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Optimization of Gas Production from Municipal Organic Solid Waste Using Layered Inoculum Technique in Anaerobic Digestion

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KEYWORDS
inoculums; VAD; methane; biogas; anaerobic digestion; Cow dung: Sheep dung: Pig manure; sewage sludge etc.

Abstract— Solid waste management is an important challenge faced by developed nations across the globe. In order to effectively manage the improper disposal of solid waste, the first stage is conducting waste characterization studies. The process of anaerobic incorporation, which involves the breakdown of organic waste materials in the absence of oxygen, is widely employed in various oxygen-deprived environments. This research aims to provide a comprehensive review of the treatment advancements for digesting municipal Organic solid waste (MOSW) utilising an anaerobic reactor with four distinct inoculums. The Municipal organic solid waste (MOSW) is combined with various inoculums, including cow dung, sheep dung, pig dung, and sewage sludge in mono and mixed inoculums in batch reactors and used the optimum one in Vertical anaerobic digester(VAD). The experiments have been conducted using various ratios of inoculums in layer filling technique in order to determine the optimal gas generation rate and VS degradation. The optimal ratio of inoculum was determined to be CD and SD, which is used as layers together with MOSW for digestion in the verticalanaerobic digestion process. The methane content of the biogas produced from the batch reactors varied between 52% to 59% in the control reactor. In the reactors with different compositions, most optized inoculums was found out to be cow dung and sheep dung with 30% of inoculums. The optimized inoculum is used in the VAD for gas generation and VS degradation were determined. The cumulative gas production was found to be 468.2 mL/g VS of biogas was produced upon the completion of a 50-day handling period. The fluctuation in pH seen over a retention time of 50 days. The methane content recored in the produced biogas was around 73%. The percentage of degradation of the solid in the VAD were observed to be 86% during the digesting process.

I. INTRODUCTION

The effective management of organic solid waste has emerged as a significant global issue owing to its adverse environmental consequences, inefficient utilisation of resources, and the potential for contributing to greenhouse gas emissions. In light of these aforementioned issues, anaerobic digestion has emerged as a viable technological solution for the conversion of Organic waste into useful biogas, thereby addressing the environmental concerns associated with waste disposal. Hence, landfills are commonly classified into categories such as sanitary, municipal, construction and demolition, or industrial waste sites. Trash can be effectively categorised into various bins based on the specific composition of the waste, encompassing plastic, paper, glass, metal, and

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organic substances. Waste materials can be categorised based on their inherent toxicity or other associated risks, including but not limited to radioactivity, flammability, infectivity, toxicity, and non-toxicity. Trash can be categorised into distinct groups based on its origin, namely building debris, demolition debris, home waste, or business waste. The methodical treatment of solid waste is essential for upholding environmental best practices, regardless of its source, characteristics, or possible hazards. The integration of solid waste management into environmental planning is vital due to its pivotal role in maintaining environmental hygiene.

The term "layered inoculation" refers to a method of anaerobic digestion in which different microbial consortia or distinct microbial populations are introduced at different times. Tailoring the populations to execute specific functions like hydrolysis, acidogenesis, and methanogenesis is the goal of this method, which strives to foster a more robust and efficient microbial community. The goal of layered inoculation is to maximise the breakdown of complex organic materials and the production of biogas by establishing a stable ecosystem of microbes that cooperate well with one another. The researchers contemplated the utilisation of diverse forms of anthropogenic waste as a primary resource for energy production, with the aim of addressing the prevailing energy crisis and providing a sustainable energy solution for human consumption.

It's important to note that the worldwide population's domestic waste accounts for 60% of organic matter [1]. Anaerobic digestion (AD) seems to be a sustainable and cost-effective method for treating food waste. Microorganisms degrade organic materials (substrate) anaerobically, typically producing biogas, methane and carbon dioxide (CO_2) (60% 40%, respectively) and anaerobic digestate. Most of the people agree that maximum and consistent CH_4 generation is the best possible outcome of the AD process. It is carried out by four microbial broad categories (hydrolysers, acidogens, acetogens, and methanogens) through several metabolic pathways, involving both sequential and parallel reactions.

