Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Vol. 8	No. 1	pp. 157-160	2009

Original Research Paper

Pilot Plant Study on Combined Treatment of Kitchen Refuse and Domestic Sewage By Anaerobic Digestion

S. T. Ramesh, S. Jayanthi* and R. Gandhimathi
Department of Civil Engineering, National Institute of Technology, Tiruchirappalli-620 015, T.N.
*Department of Civil Engineering, Government College of Technology, Coimbatore-641 013, T.N.

Key Words:
Anaerobic digestion
Kitchen refuse
Domestic sewage
Biogas

ABSTRACT

Poor management of kitchen refuse and similar garbages represent the most serious urban environmental and public health problem. Poor waste management has dire environmental and public health consequences. Public health-wise, the presence of waste in residential areas, markets, roadsides, etc. poses grave health hazards to people, in general, and children in particular. The kitchen refuse from hotels, big hostels and residential colonies can be effectively disposed off by anaerobic digestion. Pilot scale model of 500-litre capacity anaerobic digester was operated using kitchen refuse from the students hostel as a feed stock material. Digester performance was monitored by measuring daily pH and gas production. When the steady state was obtained, it was loaded with 1.08 kg total solids with 18 litres of domestic sewage. On the 17th day the steady state was obtained and it was started with a loading rate of 2.3 kg VS/m^3 of digester volume and the gas production was 0.40 m^3/kg VS/day at an HRT of 25 days. The digester performance was 87% TS reduction, 95% VS reduction, 75% of COD reduction with percentage of methane gas as 75%. The probable volume of biogas would be 6.6 m^3/day if it is completely disposed with 50 kg at the rate of 0.4 m^3/kg VS. This gas could serve 38 persons per day at the rate of 0.227 m^3/person/day.

INTRODUCTION

Food wastes are leftover food and food preparation waste from residences, commercial establishments (restaurants), institutions (schools, hospitals), and industrial sources like factory cafeterias, canteens or lunch rooms (Haug 1993, Kreith 1994). In general, food wastes contain more than 80% water aside from oil and biodegradable organic matter (Yun et al. 2000). Due to sanitary reasons such as the production of flies and pathogenic microorganisms, and putrid odours associated with anaerobic decomposition, it is difficult to store food wastes for long periods of time before dumping (Park et al. 2002). Many treatment technologies such as slurry-phase decomposition (Yun et al. 2000), anaerobic digestion (Shin et al. 2001), high-solids aerobic decomposition (Vander Gheynst et al. 1997, Walker et al. 1999, He et al. 2000) and lactic acid fermentation (Wang et al. 2001) have been proposed. At present, direct landfill and/or incineration are the most common technologies being used to handle food wastes (Muller et al. 1998, Tsukahara et al. 1999, Imai et al. 2000, Shin et al. 2001, Han & Shin 2002, Liu et al. 2002). However, available sites for landfill are lacking and incineration of high water containing food wastes requires large amount of energy. Anaerobic digestion of source-sorted and shredded garbage can be an attractive option for both energy generation as well as waste disposal. Though anaerobic digestion of cattle dung has been the commercial biogas energy production technique for many years, application of anaerobic digestion to other wastes such as municipal garbage is yet to obtain commercial acceptance in India. Batch and semi-continuous anaerobic digestion systems are two widely used techniques for bioenergy conversion of organic fraction of wastes in developing countries like India. Batch digestion systems are the simplest ones to use due to their ease of application, operation, low investment and associated maintenance costs (Rao & Singh 2004). The present study was undertaken by operating pilot scale model of 500 litres capacity to evaluate the yield of biogas plant from the hostel kitchen refuse with the following objectives.

- to determine the characteristics of kitchen refuse.
- to determine the characteristics of domestic sewage .
- to study the pilot plant model for co-disposal of kitchen refuse and domestic sewage.
- to evaluate the maximum yield of biogas at a particular organic loading rate at a fixed HRT of days.

The anaerobic digestion (AD) process: Anaerobic biodegradation of organic material proceeds in the absence of oxygen and the presence of anaerobic microorganisms. AD is the consequence of a series of metabolic interactions among various groups of microorganisms. It occurs in three stages, hydrolysis/liquefaction, acidogenesis and methanogenesis. The first group of microorganisms secretes enzymes, which hydrolyses polymeric materials to monomers such as glucose and amino acids. These are subsequently converted by second group, i.e., acetogenic bacteria to higher volatile fatty acids, H_2 and acetic acid. Finally, the third group of bacteria, methanogenic, convert H_2, CO_2, and acetate to CH_4. These stages are described in Fig. 1.

MATERIALS AND METHODS

The kitchen refuse was collected from the hostel kitchen of Government College of Technology, Coimbatore. An average of 235 g of refuse per person was obtained from hostel. This was shredded and used as feedstock for the digester. Domestic sewage was obtained from the collection well of the same campus and was used in all anaerobic experiments to supplement water for diluting the feed stock to get the required total solid concentration for the digestion. The characteristics of wastewater are given in Table 1. Seed sludge was obtained from a cow dung biogas plant located in Vadavalli, Coimbatore. The physical and chemical characteristics of kitchen refuse were estimated as per standard procedures and are given in Table 2 and Table 3.

