International Journal of Research and Development in Pharmacy and Life Sciences

Available online at http//www.ijrdpl.com

February - March, 2014, Vol. 3, No.2, pp 850-854

ISSN: 2278-0238

Review Article

ANAEROBIC BACTERIAL DEGRADATION OF KITCHEN WASTE - A REVIEW

Sher Singh Gill[1], A.M. Jana[*2] Archana Shrivastav[1]

1. Department of Microbiology, College of Life Sciences, CHRI Campus, Gwalior (M.P.), India.
2. Department of Biotechnology, College of Life Sciences, CHRI Campus, Gwalior (M.P.), India.

***Corresponding Author: Email shersinghgill84@yahoo.com**

(Received: November 01, 2013; **Accepted:** January 03, 2014**)**

ABSTRACT

Kitchen (food waste) was collected from hostels of Cancer Hospital & Research Institute (CHRI), Gwalior's Mess as feedstock for bio-reactor which works as anaerobic digester system to produce biogas energy. Production of biogas ,used as energy source, will be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce CH4 and CO2 emissions, and also bio-fertilizer which contains beneficial bacterial community. This bacterial community plays a major role in the regulation of soil properties on the basis of their biological activity. The absence of oxygen leads to controlled conversion of complex organic pollutions, mainly CH4 and CO2. Anaerobic treatment has favourable effects like removal of higher organic concentration, low sludge production, high pathogen removal, high biogas gas production and low energy consumption. The continuously fed digester requires addition of sodium hydroxide (NaOH) to maintain the alkalinity and pH at 7.0. For this purpose, we have prepared an excellent bacterial community which is applied into mixture of cow dung slurry along with the kitchen waste in bioreactor for CH4 production in large quantity. A combination of these, an excellent bacterial community, was used for biogas production at 37°C in small scale laboratory reactor of 10L capacity.

Keywords: Anaerobic biodegradation, kitchen waste, anaerobic waste treatment, energy recovery, bio fertilizer.

INTRODUCTION

India stands second in the production of Fruits and Vegetables in the world. It contributes about 10% as well as 14% of Fruits and Vegetables in the world production. [1] Vegetable Wastes are created during harvesting, transportation, storage, marketing and processing. Due to their nature and composition, they deteriorate easily and cause foul smell production. In recent years, solid waste treatment has become a serious issue worldwide. [2] Material waste is a by-product of almost all human activities and results in stress and pollution in the environment. Total waste production is not directly proportional to the economic development of the country. Waste prevention is the primary goal of the waste management. Solid waste generation is increasing gradually with the passage of time due to population explosion and urbanization.

Each urban resident generates 0.35–1.0 kg of solid waste every day. [3]This investigation focuses on the handling and utilization of restaurant, catering facility, and kitchen biodegradable waste. The kitchen waste from restaurants, canteens, catering establishments has the potential to spread biological pathogens and infectious diseases (i.e. swine flu, foot and mouth disease, diarrhea, etc). Food waste includes uneaten food and food preparation left over from residences, commercial establishments such as restaurants, institutional sources like school cafeterias and industrial sources like factory lunch-rooms, and is the single-largest component of the municipal solid waste stream by weight. [3] [4] Great potential is expected from the method of anaerobic fermentation, widely used in biogas plants. [5] The components of kitchen waste include spoilt vegetables, peelings and trimmings, fruit skins, spoilt fruit, cooked and uncooked meat, bones, fats, egg-shells, used teabags, coffee grounds, bread and pastries, cooked food waste, tissue papers, packing materials, plastics, glass and water, etc. Due to relatively high moisture content of kitchen waste, bioconversion technologies such as anaerobic digestion are more suitable as compared to thermo-chemical conversion technologies, viz. combustion and gasification. [4]

Recently organic wastes have been recognized as reusable resources and biological treatment of organic solid wastes has considerably increased. The high moisture and organic content in these wastes can be utilized in biological treatment like anaerobic digestion than in other techniques like incineration and composting. Conventional treatment methods for solid waste treatment are composting, land filling and incineration, etc. [6] [4] But these techniques have severe environmental issues associated with them such as air pollution and leachate flow from dumped waste causing water contamination, etc. Kitchen waste is characterized by high organic content, most of which is composed of easily biodegradable compounds such as carbohydrates, proteins, and smaller lipid molecules. As a result of these characteristics, interest in anaerobic digestion has increased for the efficient management of kitchen waste. [2]

ROLES OF MAJOR FACTORS IN BIOGAS PRODUCTION:-

The amount of biogas produced from the digestion process depends on several parameters like

- pH
- Temperature
- Composition of substrate
- Retention time and Organic loading rate

pH

The pH is important because the methane producing methanogens are inhibited under acidic conditions. Moreover, the methanization potential depends on the concentration of four main components present in the substrate viz. proteins, lipids, carbohydrates and cellulose. [7]

Temperature

One of the most important factors affecting anaerobic digestion of organic solid waste is temperature. [8] Generally, anaerobic digestion process is operated under mesophilic or thermophilic condition in which thermophilic digestion is reported to be the more efficient method. [9] [10] However, the anaerobic digestion process can restore its efficiency from imbalance circumstances such as the lower pH condition owning to accumulation of volatile fatty acids (VFAs) and consumption of alkalinity.

