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A Critical Review on Biochemical Process of Anaerobic Digestion

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Abstract

Municipal solid waste (MSW) management is fetching a serious threat all over the world. Anaerobic digestion (AD) is one of the oldest processing technologies, which converts the waste into useful form of energy. Anaerobic Digestion is a multistep process in which the organic matter is degraded into a gas mixture of methane and carbon dioxide by microorganisms. But in some places, having limited resources cannot fulfill the cow dung, sheep manure, goat manure or other animal manure requirements in anaerobic digestion. Therefore there is a need to have a review on the operating parameters and also the pre-treatment technologies available for treating the substrate so that one can get the maximum output with limited input. To accomplish the need, the present paper deals with the review of various operating parameters and their effects on anaerobic digestion.
Keywords: Anaerobic, biogas, bio-methanation, digestion, manure, municipal solid waste

I. INTRODUCTION

Municipal Solid Waste (MSW) is the most daunting and widespread of all environmental troubles. All states of India are facing Municipal Solid Waste Management (MSWM) problems due to the rapid growth in Municipal Solid Waste generation rate. Government bodies at all levels (Central, State and Municipal) are taking proactive steps to improve the MSW management in India. More than 90 percent of the municipal solid waste in India is dumped in an unsatisfactory way that creates environmental hazards to water, air and land. Biological conversion of biomass to methane has received increasing attention in recent years. There are many technologies such as incineration and refuse derived fuel etc., for producing energy from solid wastes. Among them anaerobic digestion has become a promising technology particularly for recovery of energy from organic fraction of solid wastes. Many research works are being carried out for treating various types of organic solid wastes using anaerobic digestion process (Tamilchelvan and Dhinakaran, 2012). It has become a major focus of interest in waste management throughout the world. Anaerobic Digestion is potential environment friendly technique produce energy in the form of biogas and residue which can be used as soil conditioner. It is known that organic waste materials such as vegetables contain adequate quantity of nutrients essential for the growth and metabolism of anaerobic bacteria in biogas production (DhanalakshmiSridevi and Ramanujam, 2012).

Waste is one of the most promising options for the production of biofuels which act as an alternative source of energy. This would also help in the treatment of wastes which is becoming a nuisance to the community (Singhal et al., 2012). Municipal waste is the abandoned materials which have been thrown away after use in daily life in the urban area. It generally composed of residential waste, institutional waste and hospitals wastes. Due to the increasing growth of urban population in the world this municipal waste is getting high concerns from the management perspective. Municipal solid waste (MSW) contains a significant fraction (30 to 50%) of organics. On the other hand, Uddin and Mojumder (2011) revealed that, the amount of municipal waste generated in six major cities of Bangladesh is about 7690 tons daily. These wastes mainly composed of about 74.4% organic matter, 9.1% paper, 3.5% plastic, 1.9% textile and wood, 0.8% leather and rubber, 1.5% metal, 0.8% glass and 8% other waste. Therefore, this huge portion of municipal waste being organic can contribute to the production of biogas. It can be a useful resource if this organic fraction could be used for power generation. Municipal Solid Waste (MSW) landfills generate biogas and leachate. Due to the amount of waste, biogas production represents a very promising way to solve the problem of waste treatment. Furthermore, the solid residuals of fermentation might be reused as fertilizers. The composition of biogas largely depends on the type of substrate. Human excreta or night soil based biogas contains 65-66% of CH_4, 32 - 34% of CO_2 by volume and the rest is H_2S and other gases in traces while the biogas composition for municipal solid waste is composed of 68 - 72% of CH_4, 18 - 20% of CO_2, and 8% H_2S (Elango et al., 2007). Biogas is a colourless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane and carbon dioxide. It is smokeless, hygienic and more convenient to use than other solid fuels. Biogas production has three stages of biochemical process comprising hydrolysis, acidogenesis/ acetogenesis and methanogenesis (Ofoefule et al., 2010). Since cow dung has enormous bacterial population and Municipal Solid Waste (MSW) and night soil, contains a relatively large amount of organic matter which decomposes by the actions of microorganisms under anaerobic conditions (Igoni et al., 2008), it is better to co-digest municipal organic wastes with these wastes for optimizing the buffer capacity of digester and hence increase biogas production and obtain excellent soil conditioner.

