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Factors Affecting the Biogas Yield Production with Different Techniques: A Review

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Abstract:- In countries like India food waste accounts for more than 50% of the Municipal solid waste collected. Food waste has a lot of potential to be used as a raw material because of its enrichment in organic properties. Thisreview paper presents a study on the basic principles of anaerobic digestion and the reactions which let it occur. Here we have observed all those factors on which the efficiency and production of biogas depends such as pH, Temperature, C/N Ratio, Retention Time. We also have discussed the parameters so that some changes in the digester can be done to increase the efficiency.

Keywords: *- Anaerobic digestion, Biogas, Methane, Municipal Solid Waste*

I. INTRODUCTION

Biological matter such as dung, crops, decaying plants, and biological excrement are examples of biomass. This is regarded as the most efficient source of energy. As per the reports, more than 50% of the municipal solid waste is collected among other waste and this is considerably a high amount of waste, therefore this food waste must be utilized in such a manner so that it can be used as a source of energy and converted to a gas which is popularly known as biogas. This biogas predominantly comprises of methane, carbon dioxide, a trace quantity of hydrogen sulphide and gases of some other compounds. These some other compounds can be filtered out by the means of purifier. The process in which food waste is converted to biogas under some standard conditions called as biomethanation. Thisprocess occurs in a closed container in the absence of oxygen (anaerobic condition) which is known asbiogas digester, this digester and its types play an important role in the biogas production as different digester methodologies work differently. Conversion of biomass to biogas occur in four stages:

A. Hydrolysis,
B. Acidogenesis
C. Acetogensis
D. Methanogenesis

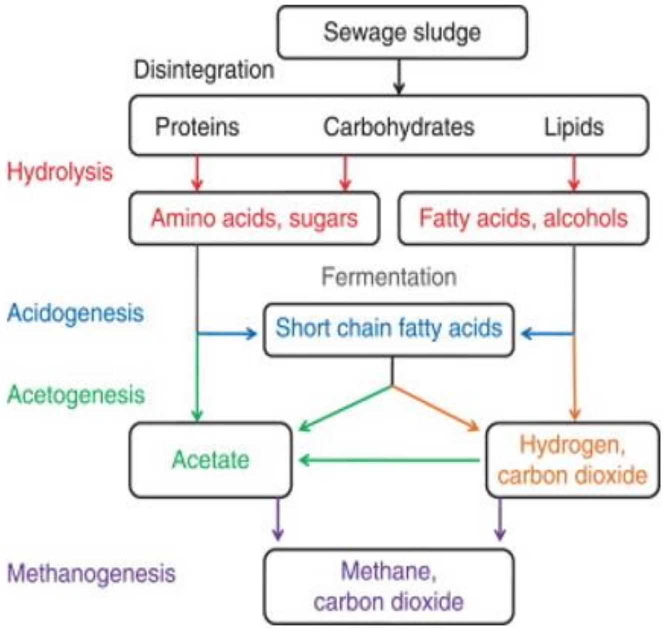

Fig.1 conversion of biomass to biogas

This Biogas has the potential to replace traditional energy sources (non - renewable sources) that are producing threats to the environment while also diminishing at a quicker rate. Considering its various benefits, biogas technology's maximum capabilities are yet to be realized because it is also bound by some limits. Some limits or some constraints are (but not limited to) such as- low efficiency in cold climate, greater hydraulic retention time, instability of pH and carbon to nitrogen ratio, not optimum range of temperature etc. As a result, efforts must be made to eliminate these numerous restrictions in order to get the maximum yield production of biogas in developing areas. Investigators have experimented with a variety of strategies to boost gas output. The several approaches that could've beenemployed to improve the biogas yield are discussed in this research.

II. LITERATURE REVIEW

Naik et al reviewed the parameters which affect the biogas productivity and its efficiency such as organic loading rate, pH, carbon to nitrogen ratio, microbial population and its increasing rate, temperature etc. these above mentioned parameters were analyzed on small scale anaerobic digester but these are not limited in context of rural and urban system both[1]. Moreover the type of feedstockmaterial either it is heterogeneous in urban or homogeneous in rural affects the

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listed parameters. Inthe present scenario, this behavior of material should be identified on small scale portable dome.

Al sadi et al. conducted tests for different carbon-to-nitrogen ratio of raw materials. This was initiallyindicated that low C/N ratio will lead to the formation of ammonia on account of liberation of free nitrogen, consequently pH is increased and toxicity is produced. Another experiment conducted by the team showed that optimum C/N ratio must be between 20 and 30[2]. Experiment conducted on chicken dung and human excreta was resulting in increasing the pH because these raw materials haveconsiderably lower value of C/N ratio. Moreover they also tried to mix the raw materials of high C/Nratio and low C/N ratio so that it can be optimized and will affect positively in digester.

