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Effect of process parameters on production of biogas from food waste

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ABSTRACT

In the world filled with exhausting fuels, biogas production could be a key technology within the development of sustainable energy supply systems that aims to cover the energy demand using renewable sources and to mitigate greenhouse gas emissions. Biogas production can be achieved through anaerobic digestion (AD), a biological process. Anaerobic digestion is taken into account to be a useful tool that can generate renewable energy and significant research interest. As this renewable biofuel can play an important role in decreasing the concerns related to rapid increase in energy demands and also the greenhouse emission emissions. A unique advantage of this renewable energy production is it uses anaerobic digestion of various organic wastes including food waste. Food wastes have a high potential for biomethane production because it has high organic matter contents. This work intends to present an overview on the effect of process parameters in an anaerobic digester for biogas production. This study is to make an organic processing facility to form biogas which can be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide and methane emissions and also, the parameters which effects or influences this process.

Keywords: *Biogas, Food Waste, Anaerobic Digestion*

1. INTRODUCTION

The majority of the planet is using non-renewable fuels which additionally emit harmful gases into the atmosphere and also tending to get exhausted. So as to scale back their use, another alternative which may be renewed easily which shouldn't have any adverse effect on the environment. Energy and resource shortage is one among the foremost significant problems faced by the globe nowadays. The rising price of petroleum products and increasing attention regarding environmental impacts along with the fuel depletion have prompted considerable research to spot renewable and alternative fuel sources [1,2]. After many studies biogas came into the picture which is typically produced from the breakdown of organic matter in the absence of oxygen. And it is also observed that biogas is eco-friendly, its production reduces the soil and water pollution, and also it is a simple and low-cost technology [3]. Biogas is a mixture of different gases, i.e., primarily methane (CH_4) and carbon dioxide (CO_2) and small amounts of water vapor (H_2O), hydrogen sulfide (H_2S), hydrogen (H_2), and siloxanes [4]. Biogas technology is a low cost fuel with production of a useful soil amendment, improved urban sanitation, and low gestation period, provision of quick benefits, participant friendliness and political acceptance. Biogas is utilized after treatment in numerous applications, like electricity and heat generation, connection to the natural gas grid, or as biofuel in vehicles.

Food wastes have a high biomethane production potential thanks to their high organic matter contents. Food waste encompasses a high organic content in its composition (with volatile solids ranging between 70% and 90%, dry mass based), also a high-water content (>80%) and is definitely biodegradable. These properties are important as they permit FW to be converted into valuable products, like energy recovery. Food waste is additionally known for some properties that are not favourable to AD processes, including low pH-values, high nitrogen content and low C/N-ratio [5]. The biogas is often produced from the food waste using the anaerobic digesters. This anaerobic digestion has become the foremost favourable method within the market. So, this process depends on the interactions between the varied microorganisms. Anaerobic digestion is a biological process, within which the microorganisms degrade the complex organic matter to simpler components under anaerobic conditions to produce biogas and fertilizer. Anaerobic digestion is considered as an acceptable treatment of food waste for biogas production, due to their high moisture and organic content [6]. This anaerobic digestion process takes place in four successive stages. They are hydrolysis, acidogenesis, acetogenesis, methanogenesis.

In the process of hydrolysis, hydrolytic bacteria are ready to secrete extracellular enzymes that may convert carbohydrates, lipids, and proteins into sugars, long chain fatty acids (LCFAs), and amino acids, respectively. After enzymatic cleavage, the products of hydrolysis are ready to diffuse through the cell membranes of acidogenic microorganisms. However, it is important to notice that certain substrates, like lignin, cellulose, and hemicellulose, may find it difficult to degrade, and might be inaccessible to microbes because of their complex structures; enzymes are often added to reinforce the hydrolysis of those carbohydrates [7].

Acidogenic microorganisms can produce intermediate volatile fatty acids (VFAs) and other products, by absorbing the products of hydrolysis through their cell membranes. VFAs constitute a class of organic acids such as acetates, and larger organic acids such as propionate and butyrate [8]. The simple sugar molecules, fatty acids and amino acids break down further into alcohols and volatile fatty acids in addition to carbon dioxide, ammonia, and hydrogen sulphide.

With the production of acetate through acidogenesis, some of the initial substrate has already been rendered into a substrate suitable for acetoclastic methanogenesis. lipids undergo a separate pathway of acetogenesis via acidogenesis and β-oxidation, where acidogenesis produces acetate from glycerol and β-oxidation produces acetate from LCFAs. The volatile fatty acids and alcohols are converted into hydrogen, CO_2 and acetic acid [9].