In addition to biological complexity, factors such as bioreactor configuration, process conditions, and feedstock type all contribute to the success or failure of AD processes as characterised by methanogenesis, inhibition, and system acidification. For instance, two- stage digester topologies have been shown in several studies to increase methane yield and conversion efficiency compared to single stage systems. Gas production from biogas in the subsequent phase. The first step is to optimise the AD process's performance in batch studies, regardless of whether it is a single-stage (traditional) or two-stage design. Predicting process performance and identifying likely sources of inhibition are greatly aided by the data uncovered by these kinds of investigations Furthermore, such research would aid in a) determining the rate of degradation of macromolecules (carbohydrates, proteins, lipids, and fibres), which can provide guidance for optimising feedstock properties to maximise volumetric yields and developing process configurations for the degradation of resistant materials, and b) understanding the maximum volumetric bio - gas yields to determine the capacity of downstream units such as gas holders, scrubbers, and generators[2].Gases such as methane and carbon dioxide are the primary elements of biogas, with the methane percentage representing the energy resource. In spite of these, biogas could also contain trace amounts of compounds containing Sulphur (H_2S, mercaptans, sulphides, etc.), compounds containing silicon (siloxanes, silanes), ammonia, halogenated compounds, and other organic compounds (VOCs). Furthermore, biogas is substantially wetter than natural gas, being saturated with moisture at the temperature of the anaerobic digester (35°C for mesophilic digesters, > 50°C for thermophilic digesters) or the temperature of the downstream processes (e.g., a gas transfer line exposed to the ambient air after the digester). This article aims to provide an overview of the biogas compositions that can be anticipated from agricultural biogas and the organic part of municipal solid waste. This is, as far as we are aware, the first release of collected data on the trace chemicals from these biogas sources. On the

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concentration of mercaptans, organic Sulphur compounds, and terpenes in particular, only limited data is known. Despite the fact that these pollutants are typically present in small amounts and do not necessitate removal for conventional biogas engine applications (on account of the larger tolerance limits), knowing their presence is crucial for fuel cell applications, which have considerably lower permissible limits and require gas cleaning units to be constructed with all potentially damaging contaminants in mind[3]. Incredibly successful inhibitory control in high solids digestion has been achieved by adjusting two process parameters: the inoculum to substrate ratio (I:S) and the moisture level of the digester. While reducing the bacteria's capacity to treat incoming waste, increasing the inoculum at the start of the batch reactor is some of the most predominant techniques in industry for preventing volatility in usually dry batch AD. Increased anaerobic microbial communities, including methanogens, and better interaction with the organic substrate reduces volatile fatty acid (VFA) build up, accelerates kinetics, and boosts community resistance to inhibitor peak concentrations. When the I:S ratio is lowered from 2:1 to 1:2, the pH of the digested kitchen waste drops from 7 to 5.5, and the methane output drops by a factor of ten. For extremely dry batch AD of MSW , many values have been published in the literature as acceptable I:S ratios; some studies have suggested ratios between 1:1.5 and 1:2.5, while others have found reductions in methane production if the inoculum quantity was dropped to an I:S ratio of 1:4. There remains an insufficient understanding about the proper ratios, which are very dependent on the type of feedstock and the operating conditions of the digester. More research is needed to find the best ratios to avoid inhibitory activity and improve kinetics and production when OFMSW is used as a substrate [4].Gardens, parks, homes, eateries, shops, and the food industry all contribute to what is known as OFMSW, a biodegradable trash collected by local governments. Typically, they contain a variety of materials, including food, garden trash, mixed papers, newspapers, wood, and cardboard. However, the categorization and features of OFMSW vary greatly and depend on a variety of criteria for each country. There were 16 separate fractional components of OFMSW, including things like fruit and vegetable peels, bread, meat and fish, snacks and sweets, dairy, tea bags and coffee granules, cereals, and other leftover items, as reported by earlier studies. Eggshell, bio bags, and bones are non-biodegradable waste that harm AD and are considered physical contaminants [5].Magnetite, hematite, charcoal, granulated activated carbon (GAC), carbon cloth, and carbon nanotubes are only some of the metal and carbon-based materials utilised as conductive agents to boost methane generation. Conductive materials may replace or augment pili as the electrical connection between microbial species. Pure and blended cultures can support DIET, however the majority of these tests were conducted using readily biodegradable substrates including glucose, fatty acids, and alcohols. In a few instances, the DIET has also been directly observed in the use of mixed cultures and complex organics, such as waste sludge, dog food, wastewater, and pig dung. Despite its widespread use, anaerobic treatment of swine effluents as a treatment connected to biogas production has low methane productivity and low efficiency in removing organic pollutants. Attempts to improve the anaerobic digestion procedure include pre-treatment techniques (electrical, thermal, biological, and oxidative), supplement additives (mineral nutrients, metal-oxide nanoparticles, co-substrates, and enzymes), and DIET acceleration. The inclusion of graphene oxides to swine dung digestion did not raise methane generation; in fact, it decreased it, but it boosted propionate decomposition. In contrast, Fe_2O_3 and magnetite boosted methane generation during swine dung breakdown. In addition, the presence of GAC increased the dry biogas production of swine excrement by boosting the volumetric biogas rate of production. However, the methane generation with carbon materials employing the solid and liquid components of swine effluents had not been tested [6]. Future applications of anaerobic digestion technology for environmental and agricultural sustainability are substantial since it

