Performance Evaluation of Anaerobic Digesters

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Abstract— Anaerobic digestion and food waste (FW) using Single-stage and two-stage reactors were studied to compare reactor startup, reactor stability and performance with respect to methane yield, volatile solids reduction and energy yield. The single-stage reactor (SSR) was a conventional reactor operated at a low loading rate with a maximum of 3% of total Solids, while the two-stage reactor consisted of an acidonegic reactor (TSAR) and a methanogenic reactor (TSMR). The TSAR was inoculated with methanogenic sludge similar to the SSR, but was operated with step-wise increase in the loading rate and with total recirculation of reactor solids to convert it into acidification sludge. Before each feeding, part of the sludge from TSAR was centrifuged, the centrifuge liquid (solubilized products) was fed to the TSMR and centrifuged solids were recycled back to the reactor. Single-stage digestion produced maximum methane yield of 1000 ml/d as CH4. The TSAR shifted to acidification mode at an (organic loading rate) OLR of 3% of total solid and then achieved stable performance at 4% of total solid and pH 6.53–6.68, a maximum methane yield of 3010 ml/d. The lower energy yield of the two-phase system was due to the loss of energy during hydrolysis in the TSAR and the deficit in methane production in the TSMR attributed to chemical oxygen demand (COD) loss due to biomass synthesis and adsorption of hard COD onto the flocs. These results including the complicated operational procedure of the two-stage process and the economic factors suggested that the two-stage process could be the preferred system for FW.

Key words**:** Anaerobic digestion (AD), food waste (FW), methane, performance

I. INTRODUCTION

A. General:

Nature has several resources like air, water, land, forest, minerals, and fossil fuels for benefit of living being. Natural resource such as crude oil, coal, natural gases and wood are becoming limited due to increase in urbanization and industrialization. In additions the newly developed energy based technologies are also reaching to a common man and creating a huge gap between demand and supply of energy. To keep a proper balance between energy demand and supply the existing non-renewable energy should be efficiently used and the new alternative renewable energy sources to be explored.

Global quantum of FW generation is 14% of the total municipal solid waste. India is expected to achieve an industrialized nation status by the year 2020. This will naturally increase significant fraction of FW in municipal waste (Sharma and Shah, 2005; 2004; Shekdar et al., 1992). The FW disposed from a household, restaurant, hotel, and industrial canteen consists of carbon and nutrients source such as soluble sugar, starch, lipid, protein, cellulose, and other inorganic components. This waste has a tremendous potential for generating propionic acid, lactic acid, ethanol, and hydrogen & methane gases. Disposed of FW in municipal waste creates odor, fly nuisance and become unmanageable for handling, collecting and transportation and mainly treated in an anaerobic process, composting or disposed to landfill.

Energy recovered from the FW can solve the dual purpose firstly, proper treatment and management of municipal solid waste, secondly hydrogen and methane can be used as energy. In India, the first anaerobic treatment route was practiced at Bombay in year
1859. As biogas was recovered from a sewage treatment facility and used for street lamp, Exeter, (Fabien Monnet et.al, 2003).

Anaerobic digestion of organic waste is performed in a single stage or multiple stages. Conventional single-stage anaerobic digestion process is often employed to recover bio-energy (methane) from biomass and various types of solid wastes, and industrial wastewaters. Recently, a two-stage anaerobic digestion system includes acidogenic and methanogenic bioreactors operated in series has several benefits over other conventional method. It allows the separation and enrichment of acidogenic and methanogenic bacteria.

Acidogenic bacteria convert soluble organic material mainly to acetate, propionate, butyrate, H_2, and CO_2. These compounds are converted to methane and carbon dioxide by varieties of acidogenic and methanogenic bacteria. The short Hydraulic retention time (HRT) and low pH are suitable for the growth of acid-forming bacteria this will adversely affect the process stability of methane-forming bacteria.

Different configurations and combinations of acidification and methanogenic reactors for two-phase anaerobic systems have been used by several authors for treating FW and allied wastes. Some of the systems studied for FW have been Continue stirrer tank reactor (CSTR) – up flow filter bed (Zhu et al., 2009), coupled anaerobic sequencing batch reactors (SBRs) (Bouallagui et al., 2004), tubular reactor (Bouallagui et al., 2003), solid bed hydrolyser – up flow anaerobic sludge blanket (UASB) methaniser (Rajeshwari et al., 2001), hydrolyser with raschig rings – inclined tubular digester (Dinsdale et al., 2000), ASBR hydrolyser – anaerobic filter methaniser and CSTR hydrolyser – anaerobic filter methaniser (Verrier et al., 1987), cascade process for organic waste (Chen et al., 2007) and hybrid anaerobic solid–liquid bioreactor for food waste (Hai-Lou et al., 2002). These processes differed mainly in the way microorganisms were retained in the bioreactor and in the phase separation of acidogenic process from the methanogenic process.

