PILOT SCALE STUDY ON ANAEROBIC DIGESTION OF MUNICIPAL SOLID WASTE

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Abstract: This paper presents the biological treatment of Organic Fraction of Municipal Solid Waste (OFMSW) by anaerobic digestion process. A pilot scale solid state anaerobic digester was used to study stability of anaerobic digestion process of treatment of sorted municipal solid waste. The inoculum was blended to the shredded particle size of 10mm waste particles to enhance the start-up of the digestion process. From this study, it is concluded that manually sorted organic fraction of municipal solid wastes can be anaerobically digested, producing a biogas containing 55%-70% CH_4..The daily biogas production obtained during loading rate 1, 2 and 3 were approximately 1500 L/d. 1000 L/d and 1100 L/d respectively and the Methane concentration in biogas was observed around 70% in loading rate 1, 68 % in loading rate 2 and was observed 55% in loading 3. Thus this study conclude that the optimum organic loading rate of 2.5 – 3.5 kg VS/m^3.day suitable for anaerobic digestion of OFMSW in thermophilic condition that too depends on the reactor volume.

Keywords: **Anaerobic digestion, Biogas, Methane, OFMSW**

I INTRODUCTION

The quest for a systematic management of an ever increasing trend of Municipal Solid Waste (MSW) generation coupled with the complex waste characteristics is a big challenge for Solid Waste Management in both developed and developing countries. 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. Resident populations have increased in numbers and public facilities have not kept pace with the increased amounts of urban wastes**(Sheehan et al., 2006).** Consequently, accumulation of large volumes of solid waste in public places has become common scenes in many cities and small towns. 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).**

Anaerobic Digestion, simply defined, is a process in which organic matter is metabolized by microorganisms in an environment free of oxygen **(Khanal, 2008).** Along with aerobic biodegradation, Anaerobic Digestion is nature's way of recycling carbon, nutrients, and other constituents present in organic material back into the cycles of life. Anaerobic microorganisms are ubiquitous life forms, some of the oldest on Earth, present nearly everywhere on the planet from the bottom of oceans, to deserts, too deep within the Earth's crust. Just as human beings consume organic material and oxygen and produce energy, biomass (cells), and carbon dioxide, anaerobic heterotrophic microorganisms consume organic material and produce biomass, biogas, and heat. Inthe context of engineered Anaerobic Digestion systems in waste management, the metabolic processes of anaerobic microorganisms are leveraged to recover energy from organic waste in the form of methane (predominantly) and stabilize the waste to produce a valuable nutrient-rich soil amendment, or bio fertilizer **(Rapport et al., 2008).** On the surface, Anaerobic Digestionseems like a simple natural process, but when investigated on the micro-scale it is revealed that Anaerobic Digestion is a complex phenomenon involving a consortium of interdependent microorganisms (**Grando et al .,2017**)

Solid state anaerobic digestion is a process that is rapidly gaining momentum to new become a major focus of interest in solid waste management worldwide. Conventionally, Solid-state anaerobic digesters are operated under mesophilic conditions (37–42°C) but recently there is an increased attention in applying the solid state anaerobic digestion at thermophilic conditions (55^0C) **(Hartmann and Ahring, 2005)** to treat the organic fraction of municipal solids waste (OFMSW) due to its capacity for higher loading rate and greater volumetric gas production potential **(Cecchi et al., 1991)** than in mesophilic condition. And also, Solid-state anaerobic digesters are operated under mesophilic conditions exhibited a poor startup performance. So, thermophilic (55–65°C) digesters were developed and have been established as a reliable and acceptable option for solid-state anaerobic digestion. Operating solid-state anaerobic digestion systems at thermophilic conditions can accelerate the anaerobic digestion process and provide the added benefit of increased pathogen kill-off during the anaerobic phase. The increased amount of heat required for thermophilic operation can be offset by the higher gas production yields and rates. Most of the solid-state digesters are operated with a solids content between 20% and 40% and an operating C/N ratio of 20 to 30, with an optimal ratio of 25 **(Liew et al., 2011).**

Researches have proved that biogas production is relatively low under mesophilic condition (37 °C) than thermophilic condition (55 °C). Besides, digestion period can be considerably shortened under higher operating temperature **(Juanga, 2005; Cecchi 2003).** In view of these findings, both batch and continuous process in this research are conducted under thermophilic condition.

