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Solid State Anaerobic Fermentation of Sorted Municipal Solid Waste under Thermophilic Condition

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Abstract: This study investigate the Solid state anaerobic digestion of Municipal Solid waste from Chidambaram Municipality with high solid content (20%) by using Solid state Anaerobic fermenter under thermophilic condition (550c). This study describes the digestion of the reactor which was conducted over a period of 40 days in a batch process. The fresh organic fraction of municipal solid waste is feeded (which is equal to 80% of the total reactor volume) with 20% TS and it was mixed with 30% of two different inoculums such as cow dung and anaerobic sludge with mixing proportion of 2:1 ratio. During the start up phase, the reactor was run under mesophilic condition (370c) and then it was shifted to thermophilic condition (550c) by gradually increasing the temperature rate by 20c per day. During the stat up phase, the gas production was fluctuated initially and gradually increased from 9th Day to 19th Day and the highest gas production of 225 L/d and the methane composition of 66% were achieved at the 20th Day.

Index Terms: COD, DOC, Ph, Anaerobic digestion.

I INTRODUCTION

A. Solid-State Anaerobic Fermentation

Solid-State Anaerobic fermentation is the quest for a systematic management of an ever increasing generation of Municipal Solid Waste (MSW). The unprecedented rate of urbanization and industrialization all over the world has created a lot of problems in respect to Solid Waste Management especially in major cities of developing countries. These have immediate public health implications, which are manifested as frequent outbreak of major epidemic diseases (cholera and Diarrhoea) and high risk to public health (Fobil et al., 2002). Solid-sate fermentation is defined as the fermentation process in which microorganism grows in solid materials with the absence of free liquid and digested the high solid content of the feed-stocks.

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Most of the Solid-state anaerobic digestion systems work in continuous process reactors, and function on the principle of adding waste to the reactor at regular intervals and removing the same amount of as finished product. In this study, a single stage solid state continuous anaerobic reactor was used to digest the MSW under thermophilic condition. The overall objective of this study is to generate biogas from sorted municipal solid waste (SMSW) by using Solid-State Anaerobic Fermentation (SSAF) process.

II EXPERIMENTAL METHODOLOGY

A. General

In this study, MSW generated from Chidambaram municipality was collected and sorted organic fraction of the waste was for biological treatment by Anaerobic Digestion process.

B.Design and configuration of the Reactor.

In this experiment, the pilot scale-single stage anaerobic reactor worked under thermophilic condition was used. The SSAF was designed and operated under various organic loading rates and the solid retention time for optimizing the biogas production The 3D model design of the reactor is shown in the fig-1.

Fig.-1 – Solid State Anaerobic Fermenter

The SSAF was fabricated BY Stainless Steel with horizontal cylindrical wall container made of mild steel to provide a thermostatic pathway for hot water bath to maintain the designed temperature (55oc) inside the digester.

The Total and working volume of the SSAF are 200L and 160L respectively. The digester was kept inclined at 300C to facilitating better biomass accommodation and easy digestate disposal The brief features of the reactor is shown in the Table.1.

Table .1 Descriptions of the Reactor Design

Total volume	200L
Working volume	160L
Volume of thermostatic pathway (hot water bath)	50 L
Shape	Cylindrical
Diameter of the cylinder	56 cm
Height	84 cm
Reactor type	Pilot scale-Single Stage Anaerobic inclined reactor
Degree of inclination	300
Type of feeding	Continuous System of Feeding
Supporting Equipment	Heater, Pump, biogas analyser digital temperature controller device with detector and Pipe Lines.

External hot water tank were provided with heating rod/coil which was connected to the digital temperature controller device and the temperature inside the reactor was monitored using temperature detector. The entire cylindrical reactor was completely sealed with thermal insulation jacket in order to reduce heat loss. And additionally, the agitator was fixed in to the reactor in order to make better mixing of the waste inside the reactor. Fig.2 shows the photographic view of experimental setup.

Fig.2 Experimental Set-up.

The feedstock was seeded with inoculums to start-up the digester. The inoculums were fed about 30 % of the total waste volume. The pH of the digester was adjusted by adding commercial soda (NaOH) until the stabilization of AD process was occurred. After the complete acclimatization of their action, the fresh waste was fed continuously according to the loading rates. The withdrawn digestate was re-circulating into the digester manually. The purpose of recirculating the digestate was to enhance the mixing and homogenization of the fresh wastes inside the digester. Biogas produced was monitored daily.

