Review Article

A Review on Biogas Production from Food Waste

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ABSTRACT

Currently, much of our biodegradable wastes such as kitchen wastes, agricultural wastes & animal wastes are used to produce Biogas, a powerful greenhouse gas. Anaerobic digestion (AD) is a treatment that composts these wastes in the absence of oxygen, producing a biogas that can be used to generate Heat & Power. Producing renewable energy from our biodegradable wastes helps to tackle the energy crisis. It is effectively a controlled and enclosed version of the anaerobic breakdown of organic wastes which releases methane. AD produces a biogas made up of around 60 per cent methane and 40 per cent carbon dioxide (CO_2). As well as biogas, AD produces a solid and liquid residue called digestate which can be used as a soil conditioner to fertilise land. The amount of biogas and the quality of digestates obtained will vary according to the feedstock used. More gas will be produced if the feedstock is more liable to decompose.

Keywords: Anaerobic digestion, food waste Biogas, Renewable energy ,solid waste management.

INTRODUCTION

Anaerobic digestion (AD) is historically one of the oldest processing technologies used by mankind. Until the 1970s, it was commonly used only in the wastewater treatment plants waste management (Palmisano at al. 1996). The amount of generated waste continuously increases and due to the large environmental impacts of its improper treatment, its management has become an environmental and social concern. Rapid biodegradation of the organic waste is of key importance to identify environmental more responsible way to process it rather than land filling or composting it. Anaerobic digestion has the advantage of biogas production and can lead to efficient resource recovery and contribution to the conservation of non-renewable energy sources. Even though proven to be effective for treating organics, anaerobic digestion plants are facing difficulties in obtaining fairly clean feedstock that results in technical difficulties with the equipment and poor compost quality. In this study we have reviewed the anaerobic digestion reactions, biogas production, challenges & management of kitchen wastes.

ANAEROBIC DIGESTION

Anaerobic Digestion (AD) is a biological process that happens naturally when bacteria breaks down organic matter in environments in the absence of oxygen. Anaerobic digestion (AD) is a microbial decomposition of organic matter into methane, carbon dioxide, inorganic nutrients and compost in oxygen depleted environment and presence of the hydrogen gas. This process is also known as bio-methanogenesis for rapid and controlled decomposition of organic wastes i.e. kitchen wastes and biomass feedstock to methane, carbon dioxide and stabilized residue. In the generalized scheme of the anaerobic digestion, the feedstock is collected, coarsely shredded and placed into a reactor with active inoculums of methanogenic microorganisms. Generally three main reactions occur during the entire process of the anaerobic digestion to methane: hydrolysis, acid forming and methanogenesis. Although AD can be considered to take place in three stages all reactions occur simultaneously and are interdependent. We have reviewed the anaerobic digestion reactions, biogas production &management of kitchen waste.

Hydrolysis

Hydrolysis is a reaction that breaks down the complex organic molecules into soluble monomers (constituents) . This reaction is catalyzed by enzymes excreted from the hydrolytic and fermentative bacteria (cellulase, protease and lipase). End products of this reaction are soluble sugars, amino acids, glycerol and long- chain carboxylic acids (Ralph & Dong 2010). The approximate chemical formula for organic waste is $C_6H_{10}O_4$ (Shefali & Themelis 2002) Hydrolysis reaction of organic fraction is represented by following reaction:

$C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2$ (Ostrem & Themelis 2004)

Acitogenesis

This stage is facilitated by microorganisms known as acid formers that transform the products of the hydrolysis into simple organic acids such as acetic, propionic and butyricacid as well as ethanol, carbon dioxide and hydrogen. . Acid forming stage comprises two reactions, fermentation and the acetogenesis reactions. During the fermentation the soluble organic products of the hydrolysis are transformed into simple organic compounds, mostly volatile fatty acids such as propionic, formic, butyric, valeric etc, ketones and alcohols. Typical reactions occurring at this stage are the following - Conversion of the glucose to ethanol: - Conversion of the glucose to propionate: (Ostrem & Themelis 2004) The acetogenesis is completed through carbohydrate fermentation and results in acetate, CO_2 and H_2, compounds that can be utilized by the methanogens. The presence of hydrogen is critical importance in acetogenesis of compounds such as propionic & butyric acid. These reactions can only proceed if the concentration of H_2 is very low (Ralph & Dong 2010). Thus the presence of hydrogen scavenging bacteria is essential to ensure the thermodynamic feasibility of this reaction (Ostrem & Themelis 2004).