According to previous studies done by **Eliyan (2007),** there was a problem of low biogas yield, low methane composition and lower removal of volatile solids in the continuous anaerobic digestion system operating in thermophilic range (**Matheri et al., 2018**). The problem was due to the design configuration of the reactor.

In this study the problems as said above has solved by modifying the design of reactor and the optimization of operational parameters such as organic loading rates, retention time for maximum volatile solids reduction has conducted. The ultimate aim is to optimize biogas generation and methane yield of Organic Fraction of Municipal Solid Waste (OFMSW) with different organic loading in an inclined anaerobic reactor.

II MATERIALS AND METHODS

In this study, the Organic Fraction of Municipal solid wastes (MSW) generated from Chidambaram municipality was collected and sorted for biological treatment by Anaerobic Digestion process as a part of solid waste management strategies. The research was conducted with an experimental model of pilot scale solid state Anaerobic Digester to study the effects of operational parameters especially Organic Loading Rates (OLR), Solid Retention Time (SRT) on stability of anaerobic digestion process of treatment of sorted Municipal solid waste (MSW).

The waste for the feedstock was collected and after collecting the wastes, the manual separation of the readily degradable organic fractions were carried out from the waste stream. The sorted wastes were fed into the shredder to obtain the average particle size of 10mm for the process. The inoculum was blended to the shredded small sized waste particles to enhance the start-up of the digestion process. To control the pathogens and reduce the digestion period the experiment was carried in at thermophilic condition of 55^0C.

The reactor is made of stainless steel horizontal cylinder with total volume of 1000 L and the working volume of the reactor is 600 L and it is fabricated with cylindrical wall container made of mild steel to provide a thermostatic pathway for hot water bath in order to maintain the designed temperature (55^oC) inside the digester. The digester was kept inclined at 30^0 to facilitating better biomass accommodation and easy digestate disposal and is also accommodated with piped outlet at bottom in order to prevent the intrusion of air inside the reactor during withdrawal. The detailed description of the reactor is shown in the Table- 1. 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. The schematic representation of the detailed design of solid state continuous anaerobic digestion system is shown in the Figures 1 and 2 show the photographic view of experimental setup.

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Table 1 Descriptions of the Reactor Design

Total volume	1000 L
Working volume	600 L
Shape	Cylindrical
Height	244.0 cm
Diameter of the inner cylinder	37.5 cm
Diameter of the outer cylinder	47.5 cm
Reactor type	Pilot scale-Single Stage Anaerobic inclined reactor
Degree of inclination	30^0
Type of feeding	Continuous System of Feeding
Supporting Equipment	Heater, Pump, biogas analyser ,digital temperature controller device with detector and Pipe Lines.

Figure 1- The conceptual experimental setup.

Figure 2 The photographic view of experimental setup.

Experimental Procedure

The feedstock was seeded with inoculums to start-up the digester. The inoculums were fed about 30 % of the total waste volume. The experiment was conducted in one reactor i.e. single stage high solid anaerobic digestion process. The complete start-up of the digester was checked from the stability of the gas production. After the complete acclimatization of the reaction, the fresh waste was fed continuously according to the loading rates. The purpose of re-circulating the digestate was to enhance the mixing and homogenization of the fresh wastes inside the digester. Biogas production was monitored daily. The experiments were conducted in two phases i.e. start-up and continuous loading. The experiments were conducted with three different continuous loadings of 2.5 kg/day, 3.5 kg/day and 4.0 kg/day for constant retention time of 25 days.

Feedstock preparation and analysis

The MSW used for this study was obtained as manually sorted organic fraction municipal solid waste from chidambaram municipal waste segregation yard. The fresh waste was collected daily, so the need for waste storage system was almost minimized. Before being loaded to the reactor, sorted-OFMSW must undergo some pre-treatments **(Bouallagui et al., 2005).** The waste collected were shredded to small particles with average size of 10 mm and homogenized to facilitate digestion. The sub-samples were dried and milled to the millimeter size and analysed for moisture content (MC), total solids (TS) and volatile solids (VS) using standard methods **(APHA,2005).**

After the analysis, the shredded waste were made for feedstock preparation in which the fresh shredded waste were blended with the inoculums to enhance the microbial diversity during start-up process and were fed into the digester based upon the organic loading rate. The inoculums was cow dung collected from the nearby cattle farm

Start-up phase of solid state Anaerobic reactor

In the start-up phase, the reactor was initiated with the fresh waste of 180 kg loaded in a batch mode. The total volume of the reactor was 1000 L and working volume was 600 L (60% 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 180 kg (equal to 60% of total volume). The reactor was operated in batch mode for 8 weeks for start-up process. The inoculum was comprised of cow dung. To avoid the risk of thermal shock inside the reactor, the reactor was initiated with mesophilic temperature 37^{o}C and the temperature was gradually increased to a thermophilic temperature 55^{o}C by increasing 2^{o}C 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.