III RESULTS AND DISCUSSION

The results obtained during the pilot scale solid state anaerobic digestion of sorted OFMSW operating in thermophilic condition. The experiments were conducted with two different continuous loadings for constant retention time. The analyses and evaluation are described to examine the performance of several strategies particularly in pilot scale experiment to achieve the objectives of this study.

A Start-up phase of solid state Anaerobic reactor.

In the start-up phase, the reactor was initiated with the fresh waste of 56 kg were loaded in a batch mode. The total volume of the reactor was 200L and working volume was 160L (80% of total volume). From the measurement the density of the waste was around 500 kg/m3. Therefore, from the calculation, the total weight of the waste loaded was 80 kg (equal to 80% of total volume) in which 30% of waste was inoculums (i.e., 24 kg). The reactor was operated in batch mode for 4 weeks for start-up process. The inoculum was comprised of cow dung and anaerobic sludge. The mixing ratio of these inoculums was 2:1 (Eliyan, 2007; Adhikari, 2006; Jean, 2005). Homogenization of fresh wastes with inoculums was done properly before feeding into the system. The composition of feedstock consists of 56 kg of fresh solid wastes, 16 kg cow dung, 8 kg anaerobic sludge. To avoid the risk of thermal shock inside the reactor, the reactor was initiated with mesophilic temperature 37oC and the temperature was gradually increased to a thermophilic temperature 55oC by increasing 2oC daily. To enhance the biodegradability of the substrates, the mixing was performed by circulating the waste inside the reactor periodically by rotating the agitator which was fixed into the reactor.B Continuous feeding phase of solid state Anaerobic digesterThe Experiments conducted for 2.2 and 3.02 kg VS/m3.d of two different organic loading rates is shown in Table-2. The operational days were at least equal to the retention time. The 80% of the working volume of the SSAF was maintained during the experiment.

Table.2 Loading Schemes for Continuous Operation

Descriptions	Loading rate (Kg/day)	Organic loading rate (KgVS/m3.d)	Retention time (days)
Loading 1	2.5	2.2	25
Loading 2	3.2	3.02	25

C Biogas and Methane production

Biogas generated were analysed using a biogas analyser. The performance of the SSAF was assessed by different loading rates. . The experimental results showed the variation of the biogas production during loading rates 1 and 2 and are shown in the Fig.3to5. The daily gas and cumulative Bio gas production and Methane are shown in Table -3.

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Table 3 Runtime in days Vs Daily gas production in L and Cumulative biogas production in L and Methane

Run time (days)	Daily gas production(L)	Cumulative biogas production (L)	Methane
31	75.7	4182.5	44.6
32	119.54	4302.04	52.2
33	142.84	4444.8	64.4
34	161.3	4606.18	65.5
35	119.2	4725.38	53.9
36	173.14	4898.52	56.9
37	161.8	5060.32	68.6
38	167.54	5227.86	65.4
39	139.41	5367.27	62.3
40	143.5	5510.77	61.3
41	243.7	5754.47	58.6
42	237.45	5991.92	58.2
43	221.32	6213.24	57.3
44	227.8	6441.09	55.4
45	217.01	6658.1	56.9
46	263.45	7138.56	58.7
47	273.4	7411.96	58.4
48	317.27	7729.23	60.5
49	366.2	7974.53	59.2
50	345.7	8361.98	61.7
51	292.3	8615.13	61.9
52	323.9	8939.03	62.5
53	289.5	9185.78	61.3
54	317.2	9502.98	62.1
55	326.1	9829.08	62
56	395.8	10224.88	61.5
57	367.9	10552.03	59.5
58	343.4	10795.45	57.3
59	289.2	11067.25	59.2
60	267.4	11304.62	55.3
61	247.5	11472.02	53.7
62	221.5	11643.92	51.4
63	209.3	11787.65	51.6
64	201.6	11897.15	53.3
65	197.4	12018.15	59.7
66	183.7	12168.25	61.1
67	187.1	12349.55	63.1
68	223.4	12482.95	58.2
69	245.4	12728.45	55.3
70	267.2	12952.15	59.4
71	249.4	13165.75	50.4
72	221.1	13323.22	55.6
73	259.2	13482.39	44.2
74	277.8	13649.59	56.1
75	256.54	13906.13	41.4
76	267.1	14173.23	56.7
77	261.3	14434.53	43.2
78	270.14	14704.67	55.6
79	303.15	15007.82	51.6
80	319.3	15227.12	50.7