II. ANAEROBIC DIGESTION

Anaerobic digestion is a natural process by which microorganisms break down the biodegradable material in absence of oxygen. AD is considered as an alternative option to manage and treat the organic fraction of municipal solid waste. This process not only treats the organic waste but also produces clean energy (biogas). The digestion residues (digestate) obtained from the process can be used as soil amendment or even nutrient rich organic fertilizer depending on its final quality. There are number of benefits resulting from the use of AD technology which are described in until now, anaerobic digestion of sewage sludge is still a standard practice for modern activated sludge plants.

Anaerobic digestion (AD) is a naturally occurring process of decomposition that is done by bacteria and archaea in the absence of oxygen. It is possible to recover nutrient and energy from different kind of waste by this method such as MSW, SS, animal waste and industrial waste. AD results in production of biogas(CH4 (65%) and CO2 (35%)). and a valuable effluent which can be used as fertilizer. It also reduces amount of greenhouse gases (GHG) emission but it is a slow process because of the low growth rate of microorganisms, it is pH sensitive so it needs high buffer, and high levels of ammonia can inhibit the process (Rittmann et al. 2001).

A. *Microbiological Processes in Anaerobic Digestion*

This is a complex process that involves many different classes of bacteria and several intermediate steps which are represented schematically in Figure 1. Performance of AD can best be evaluated by monitoring the products of the digestion process. As shown in Figure 1, the AD process can be split into four main stages: hydrolysis, acidogenesis (fermentation), acetogenesis, and methanogenesis.

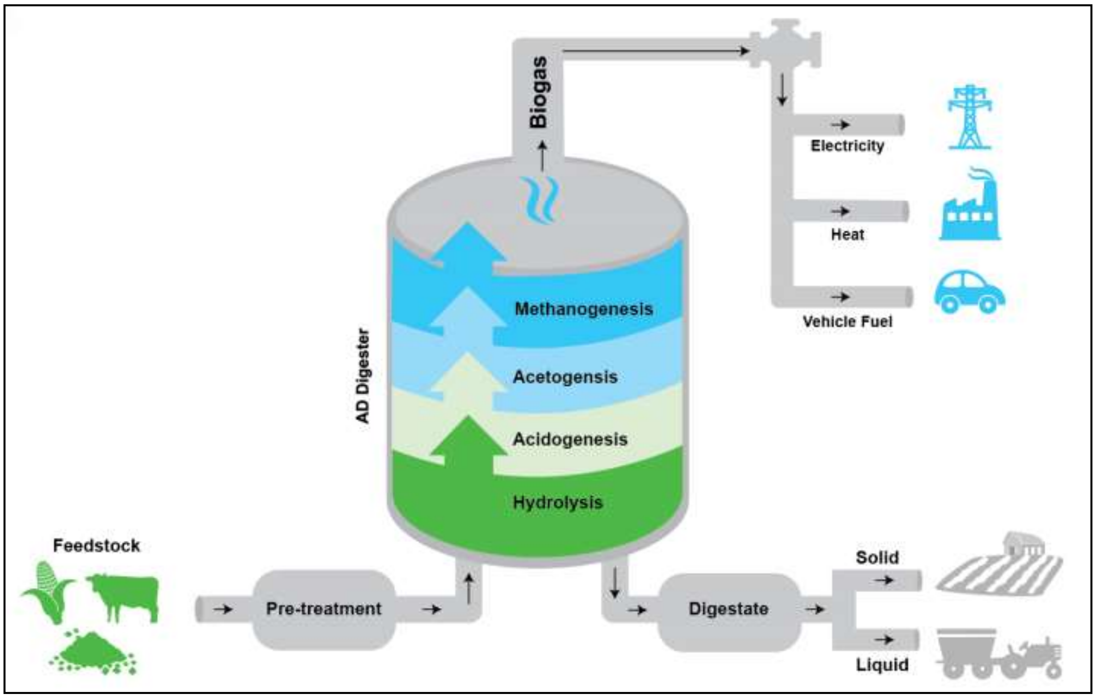

Fig. 1: Anaerobic Digestion Processes (*source*: www.globalmethane.org)

