or its composition which may affect the anaerobic digestion in a different way. The content of the organic material generally depends on the time of year, cultural habitat, environmental conditions, abiotic and biotic factors and also the region [2]. It is important to know the composition in order to predict the course and rate of the reaction also keeping in mind the amount of biogas yielded.

The rate of methane production or the bio-methanization potential is dependent upon four major concentrations which are- lipids, proteins, carbohydrates and cellulose. The AD systems having high lipids content usually have high bio-methanization efficiency but due to its complex structure, it requires a high retention time period. The retention time period is the least in the case of proteins followed by carbohydrates and cellulose [8]. However systems having an excess of proteins or lipids content may have inhibitory factors due to the accumulation of ammonium and nitrogen respectively which greatly affects the bio-methanization yield.

## IV. CONCLUSION:

The conversion of biomass into biogas can have many advantages to the ecosystem and to the existing life. Conversion has led to the decrease of greenhouse gases and also helps in the reduction of soil, water and air pollution. It was rightly said by Arnold Schwarzenegger that "The future is green energy, sustainability and renewable energy. To make life possible without a hitch, alternative sources of energy should be used.

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