Ajay et al reviewed the anaerobic digestion, challenges associated with it and design of kitchen wasteportable biogas digester. They stated that due to high moisture content kitchen food waste is a very challenging task, so the solution provided on the behalf of that problem was different kind of methods adopted to treat this waste and methods such as incineration, landfilling, composting etc. For kitchen waste fixed dome digester was used with different feedstock materials. They experimented and results have shown that food waste at the temperature of 35ºC with the 20-60 days hydraulic retention time generates about .49 m^3/kg volatile solids of biogas[3]. Design of portable digester was of two phase system only which includes abiogenesis and mathenogenesis. But the problem was the temperature as in these two steps different range of temp should be there to get optimum result.

Recently, in 2019, alkhalidi et al analyzed that there are more than thirty five million plant based biogas installations all over the world but those are not meeting with the rural areas as they felt that today dueto hiking of prices every household must contain portable digester so that it can reduce family gas bill.They designed a digester of 0.5m^3 for human waste and 0.9m^3 for food waste separately[4]. Study showed a very low biogas generation, after that they mixed both waste in a digester size of 0.54m^3 andit was significantly producing biogas for five member family[4]. They concluded in their experiment that digester size is an important parameter for portable biogas digester.

Yousuf et al. studied to examine the conversion of biomass from kitchen waste along with cow dung tobiogas utilizing an anaerobic digestion technique. Stated with this fact that anaerobic treatment is a viable technique for lowering biodegradable trash in the Municipal solid waste stream while also producing clean and renewable energy. Anaerobic digestion is a viable and successful process for converting high-moisture solid waste to biogas fuel, given the properties of the waste. Temperature 35°C, Organic loading Rate 200g/L, and 1.5% NaOH were used to produce the maximum amount of biogas (13.21ml/g)[5]. It was possible to produce 39.74 percent greater biogas generation when kitchen waste was treated with 1.5 percent NaOH[5]. Finally, a portable biogas digester was built and tested, and it performed well under ideal conditions.

Gallipoli et al. did a trial on kitchen waste to examine the effects of moderate thermal pretreatment andinoculum ratio. Results have shown that thermal pretreatment was a practical and satisfactory method in the solubilization of carbohydrate. The rapid conversion of sugars was linked to high hydrogen production of up to 113 mL Hydrogen/g Volatile solids[6]. As predicted, the thermophilic regimen yielded in quicker digestions (up to 78 mL methane/gram Volatile solids/day) and eliminated pH inhibition. The continuous lignin content and low lipid productivity resulted in comparatively modest methane production (342 to 398 mL methane/gram Volatile Solids)[6].

Namugenyi et al. assessed the practicality and business potential of constructing a portable device for refining and packaging biogas in portable cylinders for broad social usage and utility in this study. Theresearch from transition system innovation demonstrates that existing biogas consumers have a reasonably substantial level of satisfaction (50%) [7] and that this happiness might be acquired over a larger socioeconomic spectrum with the implementation of the entrepreneurial business model. But there are some limitations associated with it also which authors described as a problem of many suppliers. The portable cylinder components can’t be assessed by a single market, so it is a time takingand laborious work to do, therefore we should have many market available.

Abd Allah et al. considered that cold climate season could be best opportunity to examine the yield of methane production in Egypt. This was the primary concern of their study, to conduct it they used a floating type digester with raw material of cattle dung along with corn stover. After conducting experiments results have shown that the use of anaerobic co-digestion resulted in significant increases in average daily, cumulative, and specific methane yields of 40.30, 42.43, and 39.65 percent above anaerobic mono-digestion, respectively. Furthermore, anaerobic co-digestion increased average methane volume, average daily, and total acquired bio - gas production by 11.42, 40.16, and 42.43 percent over anaerobic co-digestion, respectively [8]. But the problem faced by the authors was the expensiveness of the steel drum used in floating digester.

III. FACTORS AFFECTING ANAEROBIC DIGESTION

A. Quantity of nutrients

There is some need of micronutrients and macronutrients as well so that micro-organisms which are involved in the digestion process in a very balanced manner which includes macronutrients like carbon, nitrogen, phosphor, and sulfur etc.

The excellent range of C/N ratio is found to be 20-30 but it was found that C : N : P : S ratio of 1000 : 20 : 5 : 3 that would be appropriate for the digestion process [9] . This might be attributed to the low supplement prerequisites of anaerobic microorganisms because of their irrelevant biomass improvement. The carbon supply is as often as possible given through method of method for dinners wastes

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and is applied for the assistance of biomass mobileular shape. Other than carbon, the microorganisms moreover need nitrogen essentially for the total of proteins.Sulfur is required as a supplement to improve methanogens and as a feature of a few amino acids.

