Effect of total solid concentration on anaerobic digestion of the organic fraction of municipal solid waste

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Abstract- In this study batch anaerobic digestion of organic fraction of municipal solid waste was carried out for 100 days at room temperature for varying substrate concentration of 115, 99 and 83g/l. The performance of reactors was evaluated by measuring the daily biogas production and calculating the degradation of total solids and the total volatile solids. Effect of organic solids concentration and digestion time on biogas yield was studied. The biogas yields at the end of the digestion from the reactors were 22.7L/KgVS, 54.4L/KgVS and 41.7L/KgVS respectively. About of 71.69%, 80.06% and 76.55% Volatile solid degradation were obtained during the loading in reactors.

Keywords: Anaerobic digestion; Volatile solid degradation; Municipal solid waste; biogas yield

I. INTRODUCTION

Municipal solid waste (MSW) generation is significantly increasing in Indian urban areas and started creating enormous waste disposal problems in the recent past [1]. In India, MSW management is the duty of the local municipalities [2].More than 90 percent of the municipal solid waste (MSW) generated in India is dumped in an unsatisfactory way, what creates environmental hazards to water, air and land. At the same time the organic fraction of MSW is about 40-60 percent [3]. In Kerala, around 70% of the waste is compostable organics enabling high level of recycling in the form of manure or fuel [4]and [5]. The anaerobic digestion is an attractive option for energy generation from the putrescible fraction of MSW as well as for reducing the disposal problem [6]. It has reduced environmental impact, especially with respect to the greenhouse effect and global warming.

Anaerobic digestion is a biological process wherein diverse group of microorganism convert the complex organic matter into a simple and stable end products in the absence of oxygen [7]. This process is very attractive because it yields biogas, a mixture of methane and carbon dioxide which can be used as renewable energy resources. AD of organic fraction of municipal solid waste (OFMSW) is used in different regions worldwide to reduce the amount of material being landfilled, stabilize organic material before disposal in order to reduce future environmental impacts from air and water emissions and recover energy. Several research groups have developed anaerobic digestion processes using different organic substrates [8]-[10].In this view, anaerobic digestion of solid waste is a process that is rapidly gaining momentum to new advances especially in the area of dry anaerobic fermentation and has become a major focus of interest in waste management throughout the world. It appears to be the reliable and promising process for the treatment of organic solid waste. Moreover, when compared to other conversion technologies for treatment of the organic fraction of MSW, the economic, energy, and environmental benefits makes anaerobic digestion an attractive option [11].

The characteristics of the biogas produced depends upon the nature and type of the biomass or feed (wastes) used. The nature of the wastes varies with the locality from which it is collected. Waste generated from a particular region shows the nature of the inhabitants living in that region, their food and other habits, various industries and other commercial units in the region etc. based on these factors the nature and characteristics of waste generated changes from place to place. Thus the quantity and quality of biogas produced depends upon the area from which the biomass is collected. In our study we are using waste collected from Kerala which has its own particular characteristics which makes the study unique.

Anaerobic digestion technology has tremendous application in the future for sustainability of both environment and agriculture because it represents a feasible and effective waste-stabilization method to convert the undiluted solid bio-waste into renewable energy with nutrient rich organic fertilizer. However, the application of this process is limitedly practiced especially in developing countries due to the lack of appropriate treatment system configurations and mainly due to the longer time required for the biostabilization of waste. Any kind of reactors design and operational criteria selection to be operated is depends upon the feedstock characteristics, financial aspects etc. Anyhow, each mode of operation always has its own advantages and limitations. Therefore the purpose of the present study is to develop feasible anaerobic digestion process for the treatment of OFMSW for potential energy recovery and sustainable waste management and the optimization of environmental conditions within the digester such as temperature, pH, buffering capacity and volatile fatty acid concentrations etc[12]for maximizing the biogas production in a shorter retention time.