Retention time and organic loading rate

The highest methane production can be obtained from systems with excess of lipids and operating at long retention times while the fastest methanization can be achieved from systems with excess proteins, cellulose and carbohydrates, respectively. In addition, overloading of the system with substrates will result in low biogas production. There are several ways to improve the efficiency of biogas yields.

Composition of substrate

One of these is known as co-anaerobic digestion which may result in a better nutritional balance in the system. The variety of organic compounds for example carbohydrates, proteins, lipids, and cellulose can be digested by anaerobic bacteria. [11] These compounds are mainly presented in different organic solid wastes those are commonly used as substrates for the anaerobic digestion. Some examples for organic solid wastes which can be used as digestion substrates are municipal solid waste, slaughterhouse waste, agricultural waste, animal manure, food waste, sewage sludge, etc.[12] The methane content of the biogas produced depends on the carbon presented in the substrate. Higher methane content can be obtained from substrate with high carbon composition. [11] Co-digestion offers many possible ecological, technological and economical benefits.[13] For example, co-digestion of slaughterhouse waste with low nitrogen and/or lipid containing substrates provides better process stability and higher methane production. Slaughterhouse waste is rich in proteins and lipids so the digestion of this waste tend to failure due to the production of ammonia, volatile fatty acids (VFAs) and long chain fatty acids (LCFA) at inhibitory high levels. [14] The biodegradation process can be divided into: (1) aerobic and (2) anaerobic degradation (Fig. 1).

Aerobic biodegradation: Polymer + $O_2 \rightarrow CO_2 + H_2O$ + biomass + residue(s) (1)

Anaerobic biodegradation: Polymer $\rightarrow CH_4 + CO_2 + H_2O$ + biomass + residue(s) (2)

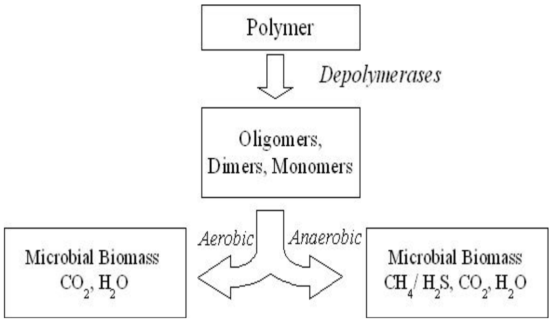

Fig.1. Schema of polymer degradation under aerobic and anaerobic conditions. [15]

If oxygen is present, aerobic biodegradation occurs and carbon dioxide is produced. If there is no oxygen, an anaerobic degradation occurs and methane is produced instead of carbon dioxide. [16] [17] [18] When conversion of biodegradable materials or biomass to gases (like carbon dioxide, methane and nitrogen compounds), water, salts, minerals and residual biomass occurs this process is called mineralization. Mineralization is complete when all the biodegradable materials or biomass are consumed and all carbons are converted to carbon dioxide. [16]

AN ACTIVITY OF ANAEROBIC MICROORGANISMS IN ANAEROBIC DIGESTION:-

In anaerobic digesters, proteins serve as a source of carbon and energy for bacterial growth and a source of nitrogen. Proteins are hydrolyzed by proteolytic enzymes to peptides, amino acids, ammonia, and carbon dioxide. It has been shown that a specialized group of anaerobic bacteria such as the proteolytic Clostridia (e.g. *Clostridium perfringens, C. bifermentans, C. histolyticum, and C. sporogenes*) are responsible for protein degradation in digesters. [19] In addition to these organisms, numerous other species of anaerobic bacteria such as *Bacterioides, Butyrivibrio, Fusobacterium, Slelnomonas, Peptococcus, Campylobacter* and *Streptococcus* are capable for depolymerization of the proteins to amino acids and further to simple fatty acids such as acetic, propionic and butyric acid. [19] [20]

