IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 3, Issue 9, September 2016

Bio-Mass Utilization for Bio-Gas Production using Anaerobic Digestion: A Review

Alok Kumar Tiwari[1], S. N. Saha[1], Arpita Shukla[2]

Department of Chemical Engineering, Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur, India[1]

Department of Chemical Engineering, Raipur institute of Technology, Raipur, India[2]

Abstract: Many of the food crops after being harvested are sent to processing for further use. During the processing operations, large amount of waste is generated, which needs to be dealt with in a sustainable way. Huge quantities of waste resulting from crop cultivation action and animal waste like manure and poultry droppings are a likely-looking source of energy supply for manufacture, treating and domestic activities in rural areas of the concerned region. The available crop residue and other solid biomass can be used effectively. There is virtually an unlimited potential of bio-energy in our country. Traditional method of waste handling is generation of biogas from it. The residues are introduced into the anaerobic bio-reactor, after that conversion of solid residue into biogas takes place by means of anaerobic microorganisms like Methanogenic bacteria. After the completion of the process the remaining solid waste can be utilized as bio-fertilizers. Both pollution control and energy recovery can be achieved efficiently in bio gas production by anaerobic digestion without intake of any external electron acceptor like oxygen having some limitation in terms of demerits including inhibition problem which has to be overcome by some means. Here in this review paper the intricacies of the anaerobic digestion process, different stages of the process are covered and a summary of the various types of substrates used and the results obtained in each case are reviewed.

Keywords: Biomass, anaerobic digestion, micro-organisms, biogas, methane.

1. INTRODUCTION

As the world's resources of petroleum dwindle day by day, an urgent need to shift our dependence to alternate sources of energy has become inevitable. There are many ideas for obtaining green, clean energy. One of those ideas employs organic waste to generate methane, which is the main component of biogas. In developing countries like India, approximately 75% of the rural population of India is dependent on biomass energy produced by the firewood, agricultural waste, kerosene and cow dung (Saha. 2014).

These cheap methods of rural energy production contribute to environmental pollution and they usually involve a lot of physical labour. The advantages of biogas generation include replacement of a less efficient fuel with a more competent and flexible one, and retrieval of fertilizer value of the digested waste (Ilaboya et al. 2010). Cooking and agricultural activities are the major areas of energy consumption in developing countries. Biogas has the potential to significantly solve the energy requirement of rural societies. It is a clean fuel obtained from microbial degradation of complex organic biomass under anaerobic conditions. It consists majorly of methane (65-75%), carbon di-oxide (25-35%) and small traces of nitrogen, ammonia, hydrogen sulphide in the tune of 35-170 ppm and other gases (Saha. 2014). The philosophy of "waste to energy" is embraced in this technology of treating the liability into asset. The process of producing biogas is completely sustainable, economical and environmentally friendly. It can be employed in agro-industries and commercial kitchens for co-generation. Biogas is commonly made from municipal waste, solid manure, sewage sludge and landfills that contain organic wastes. The ultimate methane yield is affected by several factors, such as the feed, species, breed and growth stage of the animals as well as the amount and type of the bedding materials together with the pre storage conditions prior to biogas production (Moller et al. 2004). Some 100 genera of biomass leaves, wood, vegetable solid wastes can be thought of production of biogas containing methane by the route of anaerobic digestion using plug flow digester, anaerobic filter two-stage, two-phase fluidized bed digesters (Gunaseelan et al. 1997).Until recently, the abundance and low cost of fossil fuels has precluded the need to invest on biogas technology. But now, it is not going to be long before renewable energy becomes the world's future. The main challenge of the diversity of anaerobic digestion is to find and use the cultured microbe economically in anaerobic digester.

Fig. 1. Production of biogas in lakh cubic meter (2014-15)

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 9, September 2016

Following figure 1 depicts the trend of Biogas production in various provinces of India (https://www.saddahaq.com/biogas-production-in-india-is-equivalent-to-5-of-the-total-lpg-consumption)