B. *Important Parameters in Anaerobic Digestion of Solid Waste*

1) pH

The pH of the digester is an important indicator of the performance and the stability of an anaerobic digester. The pH level changes in response to biological conversions during the different processes of anaerobic digestion. A stable pH indicates system equilibrium and digester stability. Many aspects of the complex microbial metabolism are greatly influenced by pH variations in the digester. Although acceptable enzymatic activity of acid forming bacteria can occur at pH 5.0, methanogenesis proceeds at a high rate only when the pH is maintained in the neutral range.

2) Substrate characteristics

The characterization of substrate is a key factor for the design and optimization of waste treatment and disposal methods. The physical and chemical characteristics of the organic wastes are important information for designing and operating anaerobic digesters, because they affect biogas production and process stability during anaerobic digestion.

3) Temperature

Temperature is one of the most important factors affecting microbial activity in anaerobic digester, and methane production is strongly temperature dependent. Temperature determines the rate of an anaerobic degradation processes particularly the rates of hydrolysis and methanogenesis.

4) Nutrients

A balanced availability of nutrients for the growth of the microorganisms in biogas digesters is important for the process performance, i.e stability and substrate utilization (Takashima and Speece, 1989). Apart from a balance among the macronutrients carbon, nitrogen and phosphorus, availability of certain trace elements has also been shown to have a strong impact on the biogas production. Zhang *et al.,* (2013) has reported enhancement in process performance by supplementing trace elements during continuous anaerobic digestion of food waste. Trace metal requirements for continuous methane fermentation at thermophilic temperature has been reported by Qiang *et al.,* (2013).

5) Mixing

Mixing facilitates the contact between bacteria/enzymes and substrates preventing the accumulation of substrates and intermediates and guarantee homogenous conditions in the assays vessels (Angelidaki *et al.,* 2009). It also prevents the thermal stratification and the formation of a surface crust/scum build up in an anaerobic reactor (Karim *et al.*, 2005; Meroney and Colorado, 2009). Furthermore, mixing ensures that solids remain in suspension avoiding formation of dead zones by sedimentation of sand or heavy solid particles. Mixing also enables the particle size reduction as digestion progresses and the release of produced biogas from the digester contents (Kaparaju *et al.,* 2007).

6) Inhibitions

Inhibition is usually indicated by a decrease in the microbial population and methane production. A wide variety of substances have been reported to be inhibitory to the anaerobic digestion processes. These kinds of substances can be found as components of the feeding substrate or as by-products of the metabolic activities of bacterial consortium in the digester. A material may be judged as inhibitory when it causes an adverse shift in the microbial population or inhibition of bacterial growth.

C. *Types of Anaerobic Digestion Systems*

A wide variety of systems have been developed to treat MSW anaerobically. They can be split into different categories as following:

- Dry versus wet digestion
- Mesophilic versus thermopilic digestion
- Single stage versus multi-stage digestion
- Continuous versus batch process