MECHANISM OF ANAEROBIC DIGESTION PROCESS:-

Kitchen waste has high organic content such as soluble sugars, starch, proteins, cellulose, etc. [21] Anaerobic digestion (AD) is a biological process that naturally occurs when bacteria decompose the organic matter producing mainly methane (CH_4) and carbon dioxide (CO_2) in oxygen-free environment.[7] [22] The anaerobic digestion process normally consists of four steps, each of these is completed by different groups of bacteria. These are hydrolysis, acidogenesis, acetogenesis and methanogenesis.[23] All reactions happen simultaneously and are interdependent. Nevertheless, the overall chemical reaction can be simplified to:

$$\text{Organic matter} \rightarrow CH_4 + CO_2 + H_2 + NH_3 + H_2S$$

HYDROLYSIS

In this step which large organic molecules viz. proteins, carbohydrates and fats are enzymatically broken down into smaller molecules. The enzymes are produced by the hydrolytic and fermentative bacteria present in the anaerobic environment. The results of this stage are simple monomers like sugars, amino acids, fatty acids and water. [7] The rate of the hydrolysis step depends on substrate characteristics, bacteria concentration, and also environmental factors such as pH and temperature. [23]

Carbohydrate → Sugars

Protein → Amino Acids

Fat → long chains fatty acids & glycerols

ACIDOGENESIS

Acidogenesis of kitchen waste produces biogas and soluble organic products such as organic acids. [24] Organic acids such as lactic acid followed by acetic and propionic acids were found to be the main products of kitchen waste fermentation.[25] Moreover, methanol and other simple alcohols are also produced by breaking down the carbohydrates. [23] Typical reactions occurring in this stage are presented below:

Conversion of glucose into ethanol: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{heat}$

Conversion of glucose into propionic acid: $C_6H_{12}O_6 + 2H_2 \rightarrow 2CH_3CH_2COOH + 2H_2O$

ACETOGENESIS

In this stage acetogenic bacteria transform the resulting compounds from acidogenesis into acetic acid (acetates) and hydrogen (H_2) and carbon dioxide (CO_2). [7] The concentration of hydrogen is very crucial because the reactions can only proceed when the hydrogen concentration is very low, hence acetogenic bacteria live in symbiosis with hydrogen consuming methanogens. In addition, the acetogenic bacteria are very sensitive to fluctuations of temperature. [23]

METHANOGENESIS

The methanogens convert acetic acid, simple alcohols (methanol, ethanol) or carbon dioxide and hydrogen into methane. Approximately 70 % of total methane production is acquired from the conversion of acetic acid or by fermentation of alcohols, while 30 % of the methane production comes from the reduction of carbon dioxide by hydrogen.[7] [23] The reactions which occur in methanogenesis step are the following:

Conversion of acetic acid: $2CH_3CH_2OH + CO_2 \rightarrow 2CH_3COOH + CH_4$

Followed by $CH_3COOH \rightarrow CH_4 + CO_2$

Conversion of methanol: $CH_3OH + H_2 \rightarrow CH_4 + H_2O$

Reduction of carbon dioxide by hydrogen: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

THE MAIN ADVANTAGES OF THE CO-DIGESTION PROCESS:-

These main advantages of co-digestion are given below:-

- Increased biogas production which can be used for steam heating; cooking and generation of electricity
- Higher organic matter bioconversion
- Better balance of nutrients in feedstock
- Greater fertilizer amounts (digested biomass) and volume reduction
- Reduction of odour nuisance
- Improved biomass dewatering properties. [26] [27]

Kitchen bio-wastes which constitute the main ingredient of municipal bio-wastes are considered as valuable co-substrates of anaerobic digestion. Such bio-wastes are relatively easily accessible and include a large proportion of biodegradable organic matter (approx. 90% of total solids). Biological treatment already demonstrated that is one of the most advantageous methods for maximizing recycle and recovering its components. This process also results in a lower production of leachate and easier handle of digested residues that can be further treated by composting process or be used as fertilizer. [28] Selection of waste/inoculum ratio as well as the assessment of anaerobic biodegradability of solid wastes is also crucial.[29] In case of the anaerobic biodegradability of solid waste, the use of a highly active anaerobic inoculum or animal inoculum waste will reduce significantly experimental time or reduce the amount of inoculum required in full scale batch digesters, and consequently the corresponding digester volume . [30]

REFERENCES

1. Harender Raj Gautam, and Guleria S.P.S. Jan, Science & Technology Entrepreneur; 2007.
2. Park Y.J., Tsuno H., and Hidaka T., Evaluation of operational parameters in thermophilic acid fermentation of Kitchen waste. Journal of Material Cycles and Waste Management; 10; 2008; 46-52.
3. Upadhyay V.P., Prasad M.R., Shrivastav A., and Singh K., Eco tools for urban waste management in India. The Journal of Human Ecology; 18; 2005; 253-269.
4. Zhang R., Hamed M., Hartman K., Wang F., Liu G., Choate Ch., & Gamble P., Characterization of food waste as feedstock for anaerobic digestion. Biores. Tech; 98; 2007; 929–935.
5. Bernstad A., and La Cour Jansen J., A life cycle approach to the management of household food waste – A Swedish full-scale case study. Waste Management; 31; 2011; 1879–96.
6. Schaub S.M., and Leonard J.J., Composting: an alternative waste management option for food processing industries. Trends in Food Science and Technology; 7; 1996; 263-268.
7. Arsova L., Anaerobic digestion of food waste - Current status, problems and an alternative product. M.Sc. thesis, Department of Earth and Environmental Engineering, Columbia University. NYC, USA; 2010.
8. Ahring B.K., Turn-over of acetate in hot springs at 70ºC. Proc. Of Thermophilies: Science and Technology; 1992; 130.
9. De Baere L., Anaerobic digestion of solids waste: state of the art. Water Science & Technology; 41(3); 2000; 283-290.
10. De la Rubia M.A., Romero L.I., Sales D., and Perez M., Temperature Conversion (Mesophilic to Thermophilic) of Municipal Sludge Digestion. Environ. & Energy Engineering; 51; 2005; 2581-2586.