Important reactions during the acetogenesis stage are as follow (Ostrem & Themelis 2004)

- Conversion of glucose to acetate:
- Conversion of ethanol to acetate.
- Conversion of propionate to acetate.
- Conversion of bicarbonate to acetate.

Methanogenesis.

Methanogenesis is a reaction facilitated by the methanogenic microorganisms that convert soluble mater into methane . Two thirds of the total methane produced is derived converting the acetic acid or by fermentation of alcohol formed in the second stage such as methanol. The other one third of the produced methane is a result of the reduction of the carbon dioxide by hydrogen. Considering that the methane has high climate change potential the goal is to find an alternative in order to lower the environmental foot print of the organic waste treatment. Therefore this stage is avoided and instead of methane the production of volatile fatty acids is targeted.

The reactions that occur during this stage are as follows (Ostrem & Themelis 2004).

- Acetate conversion

$2CH_3CH_2OH + CO_2 \leftrightarrow 2CH_3COOH + CH_4$

Followed by: $CH_3COOH \leftrightarrow CH_4 + CO2$

- Methanol conversion

$CH_3OH + H_2 \leftrightarrow CH_4 + H_2O$

- Carbon dioxide reduction by hydrogen

$CO_2 + 4H_2 \leftrightarrow CH_4 + H_2O$

PARAMETERS AFFECTING THE ANAEROBIC DIGESTION OF KITCHEN WASTES

1- pH value

The pH value of the reacting material is a pivotal factor in the AD of kitchen waste. The importance of the pH is due to the fact that methanogenic bacteria are very sensitive to acidic conditions and their growth and methane production are inhibited in acidic environment. In batch reactors pH value is closer dependent of the retention time and loading rate. Different stages of the AD process have different optimal pH values. Also the pH value changes in response to the biological transformations during different stages of AD process. Production of organic acids during the acetogenesis can lower the pH below 5 what is lethal for methanogens and cause decrease in the methanogens population. Consequently this would lead to acid accumulation, since the methanogens are responsible for the consumption of the formed acids, and digester failure. Constant pH is crucial in the start-up phase because fresh waste has to go first thru the stage of hydrolysis and acidogenesis before any methane can be formed, which will lower the pH. In order to keep the value of pH on the equilibrium buffer has to be added into the system, such as calcium carbonate or lime.

2 -Composition of the kitchen waste

It is important to know the composition of the kitchen waste in order to be able to predict both the bio-methanization potential and most efficient AD facility design. The bio-methanization potential of the waste depends on the concentration of four main components: proteins, lipids, carbohydrates, and cellulose. This is due to different bio-chemical characteristics of these components (Nerves et al. 2007)

The highest methane yields have systems with excess of lipids but with longest retention time. The methanization of the reactors with excess of cellulose and carbohydrates respectively. The lowest rates of the hydrolysis are with an excess of lipids and cellulose, indicating that when these components are in excess, a slower hydrolysis is induced (Nerves et al. 2007).

2- Loading rate

Organic loading rate is a measure of the biological conversion capacity of the AD system. It determines the amount of feedstock feasible as an input in the AD system. Overloading of the system can results in low biogas yield. This happens due to accumulation of inhibiting substances such as fatty acids in the digester slurry (Vandevivere et al. 1999). The events that would occur in the case of overloading the system, it would cause proliferation of the acidogenic bacteria further decreasing the pH in the system and disturbing the population of the methanogenic bacteria. Also there is a definite relationship between the biogas yield and loading rate. This is the concept that we have to use in the design of this study. The loading rate is at the point in favour of the acidogenesis avoiding the methane production and maximizing the VFA production in it.

