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FEASIBILITY STUDY ON ANAEROBIC DIGESTION OF GARBAGE USING LIME PRETREATMENT

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ABSTRACT

Freshly collected garbage could easily be decomposed to biogas by anaerobic digestion and the spent residue to vermicompost, there by alleviating a major problem of sanitation and hygiene. The mode of pretreatment required preparing a substrate for anaerobic digestion varies with composition and physical consistency of the feedstock. In this study an attempt has been made on feasibility of using lime as base for alkaline pretreatment to garbage and on an anaerobic digestion of garbage in conjunction with domestic sewage. The study was undertaken by operating laboratory scale digester of 10-litre capacity loaded with garbage after a pretreatment with lime for 24 hours. Assays were run in bio digester operated at room temperature with a constant hydraulic retention time of 25 days with different organic loading rates by varying the percentage lime pretreatment. The digester efficiency reflected as the methane yield decreases. Concerning the conversion efficiencies, the maximum gas yield of 0.22 m3 / Kgvs added was achieved at the organic loading rate of 3.34 kg vs / m3 / day, with pre treatment of 4 % lime.

INTRODUCTION

Garbage, Fruit and vegetable wastes (FVW) are produced in large quantities from towns, villages, hostels, vegetable markets, hotels and constitute a source of nuisance in municipal landfills because of their high biodegradability (Viturtia *et al.* 1989; Misi and Forster, 2002). These refuses are highly pulverisible in nature and are discharged into streets, dust bins and on open areas posing ugly scenes and create a lot of problems like bad odor, insects, rodents and in due to course cause unexpected danger to human health. Besides these ill effects, these wastes contaminate the ground water sources through leachate. In India, FVW constitute about 5.6 million tonnes annually and currently these wastes are disposed by dumping on the outskirts of cities (Srilatha *et al.* 1995).The present methods like open dumping, incineration, Pyrolysis etc for the disposal of wastes has there owned problems through out the world. The most promising alternative to incinerating and composting these wastes is to digest its organic matter using the anaerobic digestion (Bouallagui *et al.* 2003; Mata-Alvarez *et. al* 1992). The main advantage of this process is the production of biogas, which can be used to produce electricity (Mata-Alvarez *et al.* 1992; Ahring *et al.* 2002). A valuable effluent is also obtained, which eventually can be used as an excellent soil conditioner after minor treatments (Converti *et al.* 1999; Simeonov, 1999). The successful applica-

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tion of anaerobic technology to the treatment of solid wastes is critically dependent on the development and use of high rate anaerobic bioreactors (Weiland, 1993; Lissens *et al.* 2001). The reactor design has a strong effect on digester performance (William and David, 1999). Before being loaded to the reactors, FVW must undergo some pre-treatments (Srilatha *et al.* 1995; Converti *et al.* 1999). They were shredded to small particles and homogenized to facilate digestion. They were also diluted to decrease the concentration of organic matter and then to operate the reactors with optimal organic loading rate (Mata-Alvarez *et al.* 1992; Bouallagui *et al.* 2003). Due to the lower pH of FVW, some authors buffered these waste by the addition of sodium hydroxide solutions (Srilatha *et al.* 1995; Mata-Alvarez *et al.* 1992). Without any regulation, the pH quickly decreased and tended to inhibit the methanogenic bacteria (Verrier *et al.* 1987).

In this study an attempt has been made on feasibility of using lime as a base for alkaline pre treatment to garbage and on anaerobic digestion of garbage in conjunction with domestic sewage with the specific objectives as follows,

- Determination of the quantity of waste generated from an area
- Determination of the characteristics of garbage
- Determination of the characteristics of sewage
- Evaluation the maximum yield of biogas at a par ticular organic loading rate at a fixed HRT of 25 days with alkaline pretreatment to the feed stock by varying the percentage of Lime
- Determination of kinetic parameter for anaerobic digestion of garbage using first order kinetics.