II. METHODS

A. Experimental reactors

The experiments were carried on batch laboratory scale reactor (aspirator bottle) with total capacity of 2 L. The reactor was made of borosilicate glass with bottom sampling outlet. The bottles were closed by rubber stoppers equipped with glass tubes for gas removal and for adjusting the pH. The glass tube was dipped inside the slurry to avoid gas loss during the pH adjustments. The effective volume of the reactor was maintained at 1.6L.Biogas production from the reactors was monitored daily by water displacement method. The volume of water displaced from the bottle was equivalent to the volume of gas generated. The reactor was mixed manually by means of shaking and swirling once in a day. The reactors was operated at room temperature

B. Inoculum

The inoculum used in this study was fresh cattle dung which contains all the required microbes essential for anerobic digestion process. The pH, total solid and volatile solid of the inoculum were 6.5,24.2% and 85.4% respectively. The percentage of inoculum for acidogenic fermentation of the organic wastes is approximately 30% of the working volume. The inoculum was collected and kept at 4°C until used.

C. Feed stock preparation

Fresh organic fractions of MSW and inoculum were used as feed to the bio rector. Organic fraction of MSW consists of food waste, fruit waste, vegetable waste from nearby vegetable market and house hold. The wastes were sorted and shredded, then mixed several times in laboratory and kept at 4°C until used. All reactors were loaded with raw feed stock and inoculated with fresh cattle dung. Water was added to obtain the desired total solid concentration. The characteristics of the substrate and feed were shown in the Table 1.

D. Experimental procedure

The study is programmed to evaluate the mesophilic digestion of OFMSW at three different initial substrate concentrations. The substrate concentration was expressed as weight of solids/total volume of solids plus water, assuming that the density of the solids is approximately equal to the density of water. Three reactors were used of 2L total volume and 1.6L effective volume at discontinuous condition but different total solids concentrations of 115g/l , 99g/L and 83 g/L respectively. All the reactors were fed with municipal garbage, tap water and cattle dung slurry (inoculum), used as the starter in the reactors. Liquid samples were drawn from each reactor periodically and analysed for pH, volatile fatty acids, alkalinity chemical oxygen demand and ammonia nitrogen. The pH was measured every 2 days and it was maintained in the range of 6.5 to 7.5 using 6N sodium hydroxide solution as which is the optimum range for methonogens growth [13]. Volatile fatty acids, alkalinity chemical oxygen demand and ammonia nitrogen were analysed once in a week. Daily biogas production was measured by water displacement method. The substrate was mixed once each day, at the time of the gas measurement, to maintain intimate contact between the microorganisms and the substrate.

E. Analytical methods

The parameters analyzed for the characterization of substrates were as follows: Total Solids (TS), Volatile Solids (VS), pH, Volatile fatty acid (VFA), Total Kjeldahl Nitrogen (TKN), Total Organic Carbon (TOC).Following quantities were monitored during the digestion process: pH, VFA, alkalinity, Ammonia nitrogen(NH_3-N),COD and production of biogas. All analytical determinations were estimated according to the procedures recommended in the Standard methods for examination of water and waste water [14].

pH was measured using digital pH meter. TS samples were dried in an oven at 105-110 ºC, and for VS to the dried ash waste in a muffle furnace at 500 ±50 ºC. TKN and NH_3-N content were examined using the spectrophotometer ((HITACHI,U-2900 UV/VIS spectrophotometer). VFA and alkalinity were done using simple titration method (***Anderson and Young, 1992***).TOC analysis was carried out using Shimadzu TOC-LCPH/CPN analyser for non- purgeable Organic Carbon from the standard methods.

Gas production was measured at a fixed time each day by the water displacement method, with water prepared as specified in standard methods. Chemical oxygen demand (COD) was also determined using standard techniques

III. RESULT AND DISSCUSSION

A. Substrate characteristics

Table 1 shows a summary of the characterization of substrate and initial mixtures of each reactors. The experiments were concluded when no significant variation of cumulative biogas production was observed. The experiments were done for 100days.The pH and VFA values of the mixtures are in accordance with the composition of OFMSW.

B. Performance of batch reactors

In an anaerobic system, the acetogenic bacteria convert organic matter to organic acids, possibly decreasing the pH, reducing the methane production rate and the overall anaerobic digestion process unless the acids were quickly consumed by the methanogens. pH in the range of 6.8 to 7.4 should be maintained in the anaerobic digestion process, which is the optimum range for methanogens growth. A decrease in pH was observed during the first few days of digestion due to the high volatile fatty acids formation, hence the pH was adjusted to 7 using 6N NaOH solution. The profile of pH and volatile fatty acids are shown in the figures.1 to 3.