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represents a practical and effective waste-stabilization approach to convert undiluted solid bio-waste into sustainable energy and nutrient-rich organic fertilizer. However, the implementation of this technique is limited, particularly in poor nations, due to the absence of suitable treatment system configurations and primarily due to the lengthier time necessary for the bio stabilization of waste. Any reactor design and operational criterion selection depends on the characteristics of the feedstock, financial factors, etc. This paper discusses the experimental research conducted using a laboratory-scale reactor to produce biogas from municipal solid waste in layered inoculum technique. This study aimed to determine the best conditions for biogas production from the methanogenesis of MSW using diverse inoculums from various sources, such as cow dung slurry and sewage sludge. The pH, alkalinity, and chemical oxygen demand of the substrates were measured after anaerobic treatment for biogas production. The investigation of these factors will assist us in establishing a biogas system with readily available substrates and utilizing a variety of food waste types for biogas generation.[7].

The studies were conducted using a laboratory reactor with a 1-litre capacity, namely an acrylic bottle. The reactor, constructed with acrylic sheet material, featured a sampling port located at the bottom, facilitating convenient examination. Rubber stoppers equipped with glass tubes were employed for the purpose of sealing the bottles, facilitating the venting of gases, and enabling pH adjustments. The effective volume of the reactor was maintained at a constant value of 1 L. The water displacement method was employed on a daily basis to assess the biogas output of the reactors. The gas emission exhibited a direct relationship with the amount of water displaced from the bottle. All of the reactors were operated at ambient temperature. In this study, two separate sources of inoculum were utilised in an anaerobic environment: untreated sludge obtained from the sugar sector and sludge obtained from the dairy business. The recommended inoculum-to-substrate ratio for the fermentation of organic wastes is 10%, 20%, and 30% of the working volume (weight) of the substrate. A representative specimen of the inoculum was collected and thereafter maintained at a temperature of 4 degrees Celsius in order to sustain the viability of the essential bacteria involved in the anaerobic digestion procedure. The bioreactor was supplied with a diet consisting of fresh organic municipal solid waste (MSW). The majority of organic material found in municipal solid trash consists of household rubbish, along with waste generated by local grocery stores and fruit and vegetable markets. After the completion of the sorting and shredding processes, the garbage underwent multiple rounds of mixing within the laboratory setting. Subsequently, it was stored at a temperature of 4 degrees Celsius until it reached the appropriate state for utilisation. The reactors were loaded with untreated feedstock from the sugar industry. The attainment of total solid concentration was accomplished through the introduction of waste sludge and untreated waste sludge obtained from a milk and dairy products manufacturing facility [8].

The primary aims of this study were to determine the optimal parameters for the production
of biogas by anaerobic fermentation of organic solid waste (OSW). This was achieved by employing inoculums obtained from cow dung, sheep manure, and pig manure and sewage sludge as a mono inoculum and tried the mixed inoculums in batch reactors. The materials underwent anaerobic treatment for the purpose of biogas generation, with subsequent measurements taken for pH, alkalinity, and chemical oxygen demand. The investigation of these limits will facilitate the development of a biogas framework utilising accessible substrates and the utilisation of diverse forms of available food waste and other organic waste for the purpose of biogas generation.