2. ANAEROBIC DIGESTION

Anaerobic digestion of organic waste is of growing importance as it offers a chance to deal with efficient disposal of organic waste, with no deleterious effects to the environment. The production of biogas by the anaerobic digestion of human, animal, agricultural and municipal waste consists of 65-75% methane, 25-35% carbon di-oxide, small traces of nitrogen, ammonia, hydrogen sulphide and other gases (Saha. 1986; 2014). Majority of the anaerobic digestion systems in operation are single stage systems. This means all the biological reactions occur within a single reactor or holding tank. However, there are studies that show that two-stage anaerobic digestion could provide great advantages over the single-stage digestion due to a more rapid and more stable handling achieved (Baere et al.2000). Biogas prepared by anaerobic digestion has got the various advantages in comparison with other renewable energy sources including the fact that this can be distributed through the existing natural gas infrastructure, also from easy storage point of view (Holm-Nielsen et al. 2009). Renewable methane production from anaerobic digestion leads to reduction of environmental impact owing to the global warming and acid rain. Biomass energy may be apparently more costly in comparison to fossil energy, but it would be more cost competitive from the point of view of emission regulations and carbon taxes (Chynoweth et al. 2001). Globally the anaerobic digester for biogas production has been immensely increasing. As a mark of evidence the fact is revealed here that in whole Europe approximately 15 million m^3/d of methane was getting produced with the installation and operation of some 36000 anaerobic digesters (Tilche et al. 1998).

Environmental impact of random landfills by organic bio-degradable municipal solid or sludge waste may even recommend of closing the existing anaerobic digesters as a sequel of the stringent legislation act (Mata et al. 2000). Because of the presence of a considerable amount of inhibitory substances like ammonia, sulphide, light and heavy metal ions and organics existing in the agricultural, municipal or industrial wastes to be digested anaerobic ally affect badly overall efficiency of the process leading to low methane yield and process reactor instability (Chen, Ye et al , 2008). Optimization of various parameters like temperature, pH, buffer capacity and fatty acid concentration should be undertaken in the anaerobic digestion process. Basic sensory devices can be used for measuring pH, conductivity, and gas composition. Infrared Spectroscopy, Mid Infrared spectroscopy, Near Infrared Spectroscopy devices are nowadays used for monitoring volatile fatty acid, COD, Total Organic Carbon, Total alkalinity. PID controller, Fuzzy Logic, Artificial Neural Network are amongst the advanced measuring methods for trace gas and eventually the overall methane production rate (Ward et al. 2008). The anaerobic digestion reactors may be operated at psychrophilic temperature below 200°C, at mesophilic temperature 350°C, even at thermophilic temperature 550°C with the result of decrease of biogas production because of higher COD removal (Chae et al. 2008).

2.1 Stages in Anaerobic Digestion:

There are four main stages of anaerobic digestion namely: hydrolysis, acidogenesis, acetogenesis and methanogenesis.

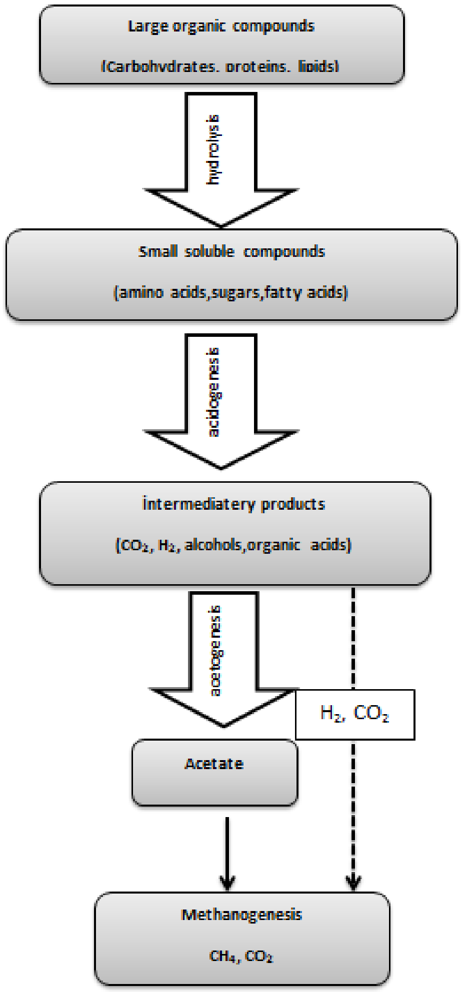

Fig.2: The key process stages of anaerobic digestion (M. Mattsson et al. 2011)

2.1.1 Hydrolysis:

This is the initial step in the digestion process, involving the enzyme facilitated transformation of insoluble molecular mass such as lipids, proteins, fats etc. into soluble organic compounds. This step is strictly executed by anaerobes such as bacteroides, clostridia and other facultative bacteria such as streptococci (Merlin Christy et al. 2014). To achieve bio-degradation, microorganisms secrete enzymes which cut the larger sized molecules into small pieces which they can assimilate as energy source. This is the first phase of the hydrolytic reactions. The