Application of high loading rate coupled with recirculation of digestate after centrifugation was expected to meet the objective of acidification. Bibliographic survey showed that there are studies which have dealt with the single-stage or two-stage digestion of FW and other organic solid waste (Shen et al., 2013), but comparative study of the SSR, TSAR and TSMR using the same waste are scarce. And hence, an attempt has been made to compare the performance of SSR, TSAR and TSMR.

1) *Objectives Of The Study :*
   - To quantify and characterize the FW.
   - To investigate the potential of FW to produce H_2 and CH_4.
   - To study the performance of single stage reactor and two stage reactors.
   - To compare the performance of SSR and TSR by assessing material and energy balance.

II. MATERIALS AND METHODS

Materials and methods used for SSR for the anaerobic digestion of the food waste have been performed by setting up a single stage reactor. Materials and methods used for the study are briefly discussed in the following:

A. *Food Waste:*

In the present study the food waste was collected from canteen, Guest house, research sholar's house (R.S.H)., food-waste was grinded, and slurry was prepared with the help of treated effluent coming out of a UASB, then passed through a 1.75 mm (1680 microns) of sieve FILTER WEL test sieves maker, the prepared feed was fed into the feed tank-I and mixed it with a lab stirrer at 250 rpm of model no. RQ-126/D (Remi lab stirrers). The typical treatment steps involved in food-waste processing is depicted in Figure 2.1

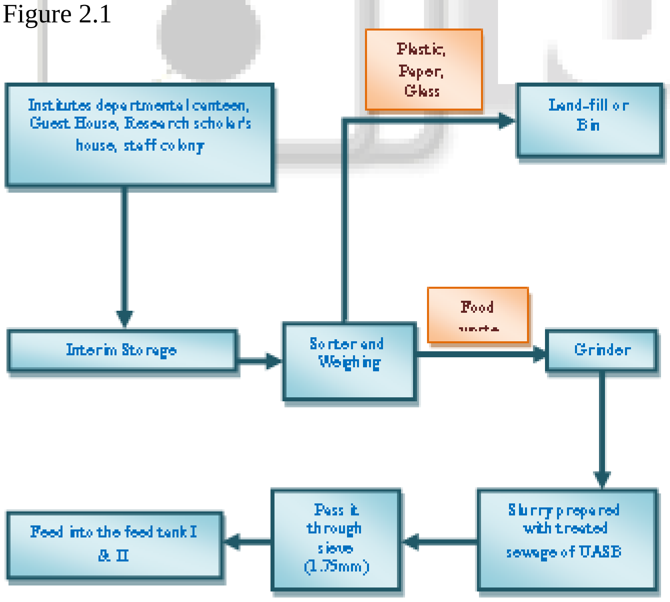

Fig. 2.1: Process overview of a food-waste collection and substrate preparation for feeding in tank-I & II

B. *Set-Up Of SSR:*

The SSR was selected for the digestion of food waste; this was made-up of a aspirator bottle of volume 7.8 L which was having a mouth at the top and an opening at the bottom. The mouth which is held at the top of the aspirator bottle consists of two opening one for feeding the substrate and another opening is connected to the gas collection unit. The influent was fed with the help of funnel through the feeding pipe in a batch process. The length of feeding pipe was adjusted in such a way that its bottom end is about 3cm above the bottom of the reactor. The gas collecting pipe was kept well above the content in the reactor to prevent siphonic action. A pipe at the bottom opening is used for the collecting effluent. The complete laboratory setup of the SSR is shown in the Plate:2.1

1) *Operating Procedure Of SSR:*

The capacity of the digester is 7.8 L, initially the digester was fed with 3.62 L inocula from well digested sludge of anaerobic digester of Dinshaw effluent treatment plant, Nagpur, 1 L of effluent from a treated anaerobic digester and remaining with slurry of food waste of 2 % of total solid.

Plate 2.1: Laboratory setup of SSR.

This digester was completely filled exclude all the air inside and to maintain anaerobic condition. Then the required effluent was removed up-to the estimated volume. The characteristics of mixed seed were determined. The digester was operated on semi continuously feeding the reactor by feed-stock in the form of slurry containing 3% of T.S. and then collecting the equal amount of effluent. The characteristics of influent, effluent and gas production were measured. Mixing was done thrice in a day by shaking the reactor, and a care was taken to maintain anaerobic condition.