From day 35to 70, the pH was almost found steady. Despite of steady pH the biogas gas production was low during that period due to lack of mixing. The VFA generation in the beginning was high due to higher acidogenesis and lower methanogenic activity. The initial pH drop and high volatile fatty acid concentration show that the substrate contains some easily biodegradable constituents. After day 40 the VFA concentration was found decreased due to methanogenic activity in which the intermediate organic acids was started to convert into biogas.

Table 1: Characteristics of the substrate and feed

Parameter	OFMSW	R1	R2	R3
pH	6.15	6.42	6.61	6.64
TS(%)	18.5	10.32	9.2	8.4
VS(%)	91.6	85.37	86.78	89.6
VFA(millieqivalents/L)	10.85	8.65	9.57	6.98
COD(mg/L)	42835	43152	37318	31987
TKN(g/L)	1.05	1.1	1.09	0.92
TOC(g/L)	20.32	23.87	20.5	16.76

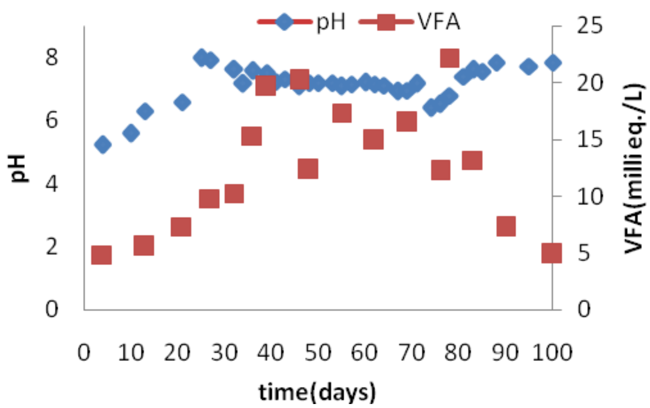

Fig.1: Variation of pH and VFA for TS concentration 115 g/L

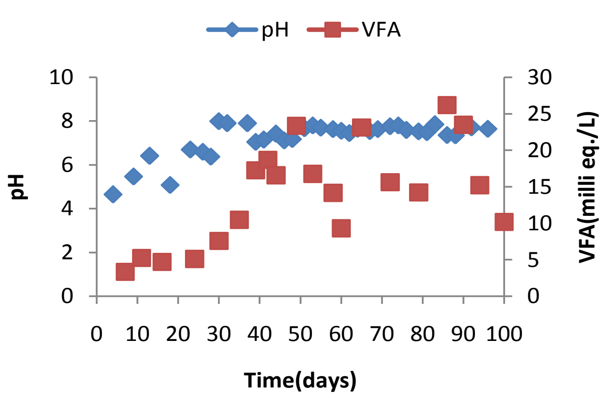

Fig.2:Variation of pH and VFA for TS concentration 99 g/L

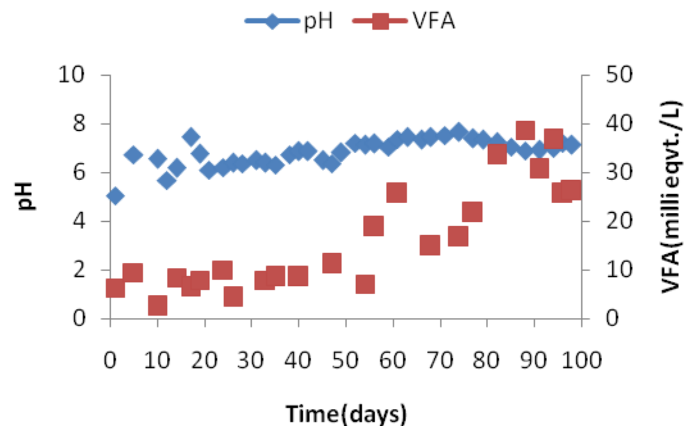

Fig.3: Variation of pH and VFA for TS concentration 83 g/L

The Figure 4 to 6 depicts the variation of COD and NH3-N during the study. The COD of the leachate was found decreasing due to conversion of organic matter into biogas.In this experiment, concentrations of NH4-N were increasing due to release of ammonia during hydrolysis of protein or utilization of nitrogen for biomass synthesis. It is evident that NH4-N concentration (>6000mg/L) indicates the inhibition of methanogens in an acclimated environment [15].In this study, the NH4-N concentration increased from 12mg/L to 1400mg/L. So it can be concluded that there was no any inhibitions of ammonia nitrogen during the AD process of this system.