In methanogenesis, microorganisms convert the remaining hydrogen and acetic acid into methane, water and more CO_2. Methanogenesis marks the ultimate stage of anaerobic digestion, where accessible intermediates are consumed by methanogenic microorganisms to produce methane [10]. Like many processes, this anaerobic digestion process is additionally facing some obstacles could also be because of the incorrect usage of the parameters, but still this process incorporates a top priority within the market. There are many process parameters which are affecting the anaerobic digestion process. They're process temperatures, pH, retention time, moisture content, agitation, hydrogen concentration, also the inoculum type we use in the process.

2. Literature Review

Table-1: Comparison table for process parameters based on literature

Reference Paper	Temperature(°C)		pH	Organic Loading Rate	Retention Time	Nutrient's ratio
	.Mesophilic	Thermophilic				
[11]	32-42	50-57	6.5	2.5kg tCOD $m^{-3}d^{-1}$	16-60 days	C:N:P:S = 6000:15:5:1
[12]	32-45	55-75	6.8-8.0	1.8 to 5.0 kg VS $m^{-3}d^{-1}$	15-30 days	C:N = 25:1
[13]	20–42	45–65	6.3-7.9	0.4–6.4 kg VS $m^{-3} d^{-1}$	7-30 days	C:N = 25:1
[14]	35	55	6.8-7.4	2 kg VS $m^{-3}d^{-1}$	15-30 days	C:N = 25:1(meso) C:N=35:1(thermo)
[15]	25-40	45-65	6.5-7.5	8 kg tCOD $m^{-3}d^{-1}$	30-50 days	C:N = 20:1 to 35:1

The comparison table of process parameters is based on the different papers collected from the literature. Here in this process, the feed is given from the bottom of the digester. After giving the feed to the digester, the feed undergo anaerobic process which consists of stages like hydrolysis, acidogenesis, acetogenesis, methanogenesis. Also an agitator is fixed to the digester, it is necessary that the slurry is mixed properly. It is found that slight mixing improves the fermentation. The most important influential parameters on the biomethane production, including feedstock characteristics (nutrient contents, particle size, and inhibitory compounds) and process parameters like process configuration, pH, temperature, retention time, organic loading rate, agitation, hydrogen concentration, moisture content, and inoculum, are discussed fully. Optimizing operational parameters, similarly, as applying additives, digestate recirculation, frequent feeding, and feedstock pre treatment are among the methods to improve biogas production process from food waste [12].

3. EFFECTS OF PROCESS PARAMETERS

3.1 Temperature

Anaerobic process is more comfortable in two temperature zones. Mesophilic temperature zone between 20-45°C and Thermophilic temperature zone between 45-60°C.

Advantages of mesophilic temperature range:
• Greater process stability.
• Better richness in anaerobic bacteria.

Disadvantages of mesophilic temperature range:
• Provide lesser biogas yield in comparison to thermophilic Anaerobic Digestion process.

Advantages of thermophilic temperature range:
• Increase in hydrolysed soluble product which make them more accessible to microorganisms.
• Increased reaction kinetics in both chemical and biological process shortening the reaction time and hence hydraulic retention time (HRT) of the reactor.
• Improves physico-chemical properties of soluble substrate.

Disadvantages of thermophilic temperature range :
• Increases the fraction of free ammonia (NH_3) which is inhibitory to microorganisms.
• Ammonia inhibition could disturb whole Anaerobic Digestion process dynamics and may affect the quality of gas.
• Reactor stability reduces.
• High accumulation of volatile fatty acids (VFAs) occur which affects the growth rate of methanogens.

Too high temperature may cause the metabolic rate to decline, due to degradation of enzymes which are critical to the life of the cell.

3.2 pH

- This parameter affects the overall efficiency of the digestion process.
- Methanogens are effective in a pH range of 6.5-7.5.
- pH varies due to parameters such as VFA, bicarbonate concentration and alkalinity of the systems and also by fraction of CO_2 produces during the Anaerobic Digestion process.
- To maintain a constant pH value, it is essential to control the relationship between the VFA and bicarbonate concentrations thus maintaining the buffering capacity of a biogas digester.
- One of the risks for digester failure may be related to the excessive accumulation of volatile fatty acids in the biogas digester.
- The acidogenic bacteria then flourishes, lowering the pH below 5.0, inhibiting growth of methanogens.
- pH > 8 proves to be toxic to most anaerobes which inhibits biological functions of the Anaerobic Digestion process.