2) *Gas Collecting Unit Of SSR:*

The amount of gas produced was measured in the gas collection unit by volume displacement method. The measuring bottles was filled with 2% KOH solution to absorb the liberate CO_2 by scrubbing action. The amount of CH_4 produced was then directly measured from the volume of KOH displaced in the measuring cylinder. The displaced KOH solution was collected in other bottles, which was kept open to the atmosphere. The gas collecting assembly having the two aspirators bottles is provided with graduated marks for the measurement of the gas produced. This gas collection unit was used for the SSR.

C. *Set-Up Of TSAR And TSMR:*

The acidogenic and methanogenic reactors had a working volume of maximum 20 L and 40 L respectively. The pH and temperature was maintained between 5.0 - 6.8 and 32 - 38 °C and 6.5 - 8.0 and 35 - 38 °C respectively, pH and temperature were measured by an online pH and temperature analyser of model no. Alpha pH 200 controllers(Thermo scientific) separately. The continuous mixing was performed with a lab stirrer at 100 and 150 rpm of model no. RQG-129/D and RQ 140/D (Remielektrotechnik ltd.) respectively. Substrate feeding was done from feed tank-I to TSAR and from feed tank II to

TSMR using a peristaltic pump at 10 rpm and 15 rpm of model no. PP 201 FLP of Sr.no.1310335 and 1310336 (Electrolab) respectively. The feeding was done through the flow controller nozzle of 6mm in inner dia (ID) which is installed at the extreme left bottom of the TSAR (acidogenesis reactor) and TSMR (methanogenesis reactor). Effluent withdrawal was done by the outlet nozzle of 6mm ID which is present at the right side of the TSAR and TSMR at the height of 75 % of the liquid volume from the extreme bottom of the TSAR and TSMR. Biogas produced by the reactor was measured by a gas flow meter of model no. CAT. No. 05.07 (Toshniwal) respectively and was collected in a gas collector of capacity 125 ml. This type of reactor was utilized in the experiment for the biogas production potential of food-waste and also in the experiment of food-waste stability as the sole substrate in anaerobic digestion. The complete setup of TSAR and TSMR is shown in Plate 2.2.a and Plate 2.2.b.

In order to simulate the condition in a full-scale anaerobic digestion reactor, two identical set-ups of laboratory cum pilot-scale reactors made from PVC pipes (ID 0.3 m, total height 0.39 m and 0.72 m, liquid working volume of 20 L and 40 L, all nozzles are sealed with pinch cork) were employed as completely-mixed reactors. There was no external heat introduced to the reactor body to raise the temperature. The effluent was withdrawn from an effluent port installed in the reactor. Feeding was done simultaneously along with the effluent removal. The reactors were also equipped with gas flow meters. These reactors were employed in the experiments for the anaerobic digestion of and food-waste 20 L reactor, 40 L reactor respectively.

1) Operating Procedure Of TSAR And TSMR:

The TSAR and TSMR reactor set-up (20 and 40 L volume respectively) was operated in order to assess the stability of the biological process, degradability, and specific biogas production of food-waste during long time continuous feeding. This experiment was performed by feeding the reactor with food-waste as a sole substrate in a draw-and-fill mode. The reactor was filled with anaerobic sludge from the full-scale UASB reactor, as inoculum. Daily biogas productions, methane content, COD, volatile fatty acids, pH, alkalinity and temperature were measured in order to evaluate the performance of the reactor. The reduction of solids was examined 2 or 3 times a week. The reactor was started with bio-waste as the sole substrate at an HRT of 5 days. After a steady state condition was reached, the feeding of the reactor was continued with appropriately diluted food-waste (COD values of diluted food-waste ranged from 84 to 132 g L^{-1}) in order to maintain the OLR and also to keep the operation of the reactor. The substrates were fed once in a day at 12:30 p.m. from Monday to Friday respectively, and feeding was stopped up during weekends in the reactors.

Plate 2.2: a) Laboratory setup of TSAR

Plate 2.2: b) Laboratory setup of TSMR.