Biogas generation and quality during start up

Digestion during start-up ran for a total of 8 weeks, during that period start-up reached Methanogenesis characterized by high methane composition (>60%). Figures 3 and 4, indicates the daily and cumulative biogas production.. The biogas production gets fluctuated during 21 to 35th days, and from 35th day it increased gradually and reached the maximum value of 800 L/day. From Figure 4., it is clearly seen that the biogas production and methane composition increased with the operation time indicating the better digester performance during start-up phase. This was achieved by the proper agitation system provided in the digester tends to better circulation of waste inside the digester.

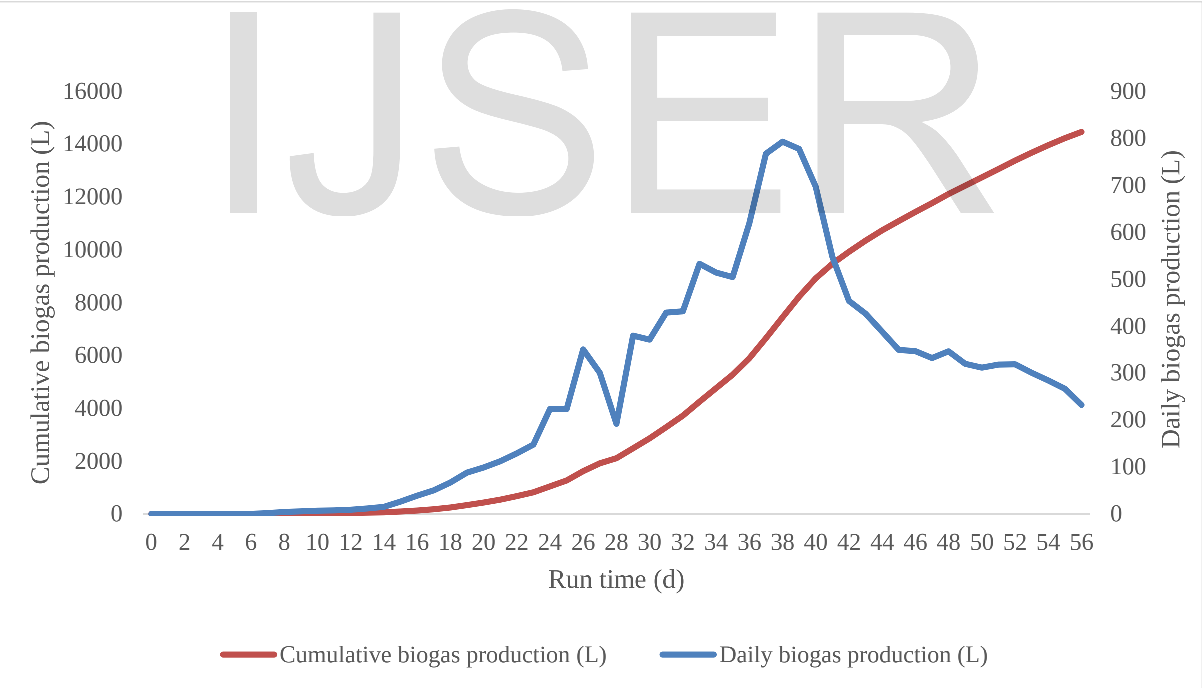

Figure 3 Daily biogas and cumulative Biogas production during start-up.