II. MATERIALS AND METHODS

Municipal solid waste is a waste sort comprising of regular things like food squander, waste disposal, market removal, yard squander, plastic compartments and different strong waste from private. Generally biodegradable and non-biodegradable is gathered independently and overseen independently civil strong waste doesn't comprise mechanical waste, farming waste, clinical waste, radioactive waste or sewage muck.

In this study of the literature, the inoculum was fresh cow dung, sheep dung, pig dung and sewage sludge, which has all the microbes needed for the anaerobic digestion process. The inoculum used to have a pH of 6.5%, total solids of 25.2%, and volatile solids of 85.9%. About 30% of total of the working volume of the acetogenesis fermentation of the organic waste is made up of the inoculum. The inoculum was taken from a farm nearby and stored at 4 °C until it was needed.[9]

The trials were continued batch reactor (acrylic bottle) with absolute limit of 1000ml. The reactor was made of acrylic with base testing outlet. The jugs were shut by elastic plugs furnished with rubber tubes for gas evacuation and for changing the pH. The compelling volume of the reactor was kept up at 1 L. Biogas creation from the reactors was observed every day by water displacement method. The volume of water uprooted from the container was identical to the volume of gas created. The reactors were worked at mesophilic temperature inside the anaerobic reactor.

The examination had been done with the Combination of different inoculums source like cow dung, sheep dung, Pig excrement and sewage sludge. The level of inoculum for acidogenic maturation of the natural squanders is roughly 10%, 20%, and 30% of the working volume of substrate. The inoculum was gathered and kept at 4°C until utilized, which contains every one of the necessary microorganisms fundamental for anaerobic absorption measure. New natural OSW were utilized as feed to the bio minister. The natural OSW comprises of food squander, organic product squander, vegetable waste from close by vegetable market and house hold. The squanders were arranged and destroyed, at that point blended a few times in lab and kept at 4°C until utilized. All reactors were stacked with crude feed stock and inoculated with cow dung, sheep dung, pig droppings and Sewage sludge each independently. This study is programmed to evaluate the mesophilic digestion of OSW at three different initial inoculums concentrations and one control (without inoculums). The substrate concentration was expressed as weight of solids/total volume of solids. Four batch reactors were operated at a volume of 1000 ml with different inoculums concentrations of 0%, 10%, 20%, and 30% of weight solids respectively. All the reactors were fed with municipal organic garbage, cow dung, sheep dung, pig dung & sewage sludge (inoculum) in layers, used as the starter in the reactors. Samples were tested in appropriate place for pH, temperature, moisture content. All the experiments were conducted under sterile conditions and experiments were carried out in triplicate. Different Inoculums are shown in Fig 1.

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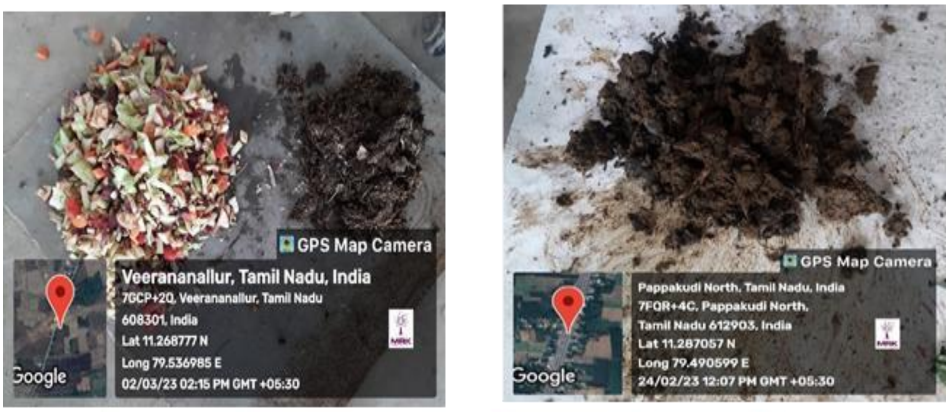

Fig 01-Substrate and inoculums like SD, CD & PD

Initially the batch reactors with mono inoculums were poured in layers is the first stage of research work.The the batch reactor with mixed inoculums were poured and get optimized for a period of 40 days.Based on the optimization from mono inoculums and mixed inoculums,the best optimized inoculums should be tried in the Vertical anaerobic digestor(VAD) to measure the gas production and volatile solids degradation for a period of 50 days.During the period Ph,temperature,moisture content and gas collection is measured.The following figure shows the batch reactor setup.