11. Luque R., Campelo J., and Clark J., Handbook of Biofuels Production - Processes and Technologies, Wood head publishing; 2011.
12. Kacprzak A., Krzystek L., and Ledakowicz S., Co-digestion of agricultural and industrial wastes. Chemical Papers; 64(2); 2009; 127-131.
13. Alvarez R., & Liden G., Semi-continuous co-digestion of solid slaughterhouse waste, manure, and fruit and vegetable waste. Renewable Energy; 33(4); 2008; 726-734.
14. Yadav R., Kaur A., Yadav D., Paliwal S., "Synthesis and antimicrobial activity of some newer biphenyl imidazo [2,1-b][1,3,4]thiadiazole derivatives", Int. J. Res. Dev. Pharm. L. Sci., 2012, 1(2), pp. 57-62.
15. Bayr S., Rantanen M., Kaparaju P., and Rintala J., Mesophilic and thermophilic anaerobic co-digestion of rendering plant and slaughterhouse wastes. Bioresource Technology; 104; 2012; 28-36.
16. Gu J.D., Microbiological deterioration and degradation of synthetic polymeric materials: recent research advances. International Biodeterioration & Biodegradation; 2003; 52-69.
17. Kyrikou J., and Briassoulis D., Biodegradation of Agricultural Plastic Films: A Critical Review. J. Polymer Environ; 15; 2007; 125.
18. Grima S., Bellon-Maurel V., Feuilloley P., and Silvestre F., Aerobic Biodegradation of Polymers in Solid-State Conditions: A Review of Environmental and Physicochemical Parameter Settings in Laboratory Simulation. J. Polymer Environ; 2002; 8-4.
19. Swift G., Requirements for biodegradable water-soluble polymers. Polym. Degrad. Stabil; 59; 1998, 19.
20. Palmisano A.C., and Barlaz Morton A., Microbiology of solid waste; 1996.
21. Rozej A., Montusiewicz A., and Lebiocka M., No Title. Archives of Env. Protection; 34(3); 2008; 299-304.
22. Wang X.M., Wang Q.H., Ren N.Q., and Wang X.Q., Lactic acid production from kitchen waste with a newly characterized strains of Lactobacillus plantarum. Chem. Bioche. Eng. Q.; 19 (4); 2005; 383- 389.
23. FOE, Briefing: Anaerobic digestion. Friends of the Earth Limited; 2007.
24. Polprasert C., Organic Waste Recycling - Technology & Mgmt. 3rd ed. IWA Pub, London; 2007.
25. Lim S.J., Kim B.J., Jeong C.M., Choi J., Yeong H.A., and Chang H.N., Anaerobic Organic Acids Production of Food Waste in Once-a-day Feeding and Drawing-off Bioreactor. Bioresour. Technol.; 9; 2008; 7866-7874.
26. Bo Z., Wei-min C., and Pin-jing H., Influence of Lactic Acid on the Two- Phase Anaerobic Digestion of Kitchen Wastes. J. Environ. Sci.; 19; 2007; 244-249.
27. Jedrczak A., Biological wastes treatment, PWN; 2007.
28. Braun R., & Wellinger A., Potential of co-digestion; 2002.
29. Ten Brummeler E., Full scale experience with the BIOCEL process. Water Science and Technology; 41; 2000; 299-304.
30. Lopes W.S., Leite V.D., and Prasad S., Influence of inoculum on performance of anaerobic reactors for treating municipal solid waste. Bioresource Technology; 94; 2004; 261-266.
31. Obaja D., Mace S., Costa J., Sans C., and Mata-Alvarez J., Nitrification, denitrification and biological phosphorus removal in piggery waster using sequencing batch reactor. Biores. Technol; 87; 2003; 103-111.

How to cite your article:

Singh G. S., Jana A. M., Shrivastava A., A review on "Anaerobic bacterial degradation of kitchen waste", Int. J. Res. Dev. Pharm. L. Sci., 2014, 3(2), pp. 850-854.

