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REVIEW ON FACTORS AFFECTING BIOGAS PRODUCTION

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Abstract: This paper focuses on the production of biogas and the factors influencing the production of biogas. A detailed analysis of the factors which affect the biogas production are discussed in detail. As fossil fuels are getting depleted and environmental concern is increasing, renewable energy is becoming a very important engineering sector. Biomass, a renewable energy source, is indirect form of solar energy. Plants does photosynthesis and store light energy as chemical energy. Anaerobic digestion of biomass produces biogas. Biogas is found to one of the effective alternative source of energy for lighting, transport, and cooking.
Keywords: Biomass, Biogas, Renewable energy, Anaerobic Digestion

I. INTRODUCTION

Energy is an essential input for social development, human welfare, economic growth and improving the quality of life. Every sector of human society like industry, agriculture, transport, domestic and commercial needs requires energy. As a result, consumption of energy has been steadily rising all over the world. This growing consumption of energy resulted in increased dependence on fossil fuels such as oil, coal and natural gas. Increase use of fossil fuels cause environmental problems both locally and globally. It is common knowledge that the world's main energy resources will be depleted within next few decades. The world has been unavoidably facing environmental degradation as a direct result of urbanization, growth in population and industrialization as they increased the use of fossil fuels to fulfill the energy needs. Consequently, alternatives, particularly renewable energy options, have been explored and discovered to potentially meet the energy demands, reducing the usage of fossil fuels and to improve the environmental sustainability. Renewable energy sources include wind energy, hydro energy, solar energy, geothermal energy and biomass [2].

Total renewable energy capacity was 921GW worldwide. Bio power has increased from 0.8% to 2.0% of the renewable energy share of global electricity production from 2015 to 2016. In India, total installed capacity of biomass power includes biomass and gasification and bagasse cogeneration was 7856.94MW at present. And India has set a target of 10000MW by the year 2022 as a part of its renewable energy mission. Waste to power contribution is 114.08MW. Energy generation biogas is classified as first generation and second generation fuels. The specialized energy crops were utilized as a source in the first generation. Residues of agroindustries and municipal waste have been utilized in the second generation biomass energy. Compared to other forms of renewable energy sources biogas can be stored and transported. The energy can also be converted into other forms such as solid, liquid or gaseous fuel. The advantage of second generation biomass over the first generation is that it reduces the problems associated with management of waste residues and the amount of energy source utilized for the generation of biogas is also reduced.

Biogas is generated by anaerobic digestion process of organic waste. The animal waste, agricultural waste and the industrial waste are some of the most commonly used sources. The production of biogas is influenced by many parameters mainly temperature, pH, organic loading rate, hydraulic retention time, stirring and C/N ratio. This paper presents the effect of variation of the above mentioned factors in the efficiency of generation of biogas.

II. BIOMASS

A. A promising energy source

Biomass is solar energy is stored in the form of chemical energy. From a legal standpoint, biomass is "the biodegradable fraction of municipal and industrial waste, as well as the biodegradable fraction of residues, products and waste from biological origin, from agriculture (including animal and vegetable substances), forestry and related industries including aquaculture and fisheries". Biomass is organic matter derived from living or recently living organisms. It most often refers to plants or plant-based materials which are not used for feed or food, and are specifically called lignocellulosic biomass. Biomass is a form of renewable source of energy.

It is considered as indirect form of solar energy as plants use it for photosynthesis. As an energy source, biomass can either be used directly (combustion to produce heat) or indirectly (converting it to various forms like liquid fuels like ethanol and methanol). These liquid fuels are used in engines. Biomass includes wood waste and bagasse, which have substantial electric power. It is not economical to transport them over long distances. Hence, conversion of biomass to usable energy hence should take place near to source [2].

B. Anaerobic Digestion

Anaerobic Digestion (AD) is the process of conversion of complex organic matter (biomass) into biogas, in the absence of oxygen, into biogas. Biogas mainly contains methane, carbon dioxide, small traces of hydrogen sulphide and moisture It also contains gases like oxygen, nitrogen, ammonia and hydrogen. The four main stages in AD are hydrolysis, acidogenesis, acetogenesis, and methanogenesis [1,7].

