FACTORS AFFECTING BIOGAS PRODUCTION DURING ANAEROBIC DIGESTION – A REVIEW

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Abstract: Biogas is a combination of different gases that is an outcome of anaerobic (absence of air) digestion. It consists mainly methane (CH_4) and carbon dioxide (CO_2) which are the main greenhouse gases. The substrate for anaerobic digester is a different kind of organic waste means it reduces a load of disposal of organic load of wastes due to the uncontrolled open dumping of organic discarded waste. There are dissimilar diseases and very bad odours during the decay of waste. There are different factors those disturb the yield of biogas by anaerobic digestion. This paper analyses different factors those affect the biogas output rate including the usage of additives, recycling of slurry and slurry filter, temperature, hydraulic retention time, particle size, C/N ratio, ph. value, dilution and consistency input, loading rate, toxicology, agitation and different pre-treatment methods and the effect of the thermal pre-treatment by using oven will be discussed.

***IndexTerms* - Anaerobic digestion, HRT (hydraulic retention time), agitation, pre-treatment techniques, C/N ratio.**

I. INTRODUCTION

There are two forms of energy sources in the world renewable (solar, hydro, biogas etc.) and non-renewable (fossil fuel, coal, oil) utmost of the world population is reliant on non-renewable energy. Non-renewable energy is limited in quantity and during combustion, it releases a diverse kind of pollutant to our nature like $CO_{2,}$ CO, $NO_{X,}$ SO_X and particulate matter our dependency on non-renewable energy sources hike the expense of coal and fossil fuels so researchers are shifting their interest toward sustainable and green technology like biogas that reduces pollutant and greenhouse gas load [1]. Biogas is a green sustainable and clean energy source because the feedstock for biogas is different kind of organic wastes those are a threat to our environment in terms of uncontrolled open dumping so organic waste treatment is necessary. Biogas is the result of an AD that produces different gases collectively known as biogas like methane, carbon dioxide as the main product and other gases with small quantity like water vapour, ammonia, hydrogen sulphide, hydrogen, nitrogen [2]. A biogas digester works by the decomposition of microorganism or inoculum in the absence of oxygen [3]. After anaerobic digestion the product is gas and it will give energy when it will oxidize with oxygen. It can be used in a different way (gas, fuel, electricity) and for a different purpose (heating, cooking etc.). The UK is having the capacity to replace it's 17% of the vehicle with biogas (state energy conservation office, Taxes 2009) [4]. The slurry of digester can be used as organic fertilizer [5]. Methane content decides the biogas quality .Anaerobic digestion also occurs in the bottom of pond naturally [6]. Biogas is having the capacity to overcome the energy problem in spite of several advantages it is hard to maintain the potential of biogas because there are several factors those affect the production or potential of gas such as temperature, ph., loading rate, toxicity, H.R.T, C/N ratio, agitation, additives etc., This paper reviews the different factors those affect the yield of biogas in the few decades.

II. Different stages in the organic waste anaerobic degradation process

For the treatment of dissimilar kind of organic wastes like industrial, municipal, agricultural, institutional wastes anaerobic digestion (AD) is being used world-wide, under anaerobic condition microbes degrade and stabilize an organic matter and form methane [8]. A study by the Food and Agriculture Organization (FAO) of the United Nations that shows the contrast of fossil fuels shows below in table 1 below [9].

TABLE I

Comparison of gaseous emissions from heavy vehicles [9]

g/kg	CO	HC	NO	CO_2	Particulates
Diesel	0.20	0.40	9.73	1053	0.100
Natural Gas	0.40	0.60	1.10	524	0.022
Biogas	0.08	0.35	5.44	223	0.015

Anaerobic degradation is a procedure which contains different degradation stages such as hydrolysis, acedogenesis, and acetogenesis, methanogenesis which produces methane (CH_4) and carbon dioxide (CO_2) as the main product of degradation process [10]

Hydrolysis

Hydrolysis is a procedure in which polymerized organic compounds such as carbohydrate, lipid, fat, proteins which are not easily soluble this process convert complex insoluble polymers to soluble monomers and dimers which is amino acids, monosaccharaide and fatty acids. Different microbes play their role in hydrolysis [9-12].