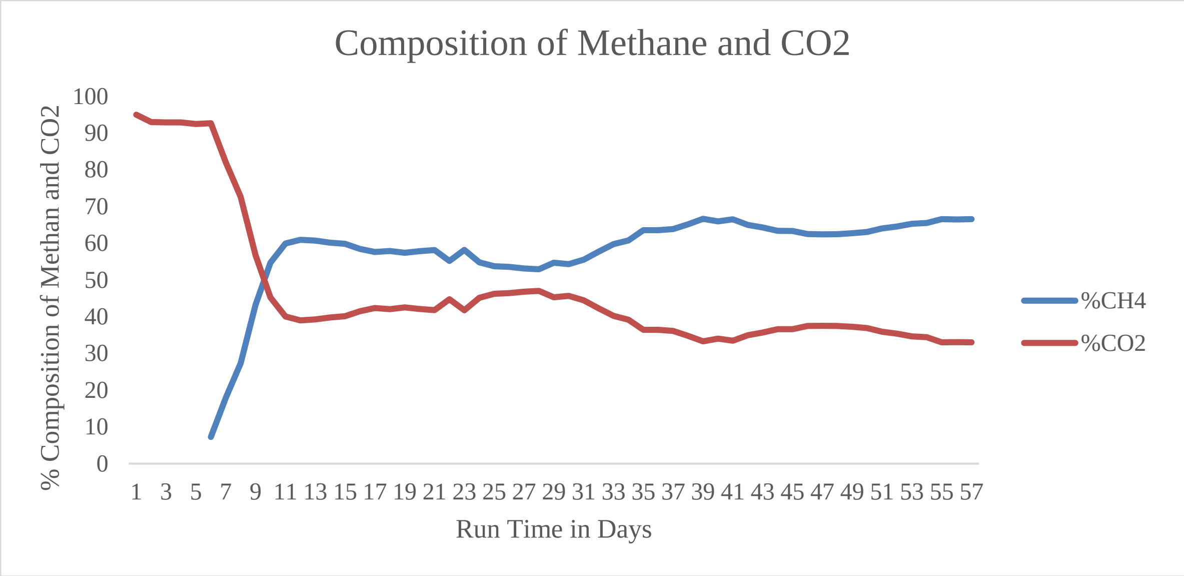

Figure 4 Composition of methane in daily biogas generated during start up.

Continuous feeding phase of solid state Anaerobic digester

This is the final and continuous phase of operation. In this operation, the continuous feeding was applied in draw and feed mode. Experiments were conducted for three different organic loading rates of 2.5 Kg/day,3.5 Kg/day and 4.0 Kg/day for constant retention time of 25 days. The experimental runs at phase 2 were carried out in a sequentially scheduled routing beginning with 2.5 kg/day. Once the reactor was operated for the required number of days as determined from the retention time, another loading rate was started. The working volume of the digester was maintained at approximately 60% and a proper volatile solids balance were done.

Biogas and methane production

The experimental results showed the variation of the biogas production during loading rates 1,2 and 3. The daily biogas production obtained during loading rates 1 , 2 and 3 were approximately 1500 L/d , 1000 L/d and 1100 L/d respectively. Figures 5 and 6 exhibit the daily biogas production with cumulative biogas production and % composition of Methane and CO_2 during continuous phase of operation.