Experimental setup: A 500 litres capacity plastic tank was used for the digester unit with necessary PVC and GI fittings and gate valves was fabricated with inlet and outlet pipes as shown in Fig. 2.

Operation of the system: To start with, digester was seeded with 40% of the volume by the digested sludge of a cow dung biogas plant with domestic wastewater. Fully shredded kitchen refuse, having 4% of total solids, was added to the digester for acclimatization. The digester was filled later to liquor

Table 1: Chemical characteristics of domestic sewage.

Sl.No	Characteristics	Range
1	pH	6.5 to 7.3
2	Total solids	320 to 800
3	Alkalinity	190 to 240
4	BOD	200 to 300
5	COD	400 to 600
6	Chlorides	180 to 200
7	Sulphates	300 to 550

All values are in mg/L except pH.

Table 2: Physical characteristics of kitchen refuse.

Sl.No	Description	Percentage of waste (on dry weight)
1	Rice	61.59
2	Cereals	19.56
3	Vegetables	15.94
4	Tomato and fruits	2.91

Table 3: Chemical characteristics of feedstock.

Sl.No	Description	Values
1	Carbon/Nitrogen ratio	26 to 32
2	pH	6.7 to 7.1
3	Nitrogen	0.865 % of TS
4	Phosphorus	0.372 % of TS
5	Potassium	0.66 % of TS

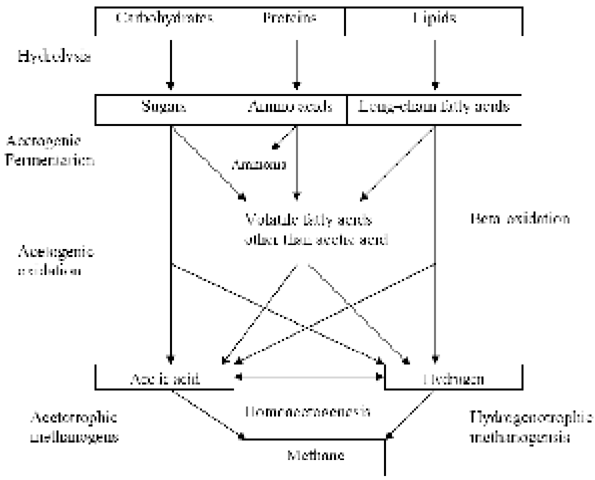

Fig. 1: Pathways in anaerobic degradation.

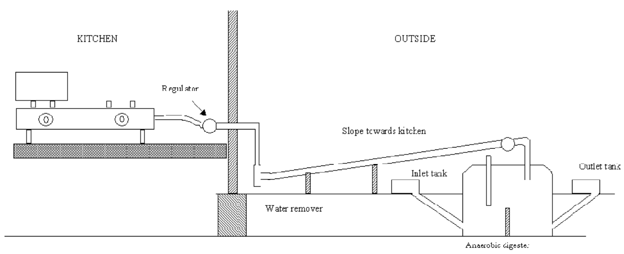

Fig. 2: Experimental pilot plant setup.

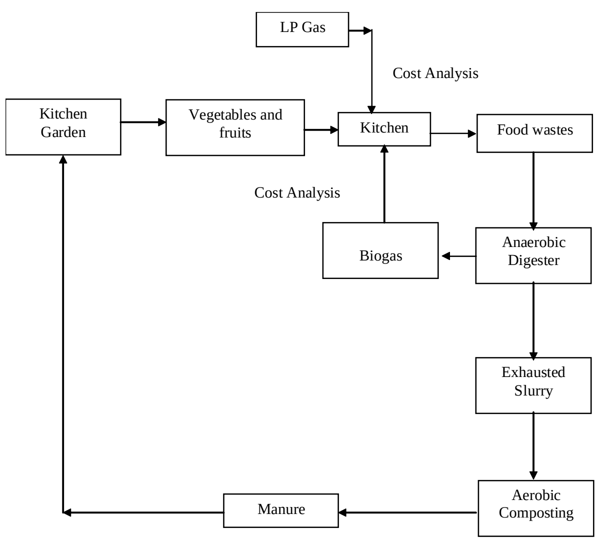

Fig. 3: Integrated anaerobic digestion for energy recovery from kitchen refuse.

volume of 475 litres with domestic sewage expelling out all air inside it for maintaining anaerobicity. Digester performance was monitored by measuring daily pH and gas production. When the steady state was obtained it was loaded with 1.08 kg TS with 18 litres of domestic sewage. Once in a week COD, VS, TS and VFA were measured as per standard procedures.