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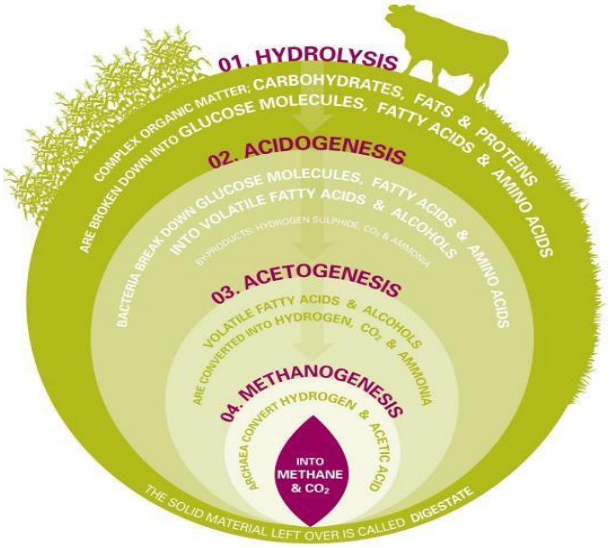

Fig.1 Various steps in AD process[1]

Hydrolysis is the first step in anaerobic digestion process, it involves the enzyme-mediated transformation of insoluble organic materials and higher molecular mass compounds into soluble organic materials i.e. to compounds suitable for the use as source of energy. This step is carried out by strict anaerobes such as bacterides, clostridia and facultative bacteria. This first stage is very important because large organic molecules are simply too large to be directly absorbed and used by microorganisms as a substrate/food source. The bacteria involved are Cellulomonas, Eubacteria, Clostridium, Ruminococcus.

Lipids ⟶ Methane+ Fatty acids, glycerol
Proteins ⟶ Amino acids
Polysaccharide ⟶ Monosaccharide

During acidogenesis single sugar molecules, fatty acids and amino acids are further broken down into alcohols and volatile fatty acids(VFAs) like ethanol and propionic acid with carbon dioxide, ammonia and hydrogen sulphide as by products. Third stage is acetogenesis in which VFAs and alcohols are converted into carbon dioxide, hydrogen and acetic acid. The terminal stage of anaerobic digestion is methanogenesis. The bacteria involved are Methano bacterium, Methanococcus, Methanosarcina. The following equations take place.

Acetic acid ⟶ Methane+ Carbondioxide
Hydrogen + Carbondioxide ⟶ Methane + Water

III. FACTORS AFFECTING BIOGAS PRODUCTION

The efficiency of AD is influenced by some critical parameters, thus it is crucial that appropriate conditions for anaerobic microoraganisms are provided. The growth and activity of anaerobic microoraganisms is significantly influenced by conditions such as exclusion of oxygen, constant temperature, pH value, nutrient supply, stirring intensity as well as presence and amount of inhibitors. The methane bacteria are fastidious anaerobes, so that the presence of oxygen into digestion process must be strictly avoided.

Factors which affect the production of biogas are [4]:

a) Temperature
b) Organic Loading Rate
c) pH Value or Hydrogen Ion Concentration
d) Hydraulic Retention Time
e) Stirring or Agitation of the Content of Digester
f) C/N ratio

A. Temperature

Internal temperature of the digester greatly affects the production of biogas. The microorganisms participating in the process of anaerobic digestion, are divided into three large categories[5]:

Psychrophiles (Less than 15^oC)

Mesophils ($15^oC – 45^oC$)

Thermophiles ($45^oC – 65^oC$)

Anaerobes are most active in mesophilic and thermophilic temperature range and hence commonly used temperatures during AD of organic wastes[6, 7].

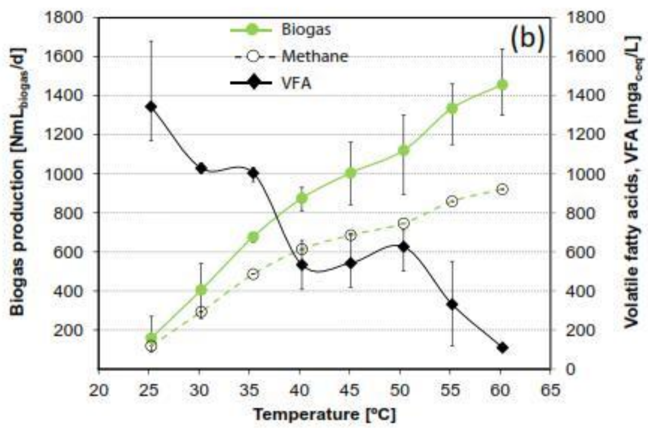

Fig 2. Variation of Biogas production with temperature[9]

From fig. 2 it is evident that biogas production increases with increase in temperature[9, 10].