3.3 Organic Loading Rate

Organic loading rate refers to the amount of volatile matter that is fed into an anaerobic reactor. High Organic loading rate alters the digester environment inhibiting the microbial activity during the initial stages of acid fermentation. Increased organic loading rate increases acid formers (hydrolytic/fermentative bacteria) activity as compared to that of the methane formers (methanogens), leading to high accumulation of fatty acids. Low organic rate leads to underutilization of microorganisms (starvation) leading to very slow rate of Anaerobic Digestion process. Organic loading rate, therefore, should be optimized bases on the type of feedstock and also reactor temperature. If the reactor is unstirred then less than 2 kg VS/m^3 day is allowed. If stirring operation is carried out then 4-8 kg VS/ m^3 day is acceptable.

3.4 Hydraulic Retention Time (HRT)

HRT is the average time that the organic substrate remains in the digester. HRT affects the biological and chemical properties if organic substrates. It plays an important role in Anaerobic Digestion process especially for methanogenic bacteria in mesophilic temperature range. It is desired to be long enough to provide sufficient methanogenic activity. In general, HRT is shorter for Anaerobic Digestion at higher temperatures and vice-versa but mostly depends on the properties of feedstock. Normal value of retention period is between 30 to 45 days and in some cases 60 days.

3.5 Nutrients

The major nutrients required by the bacteria in the digester are C, H_2, O_2, N_2, P and S. Besides Carbon the quantity of N_2 present in the wastes is a crucial factor in the production of biogas. Nitrogen is the major nutrient required for the growth of microbes, and the synthesis of amino acids and proteins which in turn converts into ammonia, a buffer compound for the neutralization of the acidification process. If the nitrogen content is low, microbial populations remain less and it might take longer duration to digest the available carbon present in the substrate. If the nitrogen content is high, then excess nitrogen leads to production of too much ammonia (NH_3) which inhibits the anaerobic process. Carbon serves to be source of energy and nitrogen controls the microbial population, so the ratio of carbon and nitrogen (C/N) plays an important role for an effective Anaerobic Digestion process. C/N ratio range of 20-35 has been found to be mostly suitable for various types of substrates.

3.6 Total Solid Content of the Feed

The adjustment of total solid content helps in bio digesting the materials at faster rate and also in deciding the mixing of various residues as feed stock as biogas digester.

3.7 Mixing Content of Digester

The bacteria present in the digester have very limited reach to their food. It is necessary that the slurry is mixed properly and bacteria get their food supply.it is found that mixing improves the fermentation and however vigorous mixing retards the digestion.

3.8 Acid Accumulation Inside the Digestion

Intermediate products such as acetic propionic butyric acids are produces, during the bio digestion. This causes decrease in pH especially when some fresh feed material is added in large amount. This naturally occurs in batch digestion systems.

4. CONCLUSION

The study evaluates biogas production from food waste through an anaerobic digestion. After comparing from different papers the mesophilic temperature zone between 20-45^oC and thermophilic temperature zone between 45-60^oC should be maintained, the effective pH range is 6.5-7.5, organic loading rate of a stirred reactor can be in the range of 4-8 kg VS/ m^3 day, C/N ratio range of 20-35 has been found to be mostly suitable, alkalinity should be around 2500-5000 mg $CaCO_3$/L, finally the retention time will be around in between 30 to 45 days and in some cases 60 days. For production of biogas all the process parameters must be monitored continuously and should be maintained for good yield.

5. FUTURE SCOPE FOR RESEARCH

In the AD of food wastes, the soundness of the method is another concern. Anaerobic digestion may be the finest method that specializes in most up-to-date research works to boost biogas production from food wastes. Feeding food wastes as co-substrate into existing plants is an option within the future to eliminate the high cost of capital for building new plants. Existing industrial digesters are usually fed with sewage sludge that is a correct option for anerobic digestion with food wastes in line with the findings of diverse studies. Therefore, studies on optimization and improvement of anerobic digestion of food wastes should be continued. Additionally, simultaneous production of biogas and other products from food wastes through biorefineries is another subject that needs further attention within the future. for instance, the production of ethanol-methane would be interesting topics to boost the efficiency of energy recovery and therefore the financial aspects of the method. Factors regarding the design, pretreatment methods, and digester conditions of a small-scale batch digester should all be considered to make sure that an efficient and cost-effective final product is viable.

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