D. Sampling And Analysis:

Soluble COD was measured by a open reflux method, other parameters (total solids (TS), volatile solids (VS), alkalinity, volatile fatty acids (VFA), total khjeldal nirogen(TKN) were measured following Standard Methods for the examination of the water and waste water, APHA (2005). Biogas composition was determined using a gas chromatograph (Shimadzu GC-8A) connected to a C-R8A integrator and equipped with a CTRI Alltech column. The following gases were measured: CO_2, H_2, O_2, N_2 and CH_4. The column was made up of 2 concentric columns. The 3.175 mm-diameter inner column was filled with Silica gel. It allowed the separation of CO_2 from the other gases. The other gases were separated in the 6.350 mm-diameter outer column filled with a molecular sieve. The carrier gas was argon at 2.8 bars. The temperatures were 30 ^{0}C for the oven and 100 ^{0}C for the injector and the detector. The detection of gaseous compounds was done using a thermal conductivity detector and the intensity of current was 80 mA. The volume of injected biogas was 1 ml. The calibration was done with a standard gas composed of 25% CO_2, 5%H_2, 2% O_2, 10% N_2 and 58% CH_4. The margin for error for this measurement was 5%. Feed samples were periodically analyzed for total and volatile solids to maintain constant the OLR in the reactors. Drained-off samples were analyzed for pH, total alkalinity, soluble COD, VFA and total and volatile solids.

III. RESULTS AND DISCUSSION

The results obtained on conducting the study are presented and discussed in the following sections:

A. Quantification And Composition Of Food Waste:

In the research institute, source-sorted food waste (organic fraction of municipal solid waste) from departmental canteen, guest house, research scholar's house (RSH) and colony households was collected for a month for quantification, the average generation of food waste from the respected source stations are given in Table 3.1.The departmental canteen and guest house's food waste generation was less on weekends.

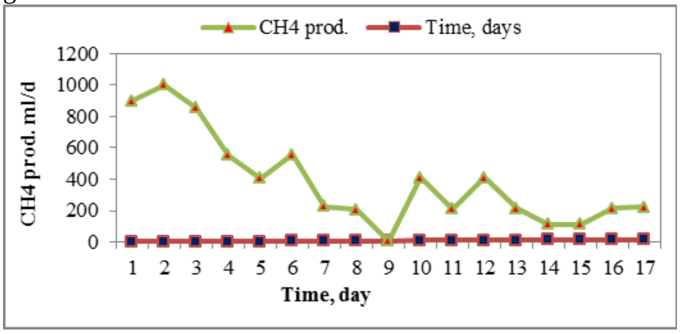

Fig. 3.1: Variations of pH rate and gas production after acclimatization period

S.No.	Source of food waste	Quantity in kg day^{-1}
	Departmental Canteen	15.5
	Guest House	2.2
	Research Scholar's House	5.7
	Staff Colony (per quarter)	0.8
Qt. type	**No. of Qt. Occupied in no.**	**Qty of food waste generation in kg day^{-1}**
VII	1	0.8
VI	5	4.0
V	10	8.0
IV	28	22.4
III	24	19.2
II	74	59.2
I	44	35.2
SA	31	24.8
	Total quantity of food waste generated day^{-1}	189

Table 3.1: Average quantity of food waste generated from research institute campus
SA-Scientist apartments, Qt-quarters

B. Single Stage Reactor:

The acclimatization of the digester was ascertained based on the pH and gas production. The performance during acclimatization period of digester is given in Table 3.2. The pH of the effluent for initial 3 days after start-up was above 7 and thereafter between 7th - 12thday the desirable when a pH values for anaerobic digestion, from Fig.3.1 it was observed that there was gas production for first 3 days when reactor was started. The gas production was attained observed 3rd day amount of gas production was about 700ml day^{-1}. Thereafter, there was sudden increase in gas production from 3rd to 8th day then the gas production was found to be fairly constant during 9th to 12th day. During the above period pH of the effluent was also observed to be fairly constant and was around 7. The constant pH and gas production indicates that reactor was acclimatized.