B. Organic Loading Rate(OLR)

Biogas production is highly influenced by organic loading rate. It indicates the amount of waste that needs to be fed daily. The actual loading rate depends on the types of wastes fed into the digester. The under loading and overloading reduces the biogas production[18]. If OLR is increased, metabolic activity of microorganisms will be high and hence improve biogas yield. A very high value of OLR causes VFA accumulation and accumulation of fine particles which causes membrane fouling and decreased biogas production[1]. Recycling of digested slurry will help underfed digesters to an extend[13].

C. pH

pH is one of the main operational factors that affect digestion process. During AD, there are various micro organisms that require different optimal pH value. It depends upon the temperature maintained inside the digester[9]. Fig.4 shows the variation of pH with respect to temperature.

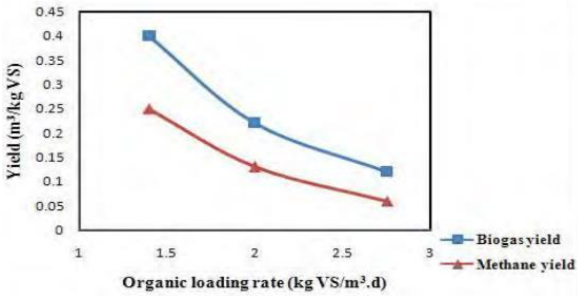

Fig. 3 Variation of Biogas production with OLR[18]

The amount of VFA and carbon dioxide produced as a result of AD affects the pH inside the digester[12]. Fig.5 shows the variation of biogas production with adjustment of pH and without adjustment of pH. Compared to without adjustment of pH, biogas production improved by nearly 67% when pH was adjusted[11].

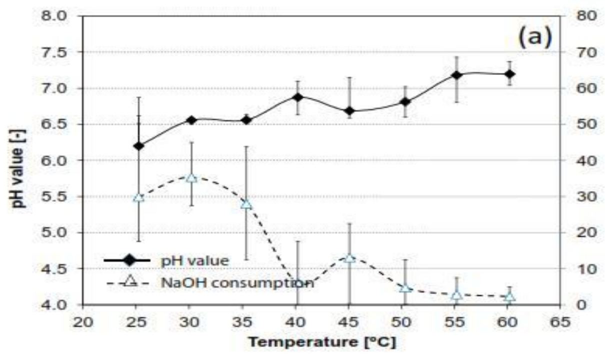

Fig. 4 Variation of pH with temperature[9]

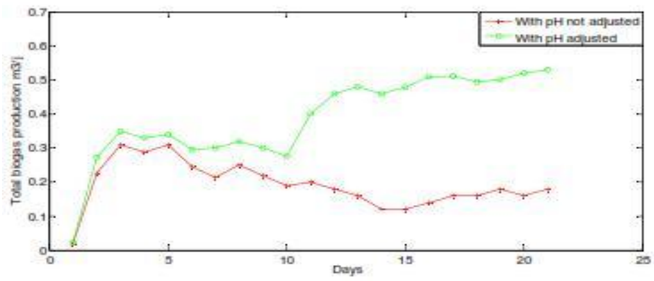

Fig. 5 Variation of Biogas production with pH adjusted and pH not adjusted[11].

The optimal value of pH which maximizes biogas production lies in the range 6.5 to 7.2[7, 11]. Fig. 6 shows variation of biogas production at different pH values from which it can be concluded that neutral pH is the optimized pH value.

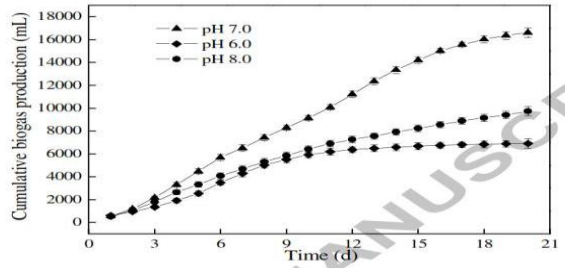

Fig. 6 Variation of Biogas production at different pH values[13]

D. Hydraulic Retention Time(HRT)

HRT indicates the time period for which the fermentable material remain inside the digester. Longer HRT will require large digester volume which increases capital cost. Short HRT will wash away active bacterial population[13]. Maximum methane production occurs at optimal value of HRT. The under loading and overloading reduces the biogas production[6]. If retention period is less than the optimal value, VFA will accumulate which will cause server fouling and result in reduced biogas production. And if retention period is above optimal value, biogas component will not be utilized effectively and hence biogas production will be reduced[1].