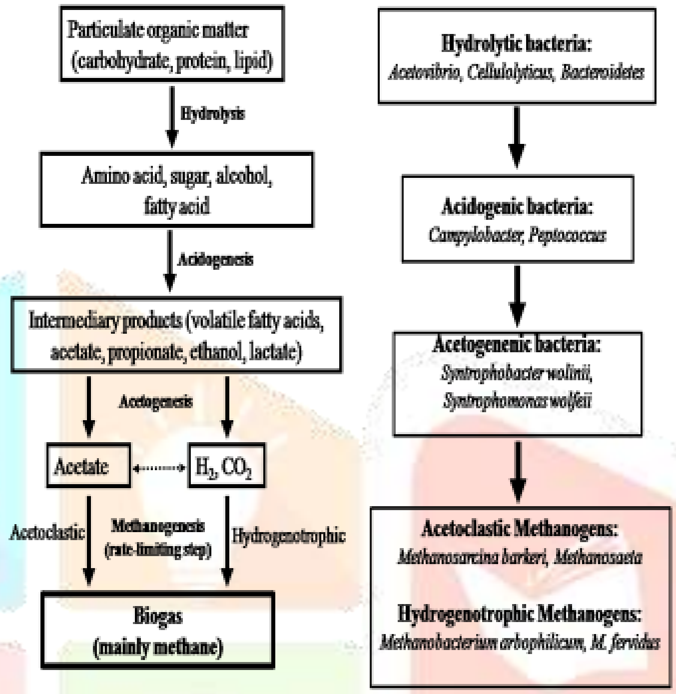

Fig. 1 Carbon flow inside the anaerobic digester and bacteria involved in different phases of anaerobic digestion

Acedogenesis

The acetogenenic bacteria which is present in this stage can be facultative (Aerobic and anaerobic bacteria) and the bacteria which was present during hydrolysis phase can also be present during the acidogenesis stage. Acedogenic bacteria convert hydrolysis products to volatile fatty acids, acetate, ethanol, lactate and propionate [12].

Acetogenesis

In this phase, the acetogenenic bacteria (syntrophobacter walinii, syntrophobacter wolfeii) change the acid phase product in to acetates and hydrogen (H_2) which will use by methanogenic bacteria [10].

Methanogenesis

In this phase, there are two kinds of methanogenic bacteria such as acetoclastimethanogen (methanosarcina Barkeri, methanobacterium arbophilicum, m.fervidus) and hydrogenotropic methanogens (methanobacterium, arbophilum, m.fervidus) which convert acetate hydrogen carbon dioxide to biogas (main methane) [9].

III. Factors affecting biogas production yield

These are the factors which affect the biogas production yield

- Temperature
- C/N ratio
- PH
- Organic loading rate
- Additives use

- Volatile fatty acid
- Hydraulic retention time,
- particle size
- Agitation
- Toxicity
- Working pressure in the fermenter
- Pre-treatment techniques
    i. Mechanical pre-treatment
    ii. Thermal pre-treatment
    iii. Chemical pre-treatment
    iv. Biological pre-treatment
    v. Combination of various pre-treatment

Temperature

Temperature is a very important factor that affects the biogas production. There are Varying temperature ranges at which different type of bacteria work such as Cryophilic (ranges from 12 - 24), Mesophilic (ranges from (22-40) and Mesophilic (ranges from 50-60) [6].

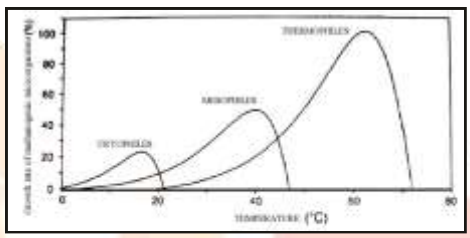

Figure 2. The growth rates of methanogenic Micro-organisms for the three temperature regimes [6].

A researcher found in his study that methanogenic bacteria are very delicate to a sudden change in temperature [7].