Fig 2- Bench scale Batch Reactor

BATCH REACTOR:

The reactors having 1) wide slot at the top which is used to feed the materials into reactor for digestion. The slot is closed by its cap and make sure it air tight, after complete the entire digestion process the sludge is removed by the same slot. 2) A tiny slot which can be open and close anytime and it is used to inject water into the reactor. To maintain optimum temperature within the reactor, water is used to reduce the temperature. 3) Tube connected at the top of the reactor which transmits the biogas from reactor to storage chamber. 4) A slot at the bottom of the reactor which is used to insert thermometer and Ph. Meter to take reading at regular intervals,5) Blower is connected to another tube which is connected at top as shown in figure 2. Every day, the amounts of gases and what they were made of were measured. At the end of each batch, when the gas stopped coming out, the vials were opened and samples were taken to measure the pH, volatile fatty acids (VFAs), and ammonia. During the next step of the new batch culture, some of what was in the vials was taken out, and the same amount of substrates was put back in.

This process, also called "batch reactor," was done four times over the course of 8 batches. The OSW is pour into bottle with different inoculums like CD, SD, PD, SS for a duration of 40 days with different condition and different mix ratios. We took samples of fermentation (about 0.3 g of wet weight) and put them in a 2-mL plastic tube with 1000 ml of deionized water. The suspensions were turned at rpm for 15 minutes at 4 °C, and the clear supernatants were used to measure pH, ammonia, and volatile fatty acids (VFAs).[10]

VERTICAL ANAEROBIC DIGESTER(VAD)

Based on many trails made with batch reactors

with different inoculums with different ratios like 0%, 10%, 20%, 30%.Based on the results obtained I have chosen the optimum batch of OSW with CD & SD as inoculum and the same has to be placed in vertical anaerobic digester(VAD) which is made up of fiber reinforced material having a working volume of $0.15m^3$.So the Substrate volume of 35.21kg and Inoculum volume of 15.1 kg is poured into the main reactor in layers and observe the pH and temperature for a period of 50 days and daily gas production, moisture content ,temperature is measured is measured with water distillation method. The experiment is carried out in VAD with collecting solid waste and done the characterization of solid waste. Then the MOSW is mixed with different inoculums and optimize the best as Cow dung and sheep dung as inoculum in equal proportions (1:1) gives the better result in gas production as well as VS degradation up to 86%. Then the optimized inoculums are tried in Vertical anaerobic digester to produce the gas and VS degradation efficiency. The following are the schematic diagram of the vertical anaerobic digester.

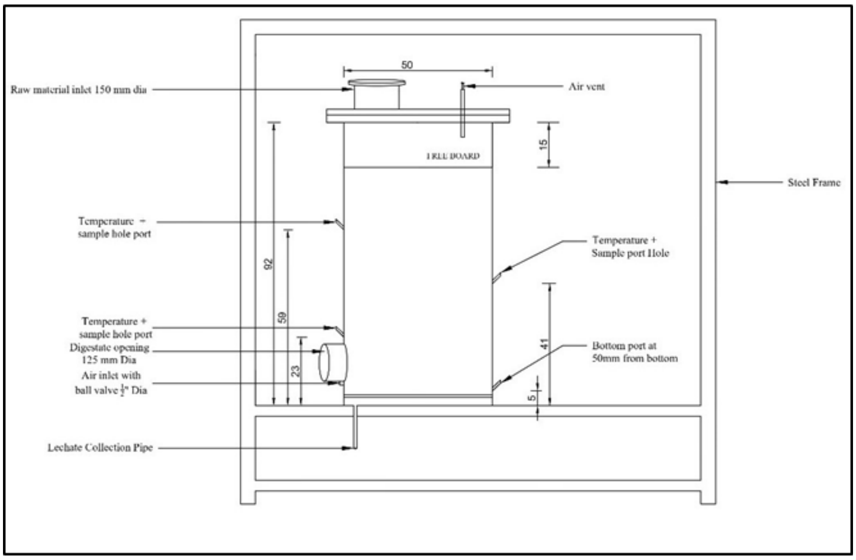

Fig 3- Schematic diagram of Vertical Anaerobic Digester(VAD)