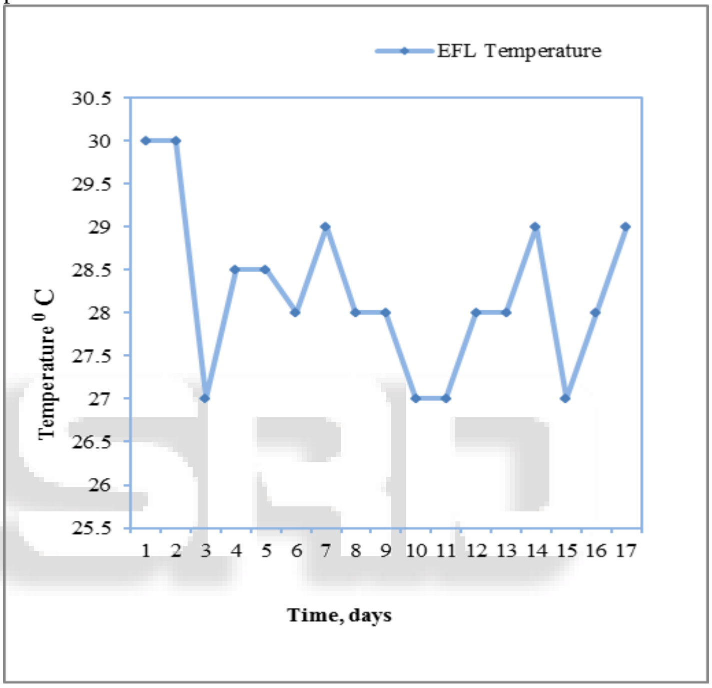

Fig. 3.2: Variation of Temperature with respect to time

Day	pH		Temp.		Total Solids		TS red.	VS		VS red.	CH_4 prod.	Alkalinity
	INF	EFL	INF	EFL	INF	EFL		INF	EFL			
			°C		(gm L^{-1})		(%)	(gm L^{-1})		(%)	mlday^{-1})	(mg L^{-1})
1	7.60	7.00	27	30	30	10.14	66.20	26.7	6.30	76.00	900	2000
2	7.65	6.85	26	30	30	9.50	68.00	25.5	6.00	74.00	1000	2000
3	7.65	6.87	24	27	30	9.00	71.00	28.5	5.02	82.30	850	2400
4	7.68	6.71	25	28.5	30	8.50	75.00	27.0	4.50	83.00	550	2400
5	6.90	6.59	25	28.5	30	7.25	77.00	27.3	4.28	84.00	400	2000
6	7.69	6.57	24	28	30	6.72	77.70	28.2	4.20	85.00	550	2500
7	7.55	5.96	25	29	30	6.65	82.73	28.5	3.00	89.00	220	1600

8	7.02	5.55	24	28	30	5.18	84.00	26.7	2.50	90.00	200	1500
9	7.25	9.71	24	28	30	4.80	84.00	26.4	2.40	90.00	0	1500
10	8.30	9.05	23	27	30	4.75	87.00	26.1	2.70	92.00	400	7000
11	7.85	6.76	23	27	30	3.75	87.00	25.5	1.92	92.00	200	6000
12	7.40	6.46	25	28	30	3.70	90.00	27.3	1.73	94.00	400	5000
13	7.78	6.16	26	28	30	3.00	90.00	25.2	1.60	94.00	200	3200
14	7.81	6.00	26	29	30	2.95	90.00	26.1	1.70	94.00	100	2800
15	7.08	5.86	24	27	30	2.76	90.00	26.4	1.50	94.00	100	2800
16	7.04	5.74	26	28	30	2.76	90.00	26.4	1.50	94.00	200	3400
17	6.69	5.65	26	29	30	2.75	90.00	26.0	1.40	94.00	206	8000

Table 3.2: Performance of single stage reactor

T.S.-total solids; V.S.- Volatile solids; INF-Inffluent; EFL;Effluent.

After acclimatization digester was operated for a loading of 3% of T.S. the influent and effluent characteristic from the digester was studied for the various parameters. The performance of the digester is given in Table 3.3. The pH of the effluent remained in the range of 7-6.7 for 6 days and continued to decrease to 5.9and 5.55 on 7th and 8thday. During this time amount of gas production also reduced drastically. To control the process the pH was adjusted by adding sodium bicarbonate. After this addition pH suddenly increased up-to 9.71 and then there is decrease in subsequent days. Later on the pH of effluent decreases up-to 5.65 and the end of 28th day. Then the reactor monitoring was discontinued because of very low gas production. The temperature in the reactor SSR during the study was between 27-30^{0}C which is below mesophilic zone and therefore maximum gas production cannot be expected. The variation of the temperature in the reactor SSR during the study period is shown in Fig. 3.2.