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 9, September 2016

second phase is the actual degradation at a constant depth per unit time. There are two types of hydrolysis- one is thermochemical which is preferred for fast reaction of small quantity of waste activated sludge, the other one is biological hydrolysis preferred for more cost effective of large scale treatment of the throughput (Chulhwan, P et al. 2005)

Equation 1: $C_6H_{10}O_5 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2$

2.1.2. Acidogenesis:

The smaller molecules in the hydrolysis process are taken up by various facultative bacteria and reduce further into short chain organic acids like acetic acid, propionic acid, hydrogen and CO_2. Acidogenesis is usually the quickest reaction in the anaerobic conversion of complex organic matter. During acidification of sugars, the long chain amino acids resulting from hydrolysis are used as substrate for fermentative organisms to produce organic acids like acetic acid, propionic acid etc.

Equation 2: $C_6H_{12}O_6 \leftrightarrow 2CH_3CH_2OH + 2CO_2$

Equation 3: $C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$

Equation 4: $C_6H_{12}O_6 \rightarrow 3CH_3COOH$

The transition from organic material to acids causes the pH of the system to drop, making it a conducive environment for all the acidogenic bacteria (Merlin Christy et al. 2014). Hydrolysis and acidogenesis can be enhanced by increasing the operating temperature however; acetogenesis adversely affected by high operating temperature. If the system is heated to enhance hydrolysis and acidogenesis, the resulting volatile acid production can overwhelm the ability of the slower reacting acetogenic and methanogenic bacteria to convert the volatile acids, resulting in increased pH and inhibited acetogenesis and methanogenesis (Chulhwan P et al. 2005).

2.1.3 Acetogenesis:

In this stage the alcohol derived from acidogenesis is reacted with higher organic acid and acetogens to produce CO_2 and H_2 (Appels, L et al. 2008). Acetogenic bacteria are strictly anaerobic microbes that have an optimum pH of 6. They are isolated from anoxic habitats and utilize a pathway that contains enzymes very sensitive to O_2 (Wood et al. 1991). Increasing hydrogen concentration in the liquid will lead to accumulation of electron sinks (lactate ethanol, propionate, butyrate and higher volatile acids) which cannot be consumed directly by the methanogens and should be degraded further by the obligate hydrogen producing acetogenic bacteria and the process is referred to as acetogenesis (Bjornsson et al. 2000). The obligate hydrogen producing acetogenic bacteria (Syntrophomonaswolfeii, Syntrophobacterwolinii) degrade the electron sinks to acetate, carbon dioxide and hydrogen. This transition is important for the successful production of biogas (Mah RA. 1982).

Equation 5: $CH_3CH_2COO^- + 3H_2O \leftrightarrow CH_3COO^- + H^+ + HCO_3^- + 3H_2$

Equation 6: $C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$

Equation 7: $CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^- + 2H_2 + H^+$

2.1.4 Methanogenesis:

Methane is produced as a metabolic by production anoxic conditions by methanogenic microorganisms. Methanogen has an unusual type of metabolism, because they use H_2/CO_2, formate, methylated C1 compounds or acetate as energy and carbon sources for growth. Methane production occurs in two ways either by means of cleavage of acetic acid molecules to generate carbon dioxide and methane or by reduction of carbon dioxide with hydrogen (Ostrem K. et al. 2004).

Equation 8: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Equation 9: $2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$

Equation 10: $CH_3COOH \rightarrow CH_4 + CO_2$

The hydrogenotrophic methanogenesis the most common metabolic pathway where CO_2 and H_2 are converted to methane. Kalle et al. (1985) improved the methanogenesis through the use of mixed cultures (cellulolytic culture C35mixed with methanogen M35) isolated from biogas digester. Lalov et al. (2001) improved the biogas production by covalent immobilization of a methanogenic consortium on to a granulated polymeric support (polyacrylonitrile- acrylamide). The inhibitory effect of oxygen was reduced by immobilizing the methanogenic consortium. Various micro-organisms become active during this stage of methanogenation forming mainly methane and carbon-di-oxide. Usually the methanogenes are not common bacteria, these are called as archaea (Garcia, J.L, et al. 2000). Besides hydrogenotrophic methanogens, acetotrophic methanogens also play a good role. The filamentous acetotrophic methanogens are favoured at low acetate concentration, but not favourable at high ammonium and sulphide concentration (Demirel, Burak et al, 2008).