ANAEROBIC DECOMPOSITION

The biomethanation of FVW is accomplished by a series of biochemical transformations, which can be roughly separated into four metabolic stages (Knol *et al.* 1978; Landine *et al.* 1983) (Fig. 1). First, particulate organic materials of FVW like cellulose, hemicellulose, pectin, and lignin, must undergo liquefaction by extracellular enzymes before being taken up by acidogenic bacteria (Koster, 1984). The rate of hydrolysis is a function of factors, such as pH, temperature, composition, and particle size of the substrate and high concentrations of intermediate products (Hans and Cosima, 1984; Veeken *et al.* 2000) . After that, soluble organic components including the products of hydrolysis are converted into organic acids, alcohols, hydrogen, and carbon dioxide by acidogens. The products of the acidogenesis are then converted into acetic acid, hydrogen and carbon dioxide. Finally, methane is produced by methanogenic bacteria from acetic acid, hydrogen and carbon dioxide as well as directly from other substrates of which formic acid and methanol are the most important (Veeken *et al.* 2000). In general, hydrolysis is the rate limiting step if the substrate is in particulate form (Adney *et al.* 1991; Veeken and Hamelers, 1991). However, the anaerobic degradation of cellulose-poor wastes like FVW is limited by methanogenesis rather than by the hydrolysis (Cecchi *et al.* 1986; Mata-Alvarez *et al.* 1990). These wastes are very rapidly acidified to volatile fatty acids (VFA) and tend to inhibit methanogenesis when the feedstock is not adequately buffered (Landine *et al.* 1983). In one-stage systems, all these reactions take place simultaneously in a single reactor, while in two-or multistage systems, the reactions take place sequentially in at least two reactors. In a well-balanced anaerobic digestion process, all products of a previous metabolic stage are converted into the next one without significant build up of intermediate products (Kubler *et al.* 2000). The overall result is a nearly complete conversion of the anaerobically biodegradable organic material into end products like methane, carbon dioxide, hydrogen sulphide and ammonia.

MATERIALS AND METHODS

Garbage

The garbage was collected from the hostel kitchen of Government College of technology. The collected garbage sample was dried in oven and shredded to the maximum particle size of 2 mm. This was stored in a plastic container at room temperature and was characterized and used during all anaerobic digestion treatment. The physical composition of garbage and the chemical characteristics are given in Table 1 & 2.

Domestic sewage

It was obtained from the collection well of the same campus before disposal and was characterized in Table 3. It was used in all anaerobic digestion experiment to supplement water for diluting the feedstock to get the required total solid concentration for the experiments.

Seed Sludge

It was obtained from the septic tank of a college campus and was used for seeding the digester.

Experimental set up

Experiments were conducted in 10-lit capacity reac-

Table 1
Physical Composition of Garbage

Sr.No.	Components of Garbage	Percentage Composition
1.	Cabbage leaves	53-68
2.	Beans	9-12
3.	Tomato	6-12
4.	Curry leaves	14-25
5.	Potato leaves	7-15

Table 2
Chemical Composition of Garbage

Sr.No.	Parameters	Values (dry basis)
1.	Moisture content %	15
2.	TS %	85
3.	VS (% of TS)	86
4.	Ash (% of TS)	14
5.	pH	6.9

Table 3
Chemical Characteristics of Domestic Sewage

Sr.No.	Characteristics	Values
1.	pH	7
2.	Total solids	940
3.	Volatile solids	390
4.	Dissolved solids	910
5.	Alkalinity	210
6.	BOD_5	230
7.	COD	540
8.	Chlorides	190
9.	Sulphates	420

All the values are in mg/L except pH

Table 4
Operating Conditions of Anaerobic Digestion Process for Garbage

Sr.No.	Parameters	Garbage
1.	Type	Slurry
2.	Process type	Semi-continuous
3.	Temperature (^{0}C)	25-40
4.	HRT (days)	25
5.	OLR (Kg_{vs} / m^3 / day)	3.06-3.55
6.	Lime (%)	2-7

tor operating in semi continuous mode with daily feeding. The digester was operated at room temperature at a constant Hydraulic Retention Time (HRT) of 25 days by varying the percentage of lime used for pre treatment. The experimental setup is shown in Fig 2.

Operation of the system

To start with the digester was seeded with 40 % of their volume (10 Lit capacity digester) by the digested sludge of a cow dung biogas plant and fully shredded Garbage having 2 % of total solids was added to the digester for acclimatization and the digester was filled to liquor volume of 8.75 litres with expelling out all air inside the digester for maintaining anaerobicity. Digester performance was monitored by measuring daily pH production. When the steady state was obtained it was loaded with 60 grams of Garbage with 360 mL of domestic sewage pretreated with lime for 24 hours. Daily pH and gas productions were measured. Once in a week, COD, TS, VS, Alkalinity were measured.

Anaerobic digestion experiment

The anaerobic digestion experiment was carried out with the substrate (Garbage + domestic sewage) at 5 different organic loading rate as follows, 3.06,3.34,3.49,3.55 Kg vs/ m3 of reactor/day with lime percentage of 2, 4,6,7 (10,15,20,25 grams) respectively.