3- Retention time

Retention time in the AD reactors, refers to the time that feedstock stays in the digester. It is determined by the average time needed for decomposition of the organic material, as measured by the chemical oxygen demand (COD) and the biological oxygen demand (BOD) of the influent and the effluent material. The longer the substrate is kept under proper reaction conditions, the more complete its degradation will be. However, the rate of the reaction decreases with longer residence time, indicating that there is an optimal retention time that will achieve the benefits of digestion in a cost effective way (Viswanath et al. 1991). The appropriate time depends on the type of feedstock; environmental conditions and intended use of the digested material (Ostrem & Themelis 2004).

4- Operating temperature

Operating temperature is the most important factor determining the performance of the AD reactors because it is an essential condition for survival and optimum thriving of the microbial consortia. Despite the fact that they can survive a wide range of temperatures, bacteria have two optimum ranges of temperature, defined as mesophilic and thermophilic temperature optimum. Mesophilic digesters have an operating temperature 25-40 °C and thermophilic digesters have operating temperature range of 50-65C.

Production of biogas from different waste

I- food waste

Four issues regarding biogas production from food- processing industrial wastes were identified:

1. Characteristics of different food-processing industrial wastes were analysed. Model wastes were chosen from three food-processing industries, i.e. desugared molasses (DM), sugar beet pulp (SBP), sugar beet top (SBT) and sugar beet leaves (SBL) from sugar industry; potato juice and potato pulp from potato starch industry; palm oil mill effluent (POME), deoiled POME and empty fruit bunch (EFB) from palm oil industry.
2. Biochemical methane potentials from the wastes above were determined in batch experiments.
3. Technical feasibility in the continuous reactor experiments using different reactor configuration i.e. continuously stirred tank reactor (CSTR), upflow anaerobic sludge blanket (UASB), expanded granular sludge bed (EGSB) was investigated for treatment of different types of wastes at different operating conditions, i.e. temperature, hydraulic retention time (HRT) and organic loading rate (OLR).
4. Improvement of biogas production and solutions to overcome the inhibition by pre-treatment methods and/or co-digestion with different types of organic wastes or animal manure was tested.

II- agriculture waste

Sustainable agriculture development and increasing the rate of renewable energy sources have become an economic issue after hungary joined the EU. Under the present economic condition the private sector cannot solve in its complexity the problem of environment protection and energy from its own sources.The eco energy system can be built by taking in to consideration the specific local condition.It does not reqire any change of agriculture structure.

III-other waste

Domestic solid waste , paper waste, fruits and vegitable waste and dairy waste etc. are used for biogas production.

Suyog Vij. (2010-11) present this Project was to create an organic processing facility to create biogas which will be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide & methane emissions. Overall by creating a biogas reactors on campus in the backyard of our hostels will be beneficial. Kitchen (food waste) was collected from different hostels of National Institute of Technology, Rourkela's Mess as feedstock for our reactor which works as anaerobic digester system to produce biogas energy. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource Anaerobic digestion is a microbial process for production of biogas, which consist of Primarily methane (CH_4) & carbon dioxide (CO_2). Biogas can be used as energy source and also for numerous purposes. The continuously-fed digester requires addition of sodium hydroxide (NaOH) to maintain the alkalinity and pH to 7. For this reactor we have prepared our Inoculum than we installed batch reactors, to which inoculum of previous cow dung slurry along with the kitchen waste was added to develop our own Inoculum. A combination of these mixed inoculum was used for biogas production at 37°C in laboratory(small scale) reactor (20L capacity) In our study, the production of biogas and methane is done from the starch-rich and sugary material and is determined at laboratory scale using the simple digesters.