3. PRODUCTION OF BIOGAS

Omar et al. (2008) observed any improvement in biogas yield up to0.207 m3 kg-1VS added with average methane content of 65 % in the anaerobic handling of cattle manure by addition of palm oil mill effluent as an inoculum in a laboratory scale bioreactor. In another study, obtained biogas production of 26.9 m^3 with an average methane content of 61 % during the anaerobic digestion of 440 kg of cow dung with an energy equivalent of 164.5kWh. These results are encouraging for the use of animal waste available to produce renewable energy and clean environment. In addition to biogas, nutrient-rich digestate is also produced which provide either fertilizer or soil

DOI 10.17148/IARJSET.2016.3930

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 9, September 2016

conditioner properties process of biogas production. Igoni et al. (2008) noted that proper reactor size reduction must be considered for the anaerobic digestion of organic wastes. They further explained that the most important aspect of digestion processes, such as, temperature, hydrogen ion concentration, C/N ratio, OLR, moisture content, heat content and HRT, need to be manipulated so as to achieve optimal performance for anaerobic digester in batch condition for cost effective and economical.

The composition of a substrate is very important for the microorganisms in the biogas process and thus also for process stability and gas production. Rao and Singh (2004) investigated the batch digestion of municipal garbage under room temperature (26±4°C) to estimate its bio-energy potential and conversion efficiencies at an HRT of 15 days. They reported a high yield of 0.56 m3 biogaskg^{-1} VS added with 70 % methane content and a VS reduction of 76.3%. These results demonstrated that municipal garbage has a high potential to be a bio-energy source. The results are comparable with the data reported elsewhere (Saha. 1990). López et al. (2008) evaluated the effect of pre-treating OFMSW (organic fraction of municipal solid waste) with lime in the anaerobic digestion process. The maximum yield of methane obtained under the anaerobic digestion of the pre-treated waste was 0.15 m^3 kg^{-1} VS added. This result is nearly 172 % increase in the methane yield over the control without pre-handling. In addition under the same condition, soluble COD and VS removal were 93 and 94%, respectively. It implies chemical pre-handling with lime, followed by anaerobic digestion, gives the best result for OFMSW stabilization. These results are comparable with the data reported elsewhere (Saha 1998). Macias-Coral et al. (2008) investigated the applicability of a two-phase pilot scale anaerobic co-digestion system for the handling of OFMSW, DCM (dairy cow manure) and CGW (cotton gin waste). They concluded that digestion of the combined wastes resulted in high methane yield as compared to the single waste digestion. Alvarez et al. (2008) experimentally investigated the potential of a semi-continuous mesophilic anaerobic handling of solid slaughterhouse wastes, fruit–vegetable wastes, and manure in a co-digestion process. Anaerobic co-digestion resulted in methane yields of 0.3 m^3 kg^{-1} VS added, with methane content between 54 and 56 % at OLRs in the range 0.3–1.3 kg VS m^3 day^{-1}. A study was conducted on the effect of alkaline condition on the bio gas generation by Ilaboya et al. (2010) results obtained reveals a high volume of gas generated when the operating conditions inside the digester is maintained at moderately alkaline condition. The results show that the addition of different strengths of caustic soda improved gas yield from 1 to 3%wt. /wt. sodium hydroxide solution, however a decrease was 3 observed from 5% wt. /wt. sodium hydroxide handling. Therefore if the pH of the system is maintained at that of prevalent for 3% wt. /wt. caustic handling, more gas will be produced. A comprehensive study on algal biomass as feedstock for biogas production was conducted by M.E. Montingelli et al. (2015). Estimates indicate that the energy potential of marine biomass is more than 100 EJ per year, higher than the land-based biomass accounting only for 22 EJ. In terms of carbon capture during photosynthesis, macro algal primary productivity rates are approximately 1600 g cm^{-2} y^{-1}, comparing favorably to a global net primary productivity of crop land of 470 g cm^{-2} y^{-1}.

Approximately half of the dry weight of the micro algal biomass is carbon, which is typically derived from carbon dioxide absorption. Youngsukkasem et.al (2012) conducted study of biogas production by encapsulated biogas producing bacteria which shows improved results. Encapsulation of methane producing bacteria was carried out with the objective of enhancing the rate of biogas production. Cell retention by filtration and encapsulation, immobilization or recycling by centrifugation has been extensively studied in connection with other processes such as ethanol production (Najatpour et al. 2004).