Micronutrients or minor added substances comprehensive of iron, cobalt, nickel, zinc, selenium, tungsten, magnesium, chromium, and molybdenum are anticipated at uncommonly low concentrations for the tolerance of microorganisms.

The micronutrients are the truth be exhorted the shape blocks to improve microorganisms and are locked in with co-precipitation, enzymatic movement, and biochemical reactions [10]. Iron, disregarding its capacity as an advancement factor, acknowledges a gigantic component as opposing proficient withinside the arrangement of ferredoxins and cytochromes; fundamental parts in mobileularhandling.

Additionally, iron can respond with H2S, sulfur as iron (II) sulfide, and reduction the deterioration outcomes of H2S in biogas. Iron in like manner has an earnestly settling movement sooner or later of the anaerobic pattern of dinners squander in assessment with the contrary minor parts [11].

Cobalt is a significant component ensuring the devotion of the anaerobic absorption cycle with better ordinary loadings [10]. This might be characterized through method of method for how cobalt is an improvement a piece of acetogenic microorganisms. Zinc is anticipated for the total of carbonic anhydrase through method of method for methanogens which relies on the methanogenic interaction.

B. Particle size

The less the particle size of the waste, more would be the surface area for the waste to react and adsorb the exo-enzymes and increase the speed of degradation and production of bio gas [12][13]. It was minutely observed that the minimized size of feedstock can further develop anaerobic digestion process in two different ways: (I) the improvement of biogas creation from substrates containing high measure of fibres, and (ii) the lessening of specialized retention time for all substrates [15].

The prior advantage of degradation and disintegration of food waste is to make the retention time similar for different type of compounds having various qualities of food waste [15], and disintegration of food waste should be done before anaerobic digestion process [9].

Moreover, it was also seen that the severe degradation of food wastes into smaller ingredients leads toVFA (volatile fatty acids) accumulation and thus we can see a reduction in methane yields can also beseen [16]. In a solid-state anaerobic digestion process, oversize reduction or pulverizationof food wastes is more detrimental than in a submerged process. Since, it was seen that over-fine particle sizes results extreme foaming as well as process failure in both kind of wet and dry digesters [17]. Thus, a suitable communition hardware should be picked in regards to digester type, as it can prompt a fruitful anaerobic digestion process.

Time (In days)	Grinded Sample	Less than 10 mm	Greater than 10 mm
	Cumulative Production (mL)	Cumulative Production (mL	Cumulative Production (mL)
0	0	0	0
3	360	290	10
6	770	700	50
9	1450	1320	460
12	1550	1530	780
15	1640	1720	940
18	1730	1850	1080
21	1740	1980	1180

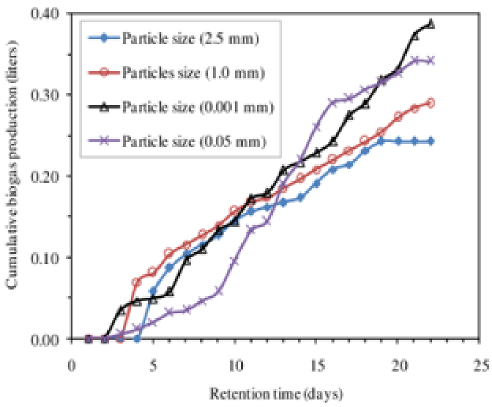

Fig2. Particle size comparision with respect to Retention Time

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C. PH

The best range of pH for methanogenesis process is somewhat around 6.8 to 8.0. The formation of methane is not viable below the pH less than 6.0 or at the pH higher than 8.5. A drop in pH is seen whenthere is an accumulation of lot of amount of volatile fatty acids and pH increases when there is a lot ofaccumulation of ammonia. Also, two normal buffering compounds are already present in digesters keeping up with the pH inside. A normally happening buffering compound is carbonate corrosive/bicarbonate/carbonate balance which accommodates too low pH values. The alkali/ammonium buffering framework can give a balance around the pH worth of 10. Be that as it may,these buffering frameworks might be over-burden by a too high OLR (organic loading rate), a decreasein temperature, or taking care of with profoundly degradable feed stocks.

The continuous indications of fermentation are an increment in the centralization of propionic corrosive, a decline in pH esteem, and the expansion in the CO2 fixation in the delivered biogas. Moreover, the proportion of propionic corrosive to acidic corrosive (greater than 1.4 g/L) and the centralization of acidic corrosive (greater than 0.8 g/L) can be utilized as different signs of the cycle unevenness.