Analysis of the experiment

The physical and chemical analysis was carried out on the feedstock and the effluent samples for their characterization and process monitoring. Moisture content, total solids, volatile solids, alkalinity, Chemical oxygen demand were determine according to the standard methods. Total biogas produced in the anaerobic digester was measured daily by water displacement methods. Methane content of the gas was estimated by displacement of saturated solution of potassium hydroxide in sacharometer.

RESULTS AND DISCUSSION

The substrate for the anaerobic digestion experiment was prepared using garbage dry sample of particle size 2 mm plus domestic sewage with lime treatment for 24 hours. Addition of lime percentage was varied from 2 to 7 %. The addition of lime increases the organic loading rate for the same amount of the substrate. The production of biogas was increased from 0.206 to 0.22 m3/kg vs added when the organic loading rate was increased from 3.06 to 3.34 Kg vs/m3/ day. Further increase in organic loading rate decreased the gas production rate. The maximum biogas production was 0.22 m3/kg vs added and an organic loading rate of 3.34 Kg vs/m3/day and with the 4 % of Lime. The conversion efficiency of Total solids,

Table 5

Steady State Profile of Anaerobic Digestion of Garbage Pre Treated With Lime for Different Loading Rate

Sr.No.	Factors Analysed	Organic Loading rate in kg_{vs} / m^3 / day			
		3.06	3.34	3.49	3.55
1.	Lime				
	Percentage	2	4	6	8
	Weight (gms)	5	15	20	25
2.	Total solids				
	Influent mg/L	120270	118730	109350	99970
	Effluent mg/L	70950	55440	72650	70980
	Percentage reduction %	41	55	33.5	29
3.	Volatile solids				
	Influent mg/L	82210	94610	82970	71350
	Effluent mg/L	50670	38990	53750	49945
	Percentage reduction %	42.5	58.78	35.22	30
4.	Chemical oxygen demand				
	Influent mg/L	66000	64000	60000	54000
	Effluent mg/L	30000	24000	40000	38750
	Percentage reduction %	54.54	62.5	33.33	28
5.	COD/VS Ratio				
	Influent	0.8	0.67	0.72	0.75
	Effluent	0.59	0.61	0.74	0.77
6.	Alkalinity mg/L	1000	2200	2600	3000
7.	Specific gas yield				
	m^3/kg vs added	0.206	0.22	0.2	0.158
8.	Specific methane				
	m^3/kg vs yield	0.2	0.21	0.18	0.15
9.	Gas production rate				
	m^3 / m^3/day	0.63	0.73	0.698	0.56
10.	Methane production rate	0.64	0.7	0.63	0.53

Volatile solids and Chemical oxygen demand at this optimum loading rates were 55 %, 59 % and 62.5 % respectively. It was found from the Fig 3, the optimum biogas yield was 0.22 m3/kg vs added and an organic loading rate of 3.34 kg vs/m3/ day. The maximum reduction of total solids is about 55 %, volatile solids reduction is about 59% and COD reduction is 62.5 occurred at the optimum loading rate. The COD/VS ratio of the effluent decreases with COD/VS ratio of the influent (Fig 4). This indicates that VS increases with an increase in organic loading rate but decreases in biodegradable COD beyond certain increase in loading rate. COD/VS ratio of the effluent increases than the COD/VS ratio of the influent after the optimum loading rate. It reveals that anaerobic bio degradability decreases beyond a certain increase in organic loading rate. The addition of lime increased by organic loading rate for the same amount of the substrate since during soaking of lime with garbage and sewage caused extensive swelling and separation of structural elements. Pre treatment with lime acted as a buffering system through out the digestion system. Lime was chosen as alkaline base because of its economic costs.