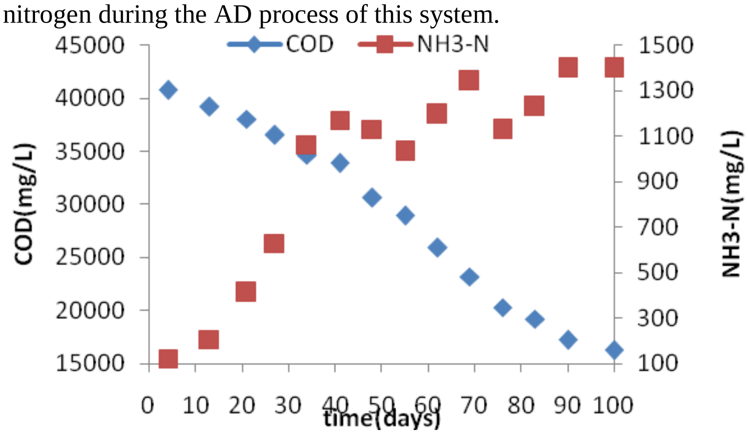

Fig 4: evolution of COD and NH3-N (mg/L) in the digester for TS concentration115 g/L

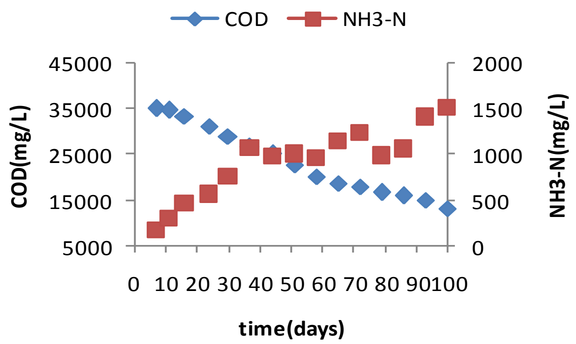

Fig 5: evolution of COD and NH3-N (mg/L) in the digester for TS concentration 99 g/L

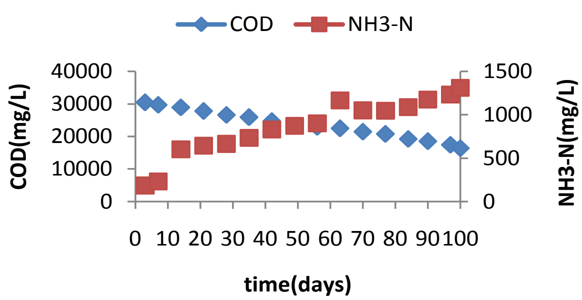

Fig 6: evolution of COD and NH3-N (mg/L) in the digester for TS concentration 83g/L

Figures 7 and 8 indicates the daily and cumulative biogas production for 3 reactors. where the biogas production was high in thebeginning which was due to the entrapped air inside the reactor and the waste itself. The reactors R1, R2 andR3 were operated with total solid concentration of 115g/l ,99g/l and 83 g/l. Initially in the reactors R1 and R2 the production was stopped due to the reduction of pH. So after adjusting the pH value in the optimum range by addition of 6N NaOH to the system, the production was increased. In reactor 3 optimum range of pH was initially made up. Hence the production was not stopped in R3.In R1 initially thick slurry was formed due to high solid contents in the reactor. So the production of biogas was reduced in the initial stages.

The maximum daily biogas production obtained for R1 was 120ml in 69th day and that for R2 and R3 were 340 ml in 58th day and 150ml in 29th day. At the end of the 90 days total cumulative biogas for R1, R2 and R3 was obtained as 3.574L, 7.474 L and 4.957L respectively. The biogas production was decreased from90-100days due to lack of amount of substrate.