Peter et al., (2001) reported finally, the microbial population dynamics during various operating conditions are, at best, superficially understood. Because, performance of anaerobic digestion is directly related to microbial activity, it is only through a detailed analysis of the relationship between the microbial community structure and the performance of the digesters. Anaerobic digestion of organic substrates to produce methane and carbon dioxide has been a well-developed biological treatment for waste water and solid waste. It was clear that the value of renewable energy and other important environmental benefits of anaerobic digestion will continue to increase the desirability of anaerobic digestion as a central treatment of solid organic waste. Banu et al., (2007) reported that the gas production commenced on the first day onwards. The maximum gas production was recorded on the fifth day, from then on, there was a gradual decrease in daily gas yield and the gas production was very less towards the end. During the twentieth day digestion period, the pH was in the range of 6.8-7.4 and it indicates that the reactor was running in a healthy condition. Sundararaman et al., (2006) studied the effect of COD loading rate on the operating condition of co-digester using secondary sewage sludge and vegetable solid waste. Vegetable solid waste was collected chipped and sieved to a size of 1mm with the help of sieves as one of the method of pre-treatment. The changes in COD loading rate showed higher COD concentration of vegetable solid waste at the bottom port compared to co- digester. And also observed that addition of COD loading reduced the biogas generation to 0mL/d at the end of 69^{th} day showed no biogas generation till the end of operation period 100 days. Macias-Corral et al., (2008) single waste anaerobic digestion and co-digestion of municipal solid wastes and agricultural wastes were investigated using a two-phase pilot-scale anaerobic digestion system. The biogas produced in the two-phase anaerobic digestion had a higher methane content (72% or more) than conventional single-phase systems, which typically produces a gas that is 60% methane.

Holm-Nielsen et al., (2009) reported that there was a considerable potential of biogas production from anaerobic digestion of animal manure and slurries in Europe, as well as in many other parts of the world. Anaerobic digestion of animal manure offers several environmental, agricultural and socio- economic benefits throughout improved fertilizer quality of manure, considerable reduction of odors and inactivation of pathogens and last but not least production of biogas production, as clean, renewable fuel, for multiple utilizations. The last decade brought about huge steps forward, in terms of maturation of biogas technologies and economic sustainability for both small and large scale biogas plants. One of the driving forces for integrating biogas production into the national energy systems will continue to be the opportunities offered by biogas from anaerobic co- digestion of animal manure and suitable organic wastes, which solves some major environmental and veterinary problems of the animal production and organic waste management sectors. Dhanalakshmi sridevi et al., (2012) reported that, the vegetable wastes containing high carbohydrates are amenable to anaerobic digestion process and the maximum gas production was observed during 5-10 days of digestion. This shows that carbohydrates have been broken down much faster than the proteins and fats present in the waste and produced the gas. The mean methane production rate calculated on the basis of substrate concentration and the corresponding mean gas production show that the reactors can be operated safely till 0.26gmVS loading beyond which inhibition of the process started. Similar trend was observed, in the specific rate constant value, k, calculated for the first order kinetics. The application of factorial (empirical) analysis using predictive models shows polynomial function seemed to be more reliable in predicting gas production in anaerobic digestion of vegetable wastes. Venkateshwar et al., (2013) reported biomass is a potentially reliable and renewable energy resource for India because of its availability as agricultural waste, sewage sludge, animal manure and industrial waste. Anaerobic digestion of biomass can be considered as one of the most promising energy carrier for the future generations. Several biomass plants are constructed to convert different forms of wastes into energy. The total numbers of family size biogas plants installed as on March 2005 are 3.71 million against 12 million. The need to optimize utilization of India's vast potential for energy generation from biomass and to improve the severe power crunch faced by the country requires the integration of bioenergy into the national energy planning thereby enabling the creation of balanced energy mix. Kigozi et al., (2014) stated that the idea of using the organic fraction of municipal solid waste (OFMSW) or simply municipal biowaste as feedstock for biogas production represents an environmentally sustainable energy source since it improves solid waste management while simultaneously providing an alternative clean energy source. Among other applications, the gas can be used for heating, cooking and electricity generation. However, notwithstanding, OFMSW as a feedstock for AD comes with its own unique challenges compared to other forms of biomass. Arafat et al., (2015) reported that anaerobic digestion is optimal to recycle wood, paper and plastics, while it dominates as the optimum technology for treating food and yard wastes. Anaerobic digestion and gasification fared well environmentally as apparent by the single score analysis.

III. Conclusion

Anaerobic digestion has been proved to be a promising energy saving and recovery process for the treatment of organic solid waste. Anaerobic digestion also has been suggested as an alternative method of removing the high concentration organic waste. Anaerobic digestion is a biological process wherein diverse group of microorganism convert the complex organic matter into simple and stable end products in the absence of oxygen. This process is very attractive because it yields biogas, a mixture of methane and carbon dioxide which can be used as renewable energy resources. Bioenergy will be the most momentous renewable energy source for the reason that it offers an economical attractions and alternatives to fossil fuels. Several research groups have developed anaerobic digestion processes using different organic substrates.