For first 2 days alkalinity was 2000mg L^{-1} which was lower to the optimum range but later there was increase in alkalinity and the value remain in the optimum range after 3 days, because the bicarbonate alkalinity should be above 1000mg/l in the anaerobic digestion process. Then there was a drop in alkalinity as well as pH. A sodium bicarbonate solution was added to control the pH and the anaerobic process. There was sudden increase in alkalinity up-to 7000 mg L^{-1} after this addition. This variation can be seen in Fig.3.3. and thereafter there was again decrease in pH and alkalinity. The sodium bicarbonate was added on 27th day to maintain the pH in proper range. The data regarding T.S and V.S. of feed stock effluent and there percentage reduction. The percentage reduction in T.S. and V.S. increased from 66.2-90% and 76-94% respectively. Where the percentage of V.S. reduction steadily increasing for initial 7 days from 78-92% and thereafter it remained constant. Also the percentage reduction in T.S. varies in similar manner as shown in Fig.3.4. The maximum amount of gas produced was 1000ml/day. On 2nd day more fluctuation and continues decrease in gas production was observed. There was also no gas after 8th day after acclimatization period this may be due to low pH. However, there was increase in gas production after addition of sodium bicarbonate but there was fluctuation could not be restored even after the addition of sodium bicarbonate 2nd time, and therefore the monitoring of digester has to be discontinued. The alkalinity at the end of digestion process was about 8000 mg/l which can be seen in Fig.3.3.

Sr. No.	Parameter	Typical range value
	pH	5.37-8.30
	Total solids	19500 to 22500 mg L^{-1}
	Volatile solids	7250-21375 mg L^{-1}
	Moisture content	15to 35 %

Table 3.3: Characteristics of influent feed stock of SSR, TSAR and TSMR

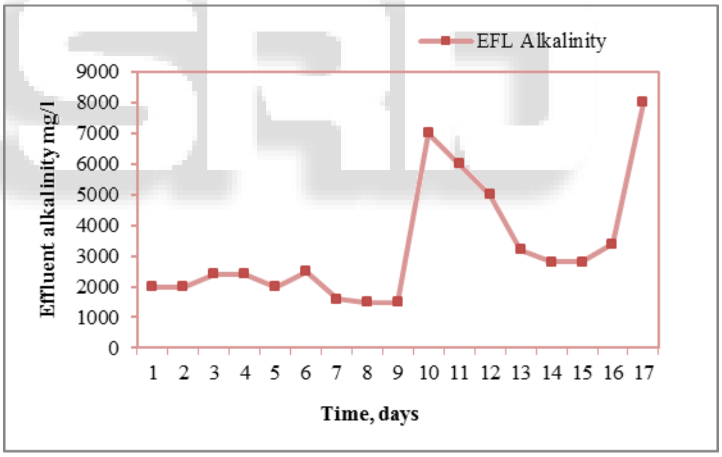

Fig. 3.3: Variations in Alkalinity with respect to time.

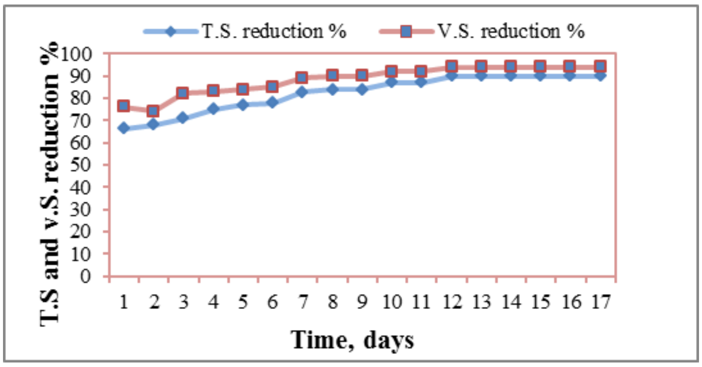

Fig. 3.4: Solids removal with respect to time.

1) *Two Stage Acidogenic Reactor (TSAR):*

The TSAR was fed with FW substrate concentration (1-2 %) during acclimatization. The performance of acidogenic reactor during acclimatization period is presented in Table

3.6. The pH of the acidogenic reactor for initial 3 days after start-up was above 7 and thereafter, the pH was observed to be around 6.6 for 11th - 20th days which was desirable for hydrolysis. From Fig.3.5, it was observed that there was no Hydrogen gas production for first 3 days when reactor was started. Hydrogen gas production was observed on 4th day and amount of Hydrogen gas production was about 500ml $day^{-1.}$ Thereafter, there was increase in Hydrogen gas production from 13th to 20th days. During the above period pH of reactor was 6.60.

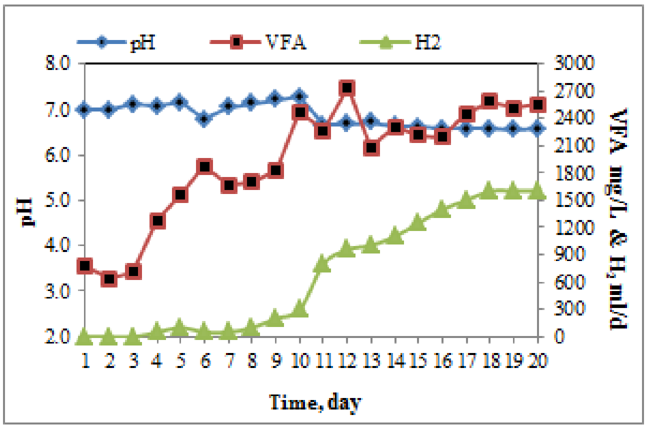

Fig. 3.5: Effect of pH and VFA on H_2 gas production.