III. RESULTS AND DISCUSSION

A. SUBSTRATE CHARACTERISTICS AND INOCULUMS CHARACTERISTICS:

The ascribes of the substrate and inoculums, untreated cow dung. Sheep dung Pig dung and sewage sludge were showed up in the Table.1, 2, 3 and 4. The tests were refined for 50 days. Degradation of substrate started reliably in the reactors; it took around 7-8 days for beginning of biogas creation.

Table.1 Characteristics of Substrate

Sl. No	Parameters	Value / weight fraction (%)
1	Moisture (%)	65.3
2	Ph	5.9
3	Total Solids (%)	20
4	Total volatile solids (%)*	86
5	Ash content (%)*	12.4
6	Total Organic carbon (%)*	19.8
7	Total Nitrogen (%)	1.02
8	Chemical oxygen demand(ppm)	2454
	* indicates wt % in total solids	

Table.2 Characteristic of Inoculum – Untreated COW DUNG

Sl.No.	Pollution indicators	Unit of Measure	Mean Values
1	COD	mg/l	1450
2	BOD	mg/l	678
3	Total Suspended solids	mg/l	950
4	Ph	Unit	6.5 - 9.2
5	Chlorides	mg/l	18 - 35
6	Nitrate	mg/l	8.4

Table.3 Characteristic of Inoculum – Untreated Sheep Dung

Sl.No.	Pollution indicators	Unit of Measure	Mean Values
1	COD	mg/l	755
2	BOD	mg/l	439
3	Total Suspended solids	mg/l	650
4	Ph	Unit	8.1
5	Chlorides	mg/l	25
6	Nitrate	mg/l	7.3

Table.4 Composition of Organic solid waste

Sl.No.	Description	Percentage
1	Food waste	41
2	Fruits and Vegetable waste	29
3	Paper waste	9.5
4	Yard waste	8.5
5	Cloths, textile waste	7.5
6	Wood Waste (Pruning waste)	4.5

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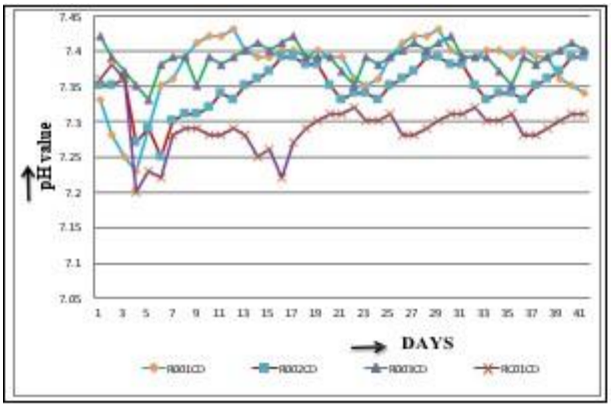
B. Performance study of Batch Reactor using CD, SD, PD, & SS as inoculum:

To examine the impact of inoculums fixation on the presentation of the anaerobic absorption measure OSW as substrate with beginning untreated CD, SD, PD & SS mono inoculums slime convergences of 0%, 10%, 20%, 30% (RC, R1CS, R2CS, R3CS) of the heaviness of substrate. In the batch reactor with mono inoculums, cow dung as an inoculum gives the better result in gas production as well as volume degradation. The daily gas production was initiated in 7th day and found the measurement 19.2 mL/g VS in R003CD as a best in gas production. The cumulative gas production is found to be 427.7 mL/g VS. The reactor R003CD gives better result compared to other reactors with other proportions like 10%, 20% inoculums. After that 40% replacement the gas production may be reduces. Then I tried the batch reactor with mixed inoculum for optimization. Cumulative gas production & pH variation over a retention period of 40 days as shown in the fig 4 & 5 respectively.