References

[1] Angelidaki, I., Alves, M., Bolzonella, D., Borzacconi, L., Campos, J. L., Guwy, A. J., and Van Lier, J. B. (2009). Defining the biomethane potential (BMP) of solid organic wastes and energy crops: a proposed protocol for batch assays. Water science and technology, 59(5), 927-934.
[2] Arafat, H. A., Jijakli, K., & Ahsan, A. (2015). Environmental performance and energy recovery potential of five processes for municipal solid waste treatment. Journal of Cleaner Production, 105, 233-240.
[3] Banu, J. R., Raj, E., Kaliappan, S., Beck, D., & Yeom, I. T. (2007). Solid state biomethanation of fruit wastes. Journal of environmental biology, 28(4), 741-745.
[4] Elango, D., Pulikesi, M., Baskaralingam, P., Ramamurthi, V. and Sivanesan, S., 2007. Production of biogas from municipal solid waste with domestic sewage. Journal of hazardous materials, 141(1), pp.301-304.
[5] Holm-Nielsen, J. B., Madsen, M., & Esbensen, K. H. (2011). Monitoring of anaerobic digestion processes: A review perspective. Renewable and Sustainable Energy Reviews, 15(6), 3141-3155.
[6] Igoni, A.H., Ayotamuno, M.J., Eze, C.L., Ogaji, S.O.T. and Probert, S.D., 2008. Designs of anaerobic digesters for producing biogas from municipal solid-waste. Applied energy, 85(6), pp.430-438.
[7] Kaparaju, P., Buendia, I., Ellegaard, L., & Angelidakia, I. (2008). Effects of mixing on methane production during thermophilic anaerobic digestion of manure: lab-scale and pilot-scale studies. Bioresource technology, 99(11), 4919-4928.
[8] Karim, K., Hoffmann, R., Klasson, K. T., & Al-Dahhan, M. H. (2005). Anaerobic digestion of animal waste: Effect of mode of mixing. Water research, 39(15), 3597-3606.
[9] Kigozi, R., Aboyade, A. O., & Muzenda, E. (2014). Technology selection of biogas digesters for OFMSW via multi-criteria decision analysis.
[10] Macias-Corral, M., Samani, Z., Hanson, A., Smith, G., Funk, P., Yu, H., & Longworth, J. (2008). Anaerobic digestion of municipal solid waste and agricultural waste and the effect of co-digestion with dairy cow manure. Bioresource technology, 99(17), 8288-8293.
[11] Peter. G., McMahon, K. D., Mackie, R. I., & Raskin, L. (2001). Anaerobic codigestion of municipal solid waste and biosolids under various mixing conditions—I. Digester performance. Water research, 35(7), 1804-1816.
[12] Singhal, Y. and Bansal, S.K., 2012. Evaluation of biogas production from solid waste using pretreatment method in anaerobic condition. International Journal of Emerging Sciences, 2(3), p.405.
[13] Sridevi, D. V., & Ramanujam, A. R. (2012). Performance of mixture of vegetable wastes with high cabohydrate content in anaerobic digestion process. International Journal of Environmental Sciences, 3(1), 181.
[14] Tamilchelvan, P. and Dhinakaran, M., 2012. Anaerobic digestion treatment of Tannery waste water. International Journal of Engineering Research and Applications, 2(3), pp.932-936.
[15] Venkateshwar, S., Govumoni, S. P., Koti, S., Kothagouni, S. Y., & Linga, V. R. (2013). Evaluation of pretreatment methods for enzymatic saccharification of wheat straw for bioethanol production. Carbohydrate polymers, 91(2), 646-650.
[16] Zhang, C., Xiao, G., Peng, L., Su, H., & Tan, T. (2013). The anaerobic co-digestion of food waste and cattle manure. Bioresource technology, 129, 170-176.