Poonam v. shukla et al. (2010) studied biogas production from substrate as cooked food waste(CF), waste bananas(BW), and vegitable waste (VB).The COD reduction in all the substrates was variable depending on the type of substrate. The highest COD removal 94.30% was in CF. The least COD reduction 65.75% and 63.83% was in substrates BW and VW respectively. The COD reduction occured at all pH levels. The initial pH for CF, BW and VW was 5, 5 and 6.3 respectively and the final pH of the three substrates was 6, 5.6 and 11.2. The pH varies with the anaerobic process. Due to acidogenesis stage of anaerobic digestion the pH decreases and later due to methanogenesis stage the pH increases. A falling pH point towards acid accumulation.11 According to Park et al12 the optimum pH range for thermopiles acidogens is 6. Results indicate that the acid concentration affects the alkalinity of the substrates. The pH and alkalinity are the only two parameters which initially decrease and later increase during the study.

UsmanM.A.et al. (2011) presented Biogas was generated from domestic solid wastes collected from residential area in the University of Lagos in a mesophilic laboratory-scale batch digester by anaerobic digestion over a retention time of 20 days at 400C. The wastes collected were characterized and organic wastes are used as feedstock in the setups. Two setups were adopted in the investigation namely digesters A and B. In digester A, 300g of the wastes was mixed water and in the digester B the wastes was blended with poultry dropping in ratio 2:1 and mixed with water, to form slurry in both cases.

Ojikutu Abimbolao et al. (2014) presented comparative study on anaerobic digestion of some common food wastes (yam peels, plantain peels, orange rind and fish waste) and mixtures of these wastes were carried out in batch type digesters for 70 days digestion period. During the experiment, the digestion temperature and volume of biogas produced were monitored daily while the pH of te slurry was monitored weekly. The digestion was carried out in mesophilic temperature range of 30 ˚C to 37 ˚C with a total solid concentration of 8%. The results of study showed that the food waste type had significant ($P \leq 0.05$) effect on substrate temperature and pH but had no significant ($P>0.05$) effect on biogas production. The mean values showed that biogas production was in the range of 1090 ml/day and 8016.67 ml/day. The study concluded that anaerobic digestion of the mixture of the food wastes enhanced biogas production .

S.Mohan et al. (2013) focuses on the generating biogas from food waste produsedby Mahendra Engineering College Canteen using anaerobic digestion process. The biogas yield have been determind using batch anaerobic thermophilic digestion test for a period of 90 days. The total biogas generated in the system over the experimental period was the sum of methane and carbon di oxide. Biogas produced from the decomposition of food waste was a mixture of 76% methane and 24% carbon di oxide.

Dupade Vikrant et al. (2013) worked on mixture of vegitable waste that was an aerobically digested in a 20 lit. capacity lab scale batch reactors. The continuous fed digester reqires addition of sodium hydroxide(NaOH) to maintain the alkalinity and pH to 7.

Thaniya Kaosol presented the co digestion with decanter cake will improve the biogas yield and biogas production of wastewater. The effect of three parameters (type of waste water,mixing and mesophilic temperature) will be evaluated in batch digesters under anaerobic condition . More over the study determines the biogas production potential of several mixtures and that of waste water alone. The codigetion of decanter cake with rubber block waste water of the R4 (wast water 200ml with decanter cake 8 g) produces

the highest biogas yield 3,809 ml CH_4 /g COD removale and the percentage maximum methane gas is 66.7 % . The experimental result shows that the mixing and mesofilic temperature have no significant effect on the biogas potential production.
Subodh kumar Sau et al. studied boiled rice is a polluted organic substance .It is necessary to control the environmental pollution and bio-energy recovery from this waste simultaneously. Human urine is unhygienic to the enviornment whereas it can be utilized as a biocatalyst in predigested with bakhar (mixture of different specific plant roots) and different levels of human urine (150 ml , 200 ml and 250 ml) were added in different batches . it was found that the maximum production of CH_4 (0.011126 m^3/kg boiled rice) was observed by addition of 250ml of urine . The mathematical model equation (chen and hasimoto equation) on biomethanation determined the maximum specific growth rate and kinetic parameter.