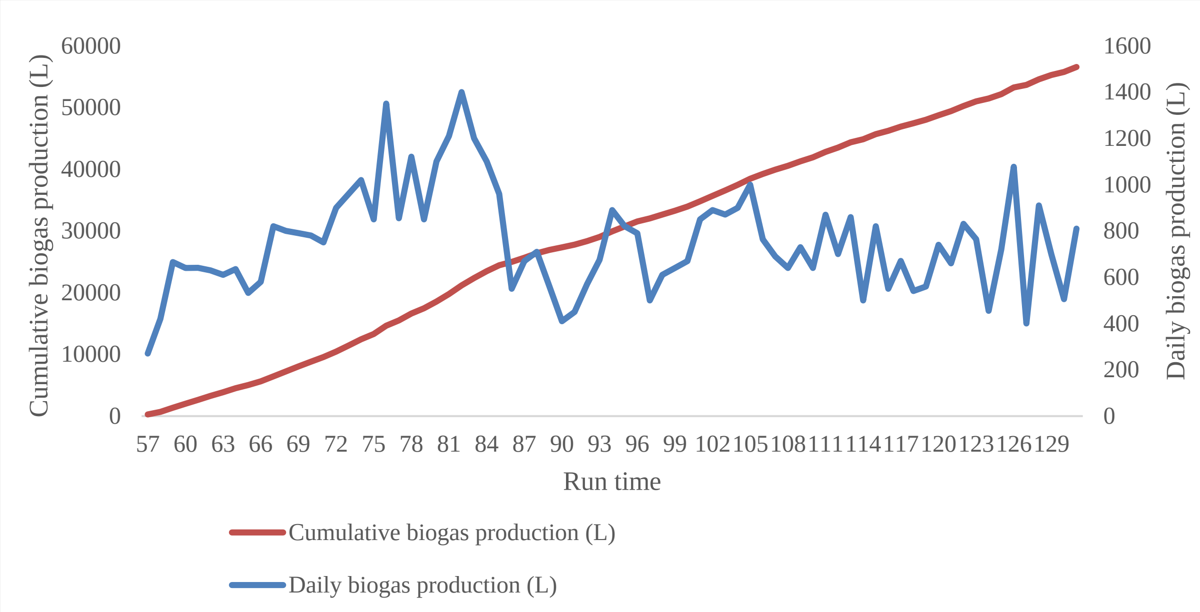

Figure 5 Daily biogas production and cumulative Biogas Production for continuous loadings

Methane concentration in biogas was observed around 70% (Figure 6) in loading rate 1 , 68% in loading rate 2 and was observed 55% in loading rate 3. The measurement of the quantity and composition of the biogas produced in terms of methane and carbon dioxide content is of fundamental important to evaluate the performance of the process.

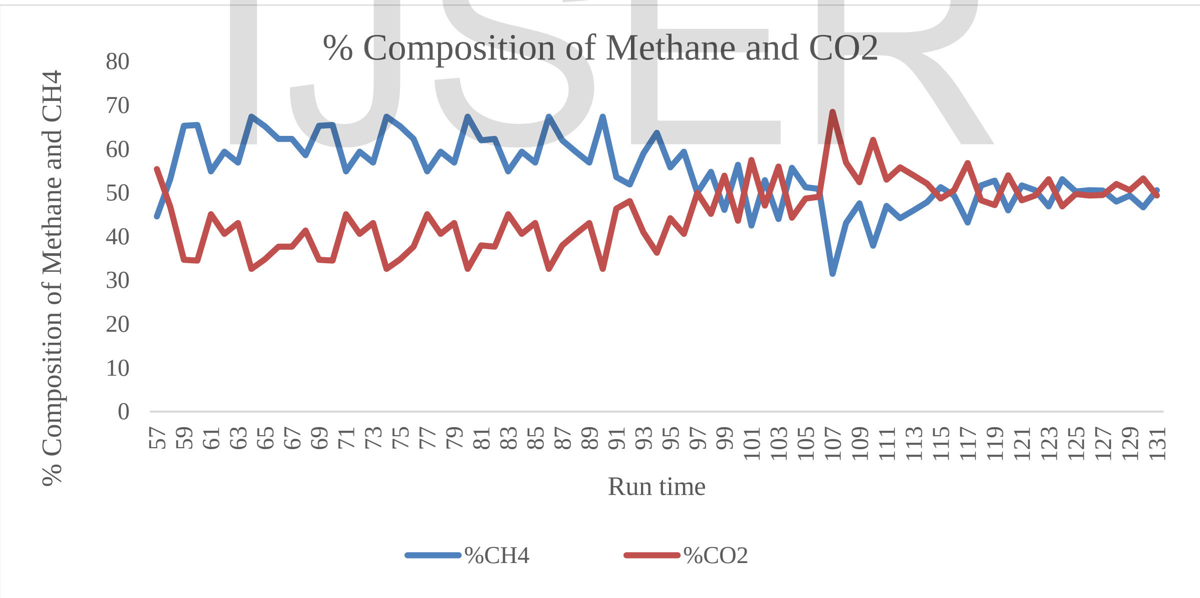

Figure 6 % Composition of Methane and CO2 during the continuous loadings

CONCLUSIONS

From this study, it is concluded that manually sorted organic fraction of municipal solid wastes can be anaerobically digested, producing a biogas containing 55%-70% CH_4..The daily biogas production obtained during loading rate 1, 2 and 3 were approximately 1500 L/d. 1000 L/d and 1100 L/d respectively and the Methane concentration in biogas was observed around 70% in loading rate 1, 68 % in loading rate 2 and was observed 55%

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