The acidogenic reactor indicates acclimatization through pH and hydrogen parameters. The substrate concentration was increase as increased in acclimatization period to prevent shock loading. Acidogenic reactor was operated at 4 day HRT for 20 days. The effect of fed substrate concentration on pH, VFA and Hydrogen production are presented in Fig. 3.5. For 1st 10 days the reactor was fed with 3% substrate concentration. At this concentration, the pH of the reactor was observed in acidic range. Due to the transit phase of acidogenic bacteria for adopting the higher substrate concentration the VFA of reactor was low in the range 780-880 mg/l. The hydrogen production at 3 % substrate concentration was in the range 780-2330 ml/d. After 10 days of operation, the reactor substrate concentration was increased from 3% to 4%. The variation in pH, VFA, Temp, and Hydrogen production was monitored. Temperature of the acidogenic reactor was in mesophilic zone (30.0-34.6°C) for 20 days. Increase in substrate concentration enhances the Hydrogen production from 2230 to 3000 ml/d, but the VFA of reactor was more or less constant 1200 mg/l. The acidogenic bacteria are mainly responsible for the formation of VFA with proper hydrolysis of organic matter.

2) Two Stage Methanogenic Reactor (TSMR):

The TSMR was fed with FW substrate concentration (1-2 %) during acclimatization. The performance of methanogenic reactor during acclimatization period is presented in Table 3.7. The pH of the methanogenic reactor for initial 3 days after start-up was above 7 and thereafter, the pH was observed around 6.74 which was desirable for methane gas. From Fig.3.6, it was observed that there was no methane gas production for first 3 days when reactor was started. Methane gas production was observed on 4th day and amount of methane gas production was about 100 ml $day^{-1.}$ Thereafter, there was increase in methane gas production from 11th to 20th days. During the above period pH of the reactor was in the range 7.6-7.7.

The methanogenic reactor indicates acclimatization through pH and methane parameters. The substrate concentration was increased as increase in acclimatization period to prevent shock loading. Methanogenic reactor was operated at 10 day HRT for 20 days. The effect of fed substrate concentration on pH, VFA and methane production are presented in Fig. 3.6 through 6.63. For 1st 10 days the reactor was fed with 3% substrate concentration. At this concentration, the pH of the reactor was observed in suitable range. The VFA of methanogenic reactor was in range 1050-3500mg/l. The methane production at 3 % substrate concentration was in the range 100-2200 ml/d. After 10 days of operation, the reactor substrate concentration was increased from 3 to 4% at same HRT. The variation in pH, VFA, Temp, and methane production was monitored through 6.63. Temperature of the methanogenic reactor was in mesophilic zone (30.8-34.6oC) for 20 days and change in temperature was due to change in ambient temperature. Increase in substrate concentration enhances the methane production from 1000 to 2200 ml/d it was keep on increasing, but the VFA of reactor was not constant. The methanogenic bacteria were mainly responsible for the formation of methane with reduction of organic matter. Further, studies are in progress with different substrate concentration and HRT. Due to variation in Temp. and VFA, its effect on methane production was not very clear. This two steps acidogenic and methanogenic generate the hydrogen and methane gases, which was not suitable in the single stage reactor.

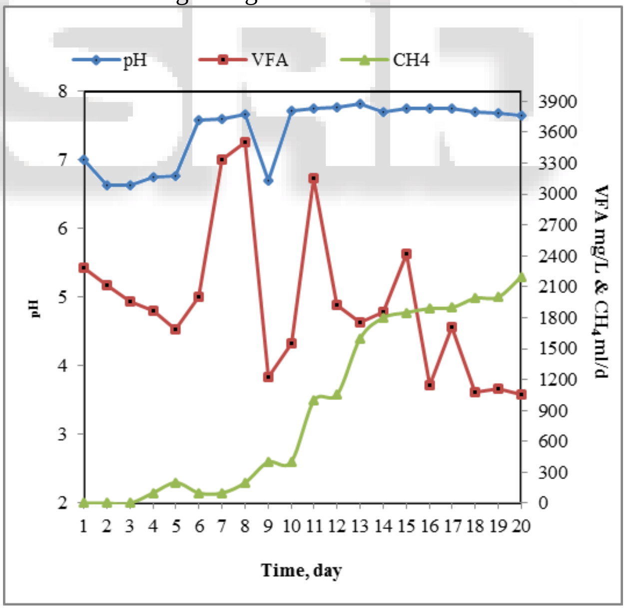

Fig. 3.6: Effect of pH and VFA on methane gas production.