Momoh, O.L. Yusuf et al. studied the effect of waste paper on biogas production from the co-digestion of fixed amount of cow dung and water hyacinth was studied at room temperature in five batch reactor for over 60 days . Waste paper addition was varied for a fixed amount of cow dung and water hyacinth until maximum biogas production was achieved . Biogas production was measured indirectly by water displacement method .T he production of biogas showed a parabolic relationship as the amount of waste paper (g) increased with a goodness of fit of 0.982 . Maximum biogas volume of 1.1liters was obsearved at a waste paper amount of 17.5 g which corresponded to 10.0 % total solid of the biomass in 250ml solution . Thus , an optimum waste paper amount of 17.5 g needs to combine with 5 g of cow dung and 5 g of water hyacinth in 250 ml of water for maximum biogas production.

Table 1: Optimal parameter of biogas generation

Material used	PH	COD(g/l)	TS(g/l)	TVS(g/l)	Amount of biogas produced(ml)	Reference
Kitchen Waste	4-7.1	5-25	80-110	68-93	89.37	Dupade Vikrant et al (2013)
Cow dung(200g)	7.25		8		23.75	Dupade Vikrant et al (2013)
Cow dung(400g)	7.25		8		60.02	Dupade Vikrant et al (2013)
Cooked food	5	615.1(mg/l)			87	PoonamV.Shukla etal(2010)
Banana Waste	5	600.2(mg/l)				PoonamV.Shukla etal(2010
Vegitable Waste	6.5	553(mg/l)				PoonamV.Shukla etal(2010
Apple	8.62	74.7	11		0.1L/gVSS	J markos et al(2010)
Acidophilus milk	8.63	74.6	12		0.4L/gVSS	-
Mixed food waste	8.31	252.0	12			-
Ham	8.42	222.6	21		1.3L/gVSS	-
Salami	8.37	729.5	28			-
Domestic Solid Waste			70	52.883	45	UsmanM.A. et al(2011)
Boiled Rice	6.8-7.2				.011126m^3/kg	Subodh Kumar Sau et al
Food waste	6				1090ml/day	Ojikutu AbimbolaO et al (2014)
Decanter cake	4.94	13.35	23.96%	20.71%	3809	Thaniya Kaosol et al (2012)
Paper	6.6-7.6				1001	Momoh et al (2008)
Kitchen wet waste	6.93		12.35%		.6m^3	Navjot Riar et al

CONCLUSION

Anaerobic digestion is a proven technology for processing source-separated organic wastes and has experienced significant growth. This technology is superior to the land filing and also the aerobic composting. The most successful AD processes at this time are thermophilic processes. Even though AD is effective, there are problems associated with the application of this technology in diverting organics from the landfills and composting facilities. Additional difficulties in the operation of AD plants are due to the problem of getting fairly clean feedstock what on the other side is crucial factor for the compost quality and the overall efficiency of the AD process. It is therefore, very important to exercise the discipline required to minimize contamination of source-separated organic wastes and for the AD process to include extensive pre-treatment for contaminant separation. The study carried out in this review has shown that the anaerobic digestion of kitchen waste is a feasible alternative to biogas generation. This finding is of special importance because this lowers the operating costs, decreases the capital and operating costs of the anaerobic digestion of source-separated kitchen waste, and reduces the greenhouse gas emissions of both processes. Further research is necessary to collect additional data on the use of the Anaerobic Digester using kitchen wastes. Also, further experiments should be performed for identifying the optimum operating parameters for producing higher concentrations of VFAs in the liquid product of an acetogenesis reactor. In addition, technical and economic feasibility studies of the environmental and economic aspects of the industrial application of this process alternative should be carried out.

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