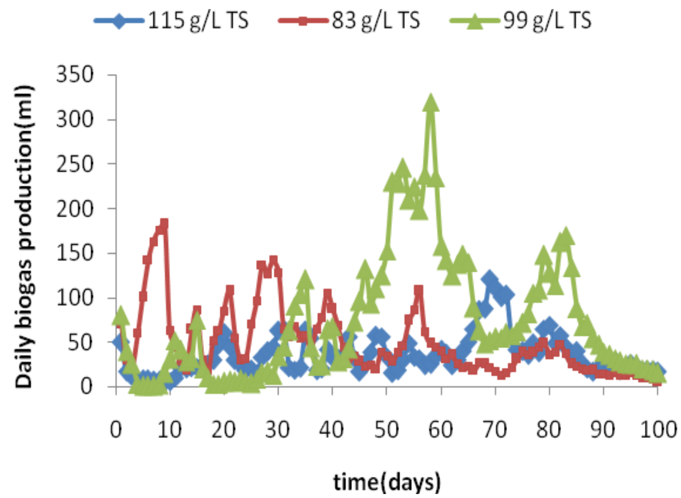

Fig7: variation of daily biogas production versus days for different substrate loading

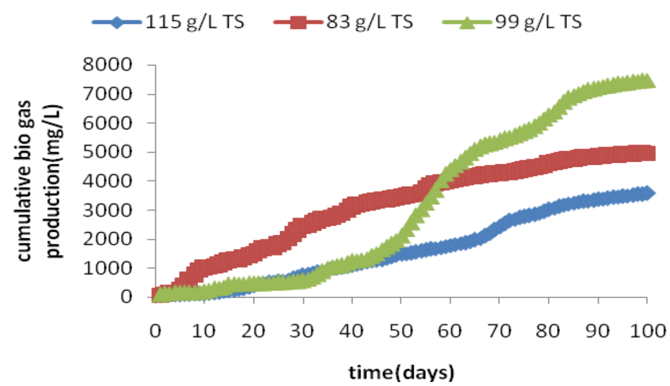

Fig 8: variation of cumulative biogas production versus days for different substrate loading

C. Comparative process efficiency

The summary of performance of batch reactors mentioning the characteristics of initial and digested substrate, along with their degradation percentages, under different conditions (TS concentration 100, 90 and 80g/l) are given in Tables 3. It was observed that 71.69% of the total volatile matter converted in reactor 1 and that for R2 and R3 are 80.06 and 76.55 respectively. From the table it was observed that maximum degradation was occurred for reactor 2.The biogas yield, biogas produced per kg organic solids (volatile solids) for different concentrations of organic loading over a 100-day digestion time at room temperatures are shown in Fig 9. The rates of biogas production differed significantly according to the organic loading. It can be observed from 9 that bulk of substrate degradation takes place up to a period of approximate

80 days suggesting that the digesters should preferably be run at a digestion time close to 75 days for optimum energy yield.

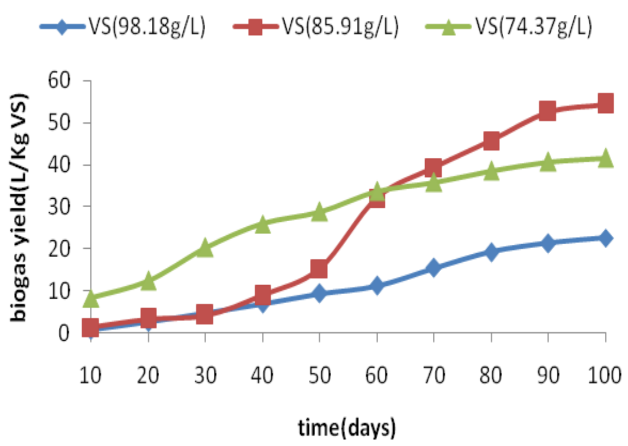

Fig.9: biogas yield at different organic loading

IV. CONCLUSION

From the results obtained, it can be concluded that digesters should preferably be run at99 g TS/l ,since maximum biogas production was obtained at this .total solid concentration. It was observed that on decreasing the concentration the production was reduced due to lack of substrate and on increasing the concentration the production was reduced due to increase of loading .At the end of the 100days digestion about 54.4 L/kg VS bio gas was produced. Volatile solid degradation of 71.69, 80.06 and 76.55 were obtained during the loading in reactor R1, R2 & R3 respectively. The low C/N weight ratio in the digested substrate indicates that it can be utilised as bio fertilizer or soil conditioner .However, the effluent chemical oxygen demand concentration indicates that it should be treated before using it for other applications.

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