Day	Sub strate Conc. (%)	HRT Day	pH	T. (^{0}C)	COD INF (mg L^{-1})	COD EFL (mg L^{-1})	VFA INF (mg L^{-1})	VFA EFL (mg L^{-1})	TS INF (mg L^{-1})	TS EFL (mg L^{-1})	VS INF (mg L^{-1})	VS EFL (mg L^{-1})	H_2 Prod. ml day^{-1}
1	3	4	6.63	32.7	9250	1500	780	3020	23648	15020	12000	2632	1750
3	3	4	6.56	33.9	9300	1100	880	3210	6050	1420	14218	434	1800
5	3	4	6.57	34.2	9120	1460	840	3090	14400	1682	4050	390	2050
7	3	4	6.56	32.7	9010	1820	800	3800	6680	1460	8382	808	2090
9	3	4	6.6	33.4	9120	1550	890	3530	2420	2162	1980	1290	2300
11	4	4	6.57	34.6	16620	4200	1300	3990	10408	1110	8030	750	2500
15	4	4	6.63	32.8	16360	5480	1270	4680	10690	1150	8690	870	2990
19	4	4	6.57	31.9	15260	5240	1320	4770	7690	1820	5630	1500	3010
20	4	4	6.63	32.7	9250	1500	780	3020	23648	15020	12000	2632	1750

Table 3.6: Performance of TSAR.

VFA-Volatile fatty acids; HRT-Hydraulic retention time; T.S.-total solids; VS- Volatile solids; INF-Influent; EFL; Effluent; T-temperature.

Day	Sub strate Conc. (%)	HRT Day	pH	T (^{0}C)	COD INF (mg L^{-1})	COD EFL (mg L^{-1})	VFA INF (mg L^{-1})	VFA EFL (mg L^{-1})	TS INF (mg L^{-1})	TS EFL (mg L^{-1})	VS INF (mg L^{-1})	VS EFL (mg L^{-1})	CH_2 ml day^{-1}
1	3	10	7.75	32.7	9250	1000	780	2020	23648	16790	12000	8000	3750
3	3	10	7.76	33.9	9300	900	880	2210	6050	1220	14218	450	3800
5	3	10	7.82	34.2	9120	960	840	2090	14400	1340	4050	446	3050
7	3	10	7.7	32.7	9010	820	800	2800	6680	1260	8382	500	3090
9	3	10	7.74	33.4	9120	800	890	2530	2420	1200	1980	660	6300
11	4	10	7.74	34.6	16620	760	1300	2990	10408	1010	8030	750	6500
15	4	10	7.75	32.8	16360	750	1270	3680	10690	1010	8690	700	6990
19	4	10	7.7	31.9	15260	640	1320	3770	7690	1050	5630	710	6010
20	4	10	7.68	30.8	-	-	-	-	-	-	-	-	-

Table 3.7: Performance of TSMR.

VFA-Volatile fatty acids; HRT-Hydraulic retention time; TS-total solids; VS- Volatile solids; INF-Influent; EFL;Effluent; T-temperature.

IV. CONCLUSION

Food waste generated from the research institute, Nagpur is acidic in nature with high concentration of organic and characterized as high strength organic waste. This waste has a great potential to generate methane gas. Presently, food waste is biodegraded through composting process for fertilizer, thus wasting the valuable hydrogen and methane gases. Single stage reactor study on anaerobic digestion of residual food waste indicates the methane production. The quantity of food generated from a Research Institute, Nagpur is 5670 kg/ month. The optimum quantity of methane produced from the single stage anaerobic digester is 1000 ml/d at 3 % organic concentration at 10 days HRT.

The lab scale study on anaerobic digestion of food waste is feasible for formation of methane gas in the single stage reactor with no hydrogen gas. Therefore, single stage anaerobic reactor is separated into two stages as acidogenic and methanogenic reactors. Pilot scale study on two stage anaerobic digestion of residual food waste is feasible through acidogenic and methanogenic bacteria for production of hydrogen and methane gases. Two stage anaerobic digestion of food waste reduced the problem of municipal solid waste and produce the energy as hydrogen and methane.

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