Analysis of gas and sludge: The moisture content was determined from the difference between the weight of sample prior and after heating at 105°C for 24 h. The volatile solids content and ash content were determined from the difference between the weight of sample prior and after heating at 600°C for 1 hour.

RESULTS AND DISCUSSION

The characteristics of the feedstock are given in Table 4. On the 17^{th} day, steady state was obtained and it was started with a loading rate of 2.3 kg VS/m^3 of digester volume and the gas production was 0.40 m^3/kg VS/day at an HRT of 25 days. The digester performed well with the TS reduction of 87%, VS reduction of 95% and COD reduction of 75%. Percentage of methane gas was 75%. The kitchen refuse generated from the hostel was with an average quantity of 235 g/person/day. For a hostel strength of 230 students, the probable volume of biogas would be 8.6 m^3/day if it is completely disposed off with 50 kg at the rate of 0.4 m^3/kg VS added/m^3/day. This volume of 8.6 m^3/day biogas could serve 38 persons/day at the rate of 0.227 m^3/person/day resulting in a saving of Rs. 17,750/year. The exhausted slurry has good fertility value and can be used for kitchen gardens for good yield of vegetables which can be used for cooking in kitchen which in turn gives the kitchen refuse material as feed stock for digesters (Fig 3). This is an integrated scheme of utilizing the waste material for energy recovery in an environmental friendly way.

Table 4: Characteristics of the feed stock.

Sl. No	Parameters	Characteristics values of the feed stock		
		On the 1st Day	On the 15th Day	% of Reduction
1	pH	7.4	6.7	-
2	TS	15,710	2303	85
3	VS	13,440	632	95
5	COD	20,800	6400	69

All values are in mg/L except pH value.

ACKNOWLEDGEMENT

The authors thank the Environmental Engineering staff members of Government College of Technology, Coimbatore for providing all facilities to carry out this work.

REFERENCES

Han, S.K. and Shin, H.S. 2002. Enhanced acidogenic fermentation of food waste in a continuous-flow reactor. Waste Manage. Res., 20: 110-118.

Haug, R.T. 1993. The Practical Handbook of Compost Engineering. Lewis Publishers, New York.

He, Y., Inamori, Y., Mizuochi, M., Kong, H., Iwami, N. and Sun, T. 2000. Measurements of N_2O and CH_4 from aerated composting of food waste. The Sci. Total Environ., 254: 65-74.

Imai, T., Ukita, M., Sekine, M., Fukagawa, M. and Nakanishi, H. 2000. Fact-finding survey of actual garbage discharged from dormitory and its biological anaerobic-aerobic treatment. Wat. Sci. Technol., 41: 129-135.

Kreith, F. 1994. Handbook of Solid Waste Management. McGraw-Hill Inc., New York.

Liu, H.W., Walter, H.K., Vogt, G.M., Vogt, H.S. and Holbein, B.E. 2002. Steam pressure disruption of municipal solid waste enhances anaerobic digestion kinetics and biogas yield. Biotechnol. Bioeng., 77: 121-129.

Muller, W., Fricke, K. and Vogtmann, H. 1998. Biodegradation of organic matter during mechanical biological treatment of MSW. Comp. Sci. Util., 6: 42-52.

Park, J.I., Yun, Y.S. and Park, J.M. 2002. Long-term operation of slurry bioreactor for decomposition of food wastes. Bioresour. Technol., 84: 101-104.

Rao, M.S. and Singh, S.P. 2004. Bioenergy conversion studies of organic fraction of MSW: Kinetic studies and gas yield-organic loading relationships for process optimization. Bioresource Technology, 95: 173-185.

Shin, H.S., Han, S.K., Song, Y.C. and Lee, C.Y. 2001. Performance of UASB reactor treating leachate from acidogenic fermenter in the two-phase anaerobic digestion of food waste. Wat. Res., 35: 3441-3447.

Tsukahara, K., Yagishita, T., Ogi, T. and Sawayama, S. 1999. Treatment of liquid fraction separated from liquidized food waste in an upflow anaerobic sludge blanket reactor. J. Biosci. Bioeng., 87: 554-556.

VanderGheynst, J.S., Gossett, J.M. and Walker, L.P. 1997. High solids aerobic decomposition: Pilot-scale reactor development and experimentation. Process Biochem., 32: 361-375.

Walker, L.P., Nock, T.D., Gossett, J.M. and VanderGheynst, J.S. 1999. The role of periodic agitation and water addition in managing moisture limitations during high-solids aerobic decomposition. Process Biochem., 34: 601-612.

Wang, Q., Yamabe, K., Narita, J., Morishita, M., Ohsumi, Y., Kusano, K., Shirai, Y. and Ogawa, H.I. 2001. Suppression of growth of putrefactive and food poisoning bacteria by lactic acid fermentation of kitchen waste. Process Biochem., 37: 351-357.

Yun, Y.S., Park, J.I., Suh, M.S. and Park, J.M. 2000. Treatment of food wastes using slurry-phase decomposition. Bioresour. Technol., 73: 21-27.