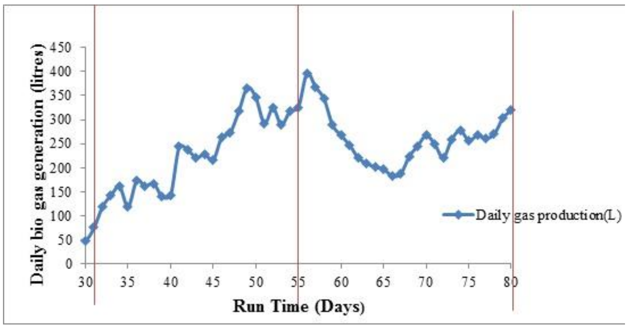

Fig..3 Daily biogas production for different loadings

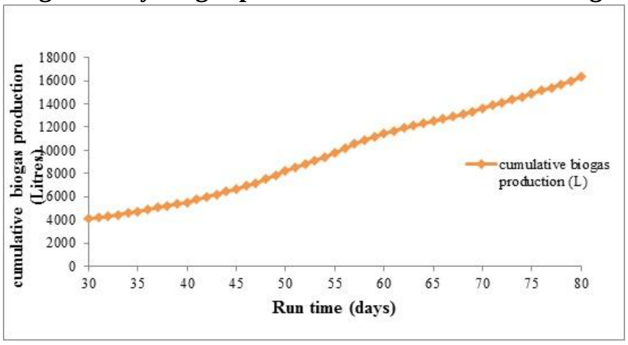

Fig.4Cumulative biogas production for continuous loading

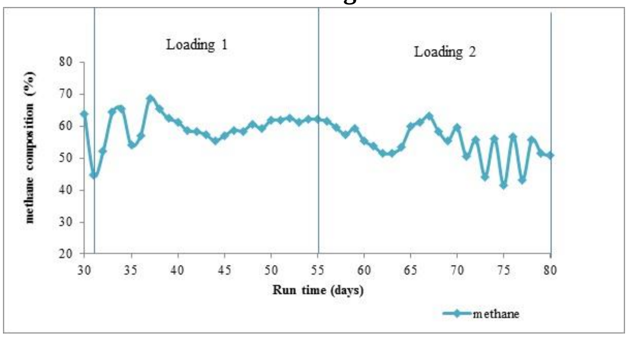

Fig.5 Variation of methane composition during various loading

Biogas generated were analysed using a biogas analyser .The performance of the SSAF was assessed by different loading rates.

IV CONCLUSIONS

From this study, it is concluded that manually sorted organic fraction of municipal solid wastes can be anaerobically digested, producing a biogas containing 50%-60% of Methane. The rate of biogas production observed in the pilot scale digester declined with regular increasing of biogas production and slightly influent volatile solids concentration traces at the end of loading 2 and this regular biogas generation was due to the ability of the digester to thoroughly mix the contents using the agitation system provided in the digester and thus it avoids the production of scum layer.In this study, pilot scale anaerobic digestion of OFMSW was conducted. An inclined anaerobic reactor was designed and operated under continuous mode. An attempt to optimize the process was done by increasing the loading rate at constant retention time.The following conclusions are drawn from this study:An effective start-up of the anaerobic digestion with inoculums and substrate acclimatization was done successfully.

A gradual increase from mesophilic condition at the rate of 20C per day reaching thermophilic (55oC) was found satisfactory.During the start-up phase, the initial methane production began after 4 days and reaches the highest yield of 63% at the day 19. The biogas yield of 223L/day was achieved at the same day itself.

The separate agitation system ensures the better mixing of waste inside the reactor that tends to get increased biogas yield at the right time. During the continuous phase, the daily biogas production obtained during loading rate 1 and 2 were approximately 228 L/d and 250 L/d respectively and around 60% and 53% of Methane concentration in biogas was observed for the loading rate 1 and 2 respectively. At the end of loading 2 ,it is observed that the increasing rate of biogas production but the methane composition started decreasing. This is due to the traces of VFA accumulation thus decreases the pH to below 7 and it lower the methanogenesis activity.This study conclude that, if the organic loading rate increases i.e, higher biodegradability means that the VFA is larger and faster which stress the biogas production rate and lowers the methane composition. So, the optimum organic loading rate of 2.2 – 3.2kgVS/m3.day is suitable for anaerobic digestion of OFMSW under thermophilic condition.

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