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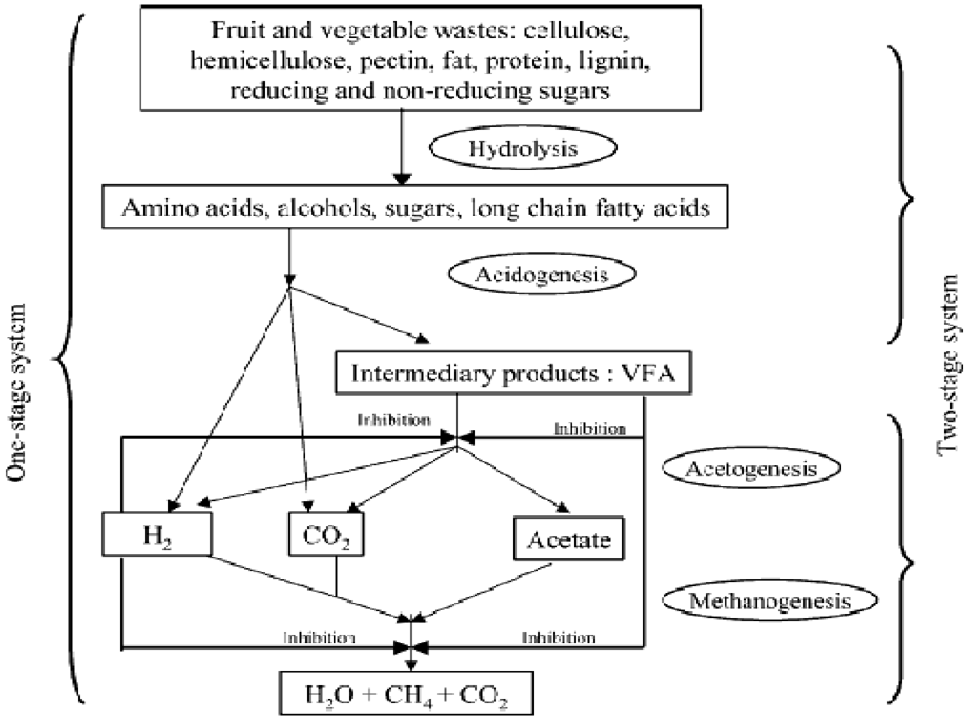
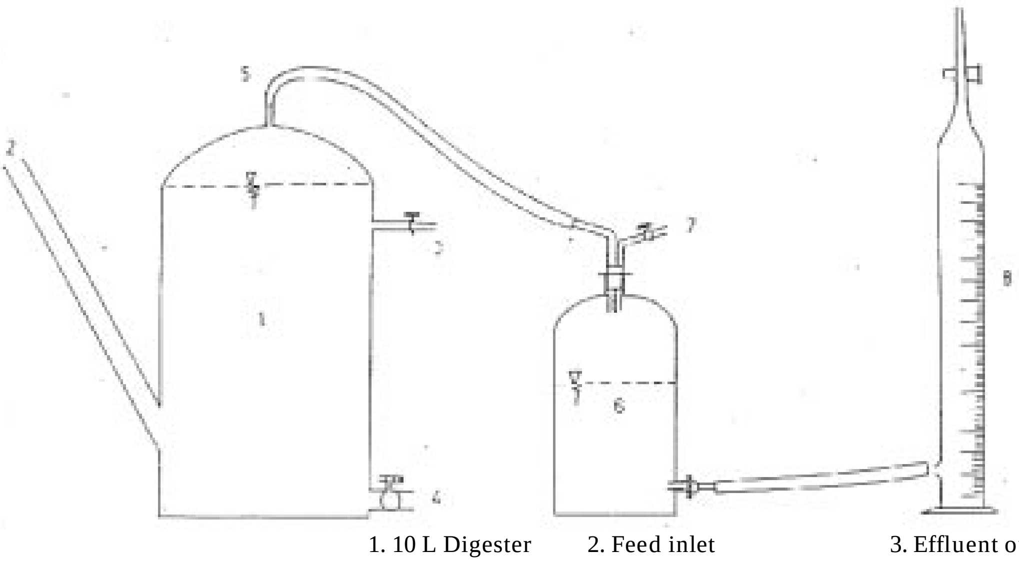


Fig. 1 Reactions scheme for anaerobic digestion of particulate organic material of FVW



1. 10 L Digester 2. Feed inlet 3. Effluent outlet 4. Sludge outlet
5. Gas opening 6. Water displacement Jar 7. Gas outlet 8. Measuring Jar

Fig 2. Experimental Setup

versus thermophilic conditions. *Bioprocess Eng.* 21: 371–376.

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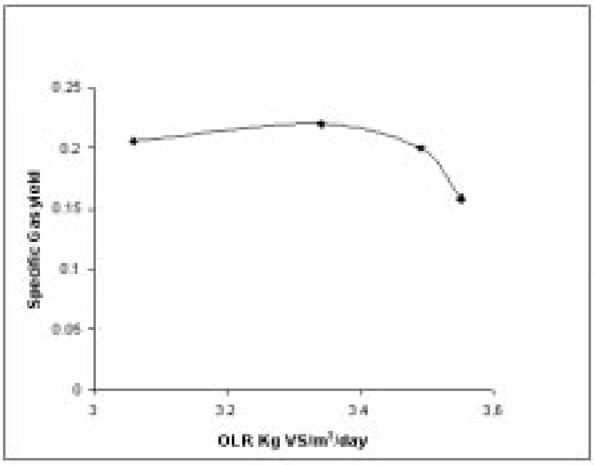

Fig. 3 Organic loading rate Vs Specific Gas yield

Fig. 4 Organic Loading rate Vs COD / VS Ratio

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