4. CONCLUSION

The growing global concerns on the increasing amount of waste, global warming and a reliance on fossil fuels as the main energy source have been invigorating research on the anaerobic digestion process and its complexities particularly with the context of greenhouse effect and sustainable development of energy supply. A critical analysis of literature reveals that the anaerobic digestion process is the principal source of biogas manufacturing as methane being the constituent fuel of power and automobile industry. In contrast with other biofuels, in biogas production a wide range of substance can be utilized as long as they are biodegradable. The use of certain substance for the process depends on the ability of the substance to meet the nutritional requirements of the microorganism. Hence substrate composition is very important in the anaerobic digestion process. Bioenergy will be the most significant renewable energy source because it offers an economical attractions and alternative to fossil fuels. Anaerobic digestion has many advantages because of its low consumption of energy, minimum chance of survival of pathogens leading to use of digested residue as fertilizer, low sludge production, smaller space demands, reduction in waste volume and the production of bio-fertilizer and valuable oil conditioners. Appropriate mathematical model taking care of proper control strategies can remove the stability problems related with anaerobic digesters used for biogas production. There needs a standard framework confining over the key step of hydrolysis of organic compound into soluble intermediates involved in the biogas generation as there is lack of sufficient published research work.

REFERENCES

[1] Saha S.N., (2014): Elements of fuel combustion & energy engineering; Dhanpat Rai Publishing Company, New Delhi, 388-389

[2] Ilaboya, I.R., Asekhame, F.F.,Ezugwu, M.O., Erameh A.A., Omofuma, F.E. (2010): Studies on Biogas Generation from Agricultural Waste; Analysis of the Effects of Alkaline on Gas Generation World applied sciencesjournal9(5), 537-545

[3] Moller, H.B., Sommer, S.G., Ahring, B.K. (2004) Methane Productivity of Manure Straw and Solid Fractions of manure. Biomass and Bioenergy, 25,485-495

[4] Gunaseelan, V.N., "Anaerobic digestion of biomass for methane production: A review", Biomass and Bioenergy, vol. 13, issue 1-3, 83-114.Bioenergy, 1997.

[5] https://www.saddahaq.com/biogas-production-in-india-is-equivalent-to-5-of-the-total-lpg-consumption

[6] S.N.Saha., (1986): Anaerobic Process in Difficult Waste Water Treatment, Proc., Ind. Chem. Engg. Congress.

[7] De Baere, L. (2000) Anaerobic Digestion of Solid Waste: State of the Art. Water Science and Technology, 41,283

[8] Holm-Nielsen, J.B., Al Seadi, T and Popiel-Oleskowicz, P (2009), Bioresource Tech., 100, 5478-5484.

[9] Chynoweth, D.P., JN Owens, R.Legand,, Renewable methane from anaerobic digestion of biomass, renewable Energy, vol. 22, 1-3, 2001, 1-8.

[10] Tilche, A. and Malaspina, F., "Biogas production in Europe", Proc., 10th European Conference Biomass for Energy and Industry, Würzburg, Germany, 8–11 June, 1998.

[11] Mata-Alvarez, S. Mace and P.Llabres. (2000): Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives, Bioresource Tech., 74(1), 3-6.

[12] Chen, Ye, Cheng, Jay.J. D Kurt, S. Creamer., (2008) Inhibition of anaerobic digestion process: A review, Bioresource Tech., 99(10), 4044-4064.

[13] Ward, Alastair J, Phil J Hobbs, Peter J Hollman, David L. Jones.,(2008) "Optimization of anaerobic digestion of agricultural resources", Bioresource Tech., 99(17) 7928-7940.

[14] K.J. Chae, A. Jang, S.K. Yim, I.S. Kim., (2008) The effects of digestion temperature and temperature shock on the biogas yields from the mesophilic anaerobic digestion of swine manure, Bioresource Tech., 1–6.