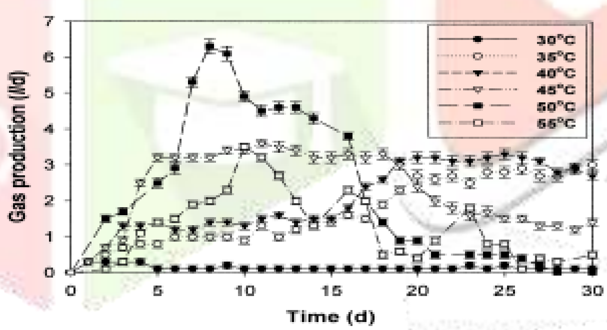

FIG. 3. Biogas production profiles at

Different temperatures through batch reaction [13].

This figure shows gas production with different temperature, in this study gas production increased at 45 and 50 so it indicates that during digestion mesophilic bacteria were active [13].

C/N Ratio

The C/N proportion is the relationship of carbon (C) and nitrogen (N) present in the digestion tank from organic material. Carbon and nitrogen is nutrient for microorganism they can grow due to Carbon and Nitrogen [3]. It has been found in many studies that during digestion bacteria use carbon 25-30 times faster than nitrogen [2]. Thus to complete this requirement microbes require 20-30:1 proportion of carbon to nitrogen [7]. The amount of volatile fatty acids (VFAs) and total ammonia nitrogen (TAN) could hinder methanogenesis and gathering of these two can be responsible for the total failure of AD process [14].

pH

pH is well-defined as –log [h+]. It decides whether feedstock is neutral, acid or alkaline if the reading of ph. the scale is 7 then the feedstock is neutral, > 7 than acid and < 7 means alkaline. The previous study shows that throughout fermentation microorganism require alkaline environment [3]. Different AD stages require different ph by microbes, methanogenic archea need pH interval (5.5-8.5) and its optimal range is (6.5-8.0) in diversified culture digester optimal ph. range is (6.6-7.8) [2].

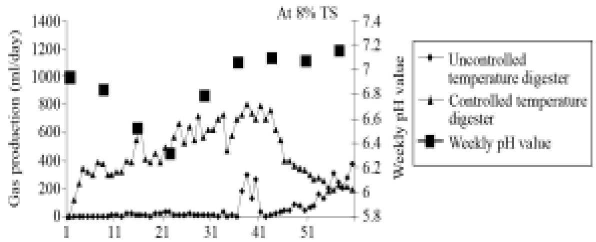

Fig. 4. Effect of pH value on biogas production [3]

The drastic change in pH happens due to rapid acidification of anion storage waste [7]. A study was done at varying pH. 5,6,7,8 and 9 for 30 days at mesophilic temperature shows that biogas yield was at pH. 7 and minimum at ph. 5 [14].

Organic loading rate

Organic loading rate is defined as the amount of raw materials fed per day per unit volume of digester loading [3]. Organic loading rate is a kind of food for micro-organism when they break the bond of organic waste, produce gas (methane and carbon dioxide mainly) so more organic loading rate produce more gases. A study in Pennsylvania shows that variation in organic loading rate from 346 kg VS/day to 1030VS/day due to this change gas yield improved from 67 to 202 m3/day [2]. Another study shows in the event that the digester is overloaded then acid will accumulate and methane production will be inhibited [3].

Additives use

Additives are the thing that increases the biogas creation rate that can be either biological or chemical additives [2]. A study shows that by adding 5% of commercial charcoal with cattle dung on a dry weight basis it increases the yield by 17 and 35% in batch [3].

Volatile fatty acids

Acidogenic and acetogenic bacteria is responsible for the formation of volatile fatty acids because acidogenic bacteria converts amino acids sugar and fatty acids to alcohol, ketones, acetates, hydrogen (H_2), and carbon dioxide (CO_2) [16]. The amount of VFA works as an indicator for the digester if VFA is in the high amount it will inhibit the AD process [2].

Hydraulic retention time

HRT is characterised as the time spent inside the digester till it comes out [2]. HRT varies between 20 to 120 based upon the climate condition of location. Countries of the tropical region such as India HRT is considered as 40 to 60 days [3]. It is the measurement of COD and BOD of interfluent and effluent material. The optimal retention time for thermophile is 12-24 days and for mesophyll is 15-30 days [17]. HRT is the volume of the aeration tank divided by influent tank [18].