D. Temperature

The anaerobic digestion process is done at two different temperature ranges called thermophilic and mesophilic. The temperature in thermophilic ranges in (55–70 °C) and in mesophilic (32–45 °C). It is very important and necessary to keep a same degree of temperature in the biogas digester. This is donebecause methanogens and thermophilic methanogens are temperature sensitive. Most importantly, the diversity of thermophilic methanogens is less than that of mesophiles. A fluctuation of ±3 °C can be seen in normal conditions but not more than that.

Nonetheless, temperature change could turn out to be more basic for mesophilicaly active methanogens inside temperature ranging between 40–45 °C because of their non-revertible inactivation property. Despite their ability to not tolerate to temperature variances, thermophilic anaerobic digestion is invaluable over mesophilic anaerobic digestion to higher development and degradation rates (around half), making the interaction more effective. In addition, thermophilic anaerobic digestionenjoys other upper hands over mesophilic anaerobic digestion, like no need for the hygienization of the compost, low dissolvability of oxygen, minimal hindrance by alkali collection, and elevated potential to ease therestraint brought about by more OLRs.

By the way, the mesophilic anaerobic digestion is as yet worth being considered for certain reasons, forexample, its higher security against the natural changes and the higher paces of food squanders solubilization at mesophilic temperatures [17]. As a general rule, the mesophilic anaerobic digestion is steadier than the thermophilic anaerobic digestion for food squanders because ofits high natural substance [18].

Fig.3 Temperature Ranges

IV. RETENTION TIME

Retention time plays an important role in the generation of biogas because it is the need of microorganisms to have enough retention time to process the food waste into bio gas because it affectsthe yield of methane [21].

Pretty much enough time is needed for the microorganisms to reduce the organic matter into biogas by decomposition. Retention time is perhaps the most important process factor influencing results [21]. Increasing the retention time increases the amorphous solids due to high data volumes, pH and high adhesion to hazardous mixtures. However, shorter quench times reduce the need for required vias,leading to lower assumptions when producing biogas of comparable quality and quantity [15].

Maintenance of Holding Time to affect microbial groups to microbiology groups on a schedule that is not provided as car carts to back or reuse microbial biomass. Therefore, these digesters require a basicmaintenance time of 10 to 15 days to avoid biomass washing.

The anaerobic digestion start-up time must be long enough to achieve the biomass grouping required to fully comply with the limits [22]. Dwell time is specified by two explicit limits: hydraulic pressure dwell time (HRT) and fixed dwell time (SRT). HRT is characterized as the ratio of fermenter volume to substrate flow rate, and SRT indicates the normal length of time that a strong (microorganism)is present in the fermenter.

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V. FUTURE PROSPECTS

Municipal solid waste can become the primary source as a raw material in India. The difficulty with themunicipal solid waste is that it contains other materials like plastics, metals and other in organic materials.

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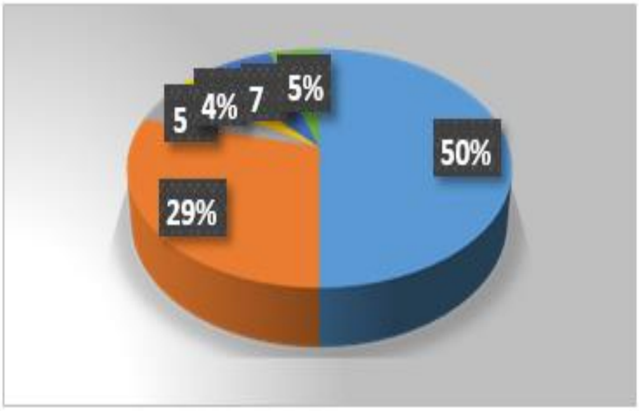

Fig.4 Municipal Solid Waste condition in India

50% - Food Waste
29% - Construction Waste5% - Glass Metal
4% - Plastic
7% - Clothes
5% - Paper

VI. CONCLUSION

During the anaerobic digestion of food wastes, the strength of the cooperation is a matter of concern.Digeston is a normal strategy that is the point of importance of most recent assessment endeavours to improve the generation of biogas creation with the help of food wastes. Dealing with food wastes as a raw material in the pre-existing biogas plants is a decision in the upcoming time to reduce and minimizethe financial cost to build new plants. In current days, present day digesters are using the sewage grimeas primary source of raw material that is a real decision for co-handling with food wastes as demonstrated by the revelations of different examinations.

If necessary, the center should continue to facilitate and improve the joint treatment of food waste. Also,a coordinated process for everything from biogas and food waste to biotreatment centers is another topic that needs further consideration later. It should be noted that in the field of biofuels, it is one of the evaluation requirements to make biofuel production more financially attractive and therefore the production of biogas from food waste is not rejected. For example, the formation of biohitan and ethanol methane would be an interesting modification to address the adequacy of energy recovery.

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