[15] Mattson M., Rundstedt J., karlsson N., (2011), Improving biogas production by anaerobic digestion of different substrate; halmstad university; 8

[16] Merlin Christy, P., Gopinath, L.R., Divya, D., (2014): A review on anaerobic decomposition and enhancement of biogas production through enzymes and microorganisms. Renewable and Sustainability Energy Reviews, 34: 167-173

[17] Chulhwan, P., Chunyeon, L., Sangyong, K., Yu, C., Howard, C.H., (2005) Upgrading of anaerobic digestion by incorporating two different hydrolysis processes. J Biosci Bioeng 100(2):164–7

[18] Appels, L., Jan Degreve, R. Dewil., (2008) Principles and potential of the anaerobic digestion of waste- activated sludge, Prog. In Energy & Comb. Sc., 34: 755-781.

[19] Wood, H.G., Ljungdahl, L., (1991) Autotrophic character of acetogenic bacteria. In: In Shively JM, Barton LL, editors. Variations in autotrophic life. San Diego, Calif.: Academic Press; 201–50

[20] Bjornsson, L., Murto, M, Mattiasson, B., (2000): Evaluation of parameters for monitoring an anaerobic co-digestion process. Appl Microbiol Biotechnol 54:844–849

[21] Mah. R. A., (1982), Methanogenesis and methanogenic partnerships, Phil. Trans. R. Sac. Lond. B 297:599-610.

[22] Kalle, G.P., Kalpana, K., Nayak, Christina, D.A., (1985): An approach to improve methanogenesis through the use of mixed cultures isolated from biogas digester. Journal of BioSci 9:137–144

[23] Lalov, I.G., Milka, A.K., Jean-Louis, P., (2001) Improvement of biogas production from Vinasse via covalently immobilized methanogens. Bioresour Technol; 791:83–5

[24] Garcia, J.L., B.K.C. Patel and B. Ollivier., 2000 Taxonomic, phylogenetic and ecological diversity of methanogenic archaea, Anaerob, 6(4), 205-226

[25] Demirel, Burak and Paul Scherer., (2008); The roles of acetotrophic and hydrogenotrophic methanogens during anaerobic conversion of biomass to methane: a review; Reviews in Env. Sc. And Biotech, 7(2), 173-190.

[26] Omar, R., Harun, R.M., Mohd. Ghazi, T.I., Wan Azlina, W.A.K.G.,Idris, A., Yunus, R., (2008) Anaerobic handling of cattle manure for biogas production. In: Proceedings Philadelphia, Annual meeting of American Institute of Chemical Engineers, Philadelphia, USA, 1-10

[27] Igoni, A.H., Ayotamuno, M.J., Eze, C.L., Ogaji, S.O.T., Probert, S.D., (2008) Designs of anaerobic digesters for producing biogas from municipal solid-waste. Appl Ener 85:430–438

[28] Rao, M., Singh, S., (2004); Bioenergy conversion studies of organic fraction of MSW: kinetic studies and gas yield-organic loading relationships for process optimization. Biores Technol; 95:173–185

[29] Saha, S. N., A Dey, (1990); Development of Dynamic Models For Variability Control in Biological Treatment Process, Proc., Workshop on Pollution Assessment, Monitoring and Abatement In Process Industries With Particular Reference to West Bengal, Calcutta,

[30] Lopez, T.M., Espinosa, L.M.C., (2008) Effect of alkaline prehandling on anaerobic digestion of solid wastes. Waste Manag; 28:2229–2234

[31] Saha, S.N., (1998); Modelling and Simulation of Fluidized Bed Sludge Incinerator, Proc., 28th ISTE Annual Convention, Ludhiana.

[32] Macias-Coral, M., Samani, Z., Hanson, A., Smith, G., Funk, P., Yu, H. Maroun, R., EL Fadel, M., (2007) Startup of anaerobic digestion of source sorted organic municipal solid waste in the absence of classical inoculum. Environment Sci Techno l41:6808–6814

[33] Alvarez, R., Liden, G., (2008) Semi-continuous co-digestion of solid slaughter house waste, manure, and fruit and vegetable waste. Renew Energy; 33:726–734

[34] Montingelli, M.E., Tedesco, S., Olabi, A.G., (2015) Biogas production from algal biomass: A review. Renewable and Sustainability Energy Reviews 43:961-972

[35] Supansa Youngsukkasem, Sudip,K., Rakshit, Jaherzadeh., (2012)Biogas production by encapsulated methane producing bacteria" Bioresources7(1), 56-65

[36] Najatpour, G., Younesi, H., Syahiddah, k., (2004). Ethanol fermentation in an immobilized reactor using saccharomyces cerevisiae. Bioresour Techno 92(3), 251-260