Particle size

Particle size refers to the size of feedstock of digestion tank, if the size of feedstock will be larger than it can clog the tank and it would be difficult for microorganism to carry out degradation because surface area will be small if the size will be small than surface area will be more for adsorbing the substrate [2]. It increases surface area that enhances the microbial decomposition [17].

Agitation

Agitation is a technique in which stirring of feedstock with different mixing ways increase contact between microorganism and substrate which result in improved digestion process [2]. A fomentation is finished by mechanical stirrers, gas distribution relying on the aggregate strong focus inside the digester amid blending moderate blending is favoured in light of the fact that unnecessary blending can disturb organisms

Toxicity

There is some toxic material that prevents the development of microbes such as mineral ions (sodium, potassium, magnesium, and sulphur), detergents (soap, antibiotics, organic solvents) and heavy metals (copper, nickel, chromium, zinc, lead). Lesser amount of mineral ion increase the gas production yield like when ammonia (NH_4) concentration is present from 50 to 200 mg/l, it enhances the growth of microbes where as its concentration above 1500mg/l produces toxicity likewise heavy metals like copper, nickel, zinc, lead, chromium, etc. in small quantity are beneficial but higher concentration inhibits the microbial growth [3]. A study shows that the very small quantity of certain element copper, nickel, manganese and iron are found to increase biogas production [19].

Working pressure in the fermenter

A researcher has found that low pressure in digestion tank is suitable for the gas formation and vice versa. In this study cattle, manure and unfiltered whey have been used at a mesophilic temperature range (39+- 0.5) for pressure set at 0, 2, 4, and 6 bar based on the recorded chromatograms. The values of methane content after the experiment has been shown in Table 2 [20].

Table 2. Amount of methane in biogas for various conditioning pressure [20]

Date	**Methane content in biogas, [volume %]**			
	0 bar	**2 bar**	**4 bar**	**6 bar**
26.07.2012	72.91	7.66	3.80	2.85
31.07.2012	90.89	10.55	4.01	3.08
06.08.2012	71.82	11.89	4.49	2.96
11.08.2012	78.58	14.42	4.50	3.35
17.08.2012	71.69	14.76	5.06	3.38
23.08.2012	69.75	16.13	5.12	3.71
28.08.2012	69.81	16.97	5.44	3.94
03.09.2012	83.55	21.59	7.04	4.31
08.09.2012	96.35	47.50	17.91	10.66
14.09.2012	90.00	43.66	18.73	14.70
20.09.2012	86.33	46.88	21.58	13.79

Various pre-treatment techniques

Pre-treatment techniques are very hot topic now a days among researcher. These techniques have been used for organic waste treatment there are dissimilar kind of pre-treatment techniques like mechanical pre-treatment (In mechanical pre-treatment reduction of organic solid waste is done to increase surface area that provide batter contact between substrate and microorganism by using different mechanical pre-treatment techniques like sonication, lysis-centrifuge, high pressure homogenizer, maceration, and liquefaction), thermal pre-treatment (thermal pre-treatment is a type of pre-treatment technique in which heat is given to the substrate by using steam, microwave, electric and hot air heating. This method is a most successful method at industry level), chemical pre-treatment technique (In chemical pre-treatment degradation of organic waste is done by using strong acids, alkalis or oxidants. Oxidation method such as ozonation is used to increase anaerobic digestion process), biological pre-treatment (biological pre-treatment is used to enhance the anaerobic digestion rate by using both anaerobic and aerobic methods as well as the addition of specific enzymes such as pesticides, lipids and carbohydrates to the AD), combination of various pre-treatment (this technique is a combination of two or more than two pre-treatment techniques like thermo-chemical techniques, thermo mechanical techniques, various pre-treatment combined with AD) [21].

IV. Conclusion

Biogas is a green and clean energy it consists methane that decides the quality of biogas production. There are different factors that affect in a different way during the production of biogas, it is necessary to maintain all the factors otherwise they can cause a problem. These factors are like temperature, C/N ratio, ph., organic loading rate, additive use, volatile fatty acids, operational parameters like hydraulic retention time, particle size, agitating, toxicity, working pressure in the fermenter and different pre-treatment techniques. The detail about the limit of all the factors is in the description.

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