Fig. 7 shows the variation of biogas production with increasing hydraulic retention time.

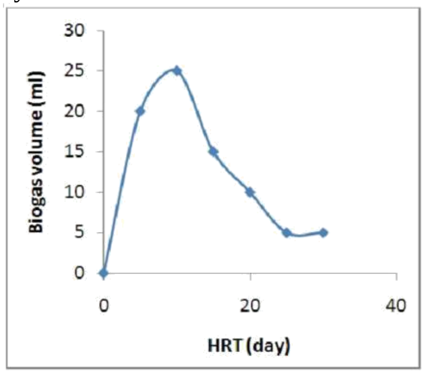

Fig. 7 Variation of Biogas Production with Retention Period[17]

E. Stirring

Stirring or agitation is done to make sure that the contact between substrate and microorganisms are intimate and hence result in enhanced degradation rate of substrate[12]. It is not essential but always advantageous. If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of biogas[14]. Fig 8 shows the variation in biogas production with and without agitation. Biogas production enhanced by about 62% compared to the gas production without agitation[11].

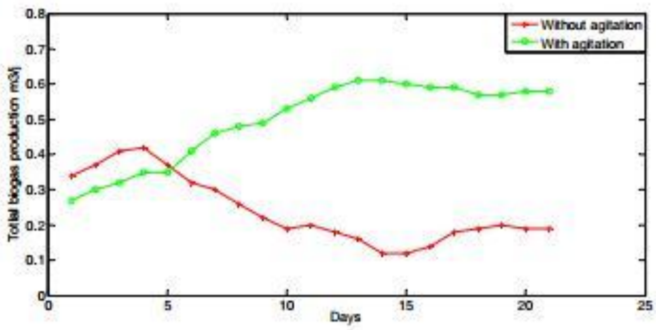

Fig. 8 Production of Biogas as a function of time and mode of Agitation[11]

F. C/N Ratio

Relationship between carbon and nitrogen present in organic materials is expressed as C/N ratio. Benefits of nitrogen present in feedstock are : (a) it is an essential element for synthesis of amino acids and proteins ; (b) it will be converted to ammonia which helps to maintain favorable pH conditions for microorganisms[19]. Too much nitrogen will cause toxic effect and too little nitrogen cause nutrient limitation[24]. The optimum value of C/N ratio lies between 20 and 30[9,20]. C/N ratio varies depending on the type of substrate, trace elements and biodegradability. Table 1 shows the C/N values of different substrates[23].

Table I: Various substrates and their C/N ratio[8,23]

Substrate	C/N Ratio
Cow dung	16-25
Poultry manure	5-15
Pig manure	6-14
Kitchen waste	25-29
Fruits and vegetable waste	7-35
Food waste	3-17
Mixed food waste	15-32
Rice straw	51-67
Potatoes	35-60
Fallen leaves	50-53
Wheat straw	50-150

If it is above or below optimum value it affects system stability and results in reduced biogas production[21]. Fig 9 shows the variation of Biogas production with C/N ratio. From the graph we can infer 25 is the optimum value.

IV. CONCLUSION

Biogas is renewable energy which is obtained by the anaerobic digestion of organic waste. It can replace fossil fuels and thereby reduce emission of GHGs and other harmful gases.

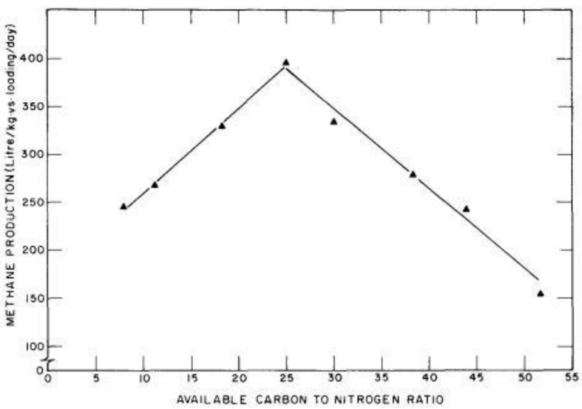

Fig. 9 Variation of Methane production at different C/N ratios[22]

Efficiency of AD is determined by the bacterial activity which is influenced by several factors like temperature, pH, OLR, HRT, stirring, C/N ratio. These factors need to be regulated so that the biogas plant operate efficiently. The byproduct of AD can be used fertilizer

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