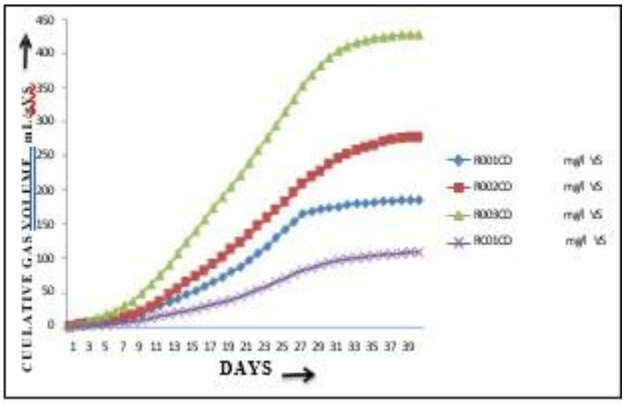


Fig 4-Variation of pH for untreated cow dung as Inoculum

Fig 5- Cumulative Gas Productions with Untreated Cow dung as Inoculum

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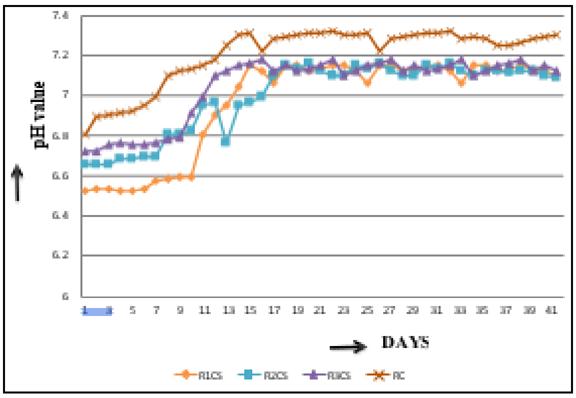
C. Performance study of Batch Reactor using CD, SD, PD, & SS as mixed inoculum:

To examine the impact of mixed inoculums like cow dung & sheep dung, cow dung & pig dung, sheep dung & pig dung, cow dung, sheep dung & pig dung as mixed inoculums in batch reactors. The daily gas production and VS degradation was measured in batch reactor with mixed inoculums. Out of that the cow dung and sheep dung with equal proportions gives the better reseul in gas production. The gas production was started in the 4th day and produced the maximum at the end of 26th day. Cow dung and sheep dung inoculums gives the better result in cumulative gas production and VS degradation is found to be 432.9mL/g VS and 88% respectively. The methane content was found to be 76%. The TS content was introduced in term of dry issue and the combined biogas kept up at room and surrounding temperature along. The examination was done in tripling. The information got from the investigation at that point is found the middle value of and the aggregate volume of biogas creation was seen during 40 days. [11]The assimilation was portrayed without variance of biogas creation toward the start. Corruption of substrate began very quickly and continued without issues in all absorptions and biogas creation is fundamentally expanded because of outstanding development of microorganisms and to their higher transformation to the difference in the centralization of inoculum. The biogas creation was low to start with which was because of the log stage. The everyday biogas yield, biogas delivered per gram natural solids (unstable solids) for various centralizations of inoculum throughout a multi-day assimilation time at room temperature (32°C) is appeared. The paces of biogas creation contrasted apparently as per the TS fixation. Moreover, as appeared in Figure 5, 6 & 7, the greatest total cumulative biogas creation acquired for Rc was 113 mL/g VS in 40 days. Toward the finish of the 40 days all out aggregate biogas for R1CS, R2CS, R3CS was gotten as 173.06 ml/g VS, 270.56 ml/g VS, 432.9 ml/g VS individually for OSW and SM &CD as inoculums in equal proportions. The lower biogas yield demonstrated that there was a restraint of methanogenic microscopic organisms. It tends to be seen from Figure 5 & 6, that the greater part of substrate debasement happens up to a time of 25-27days proposing that the digesters should ideally be run at an assimilation time near 25-27 days for deal energy yield.



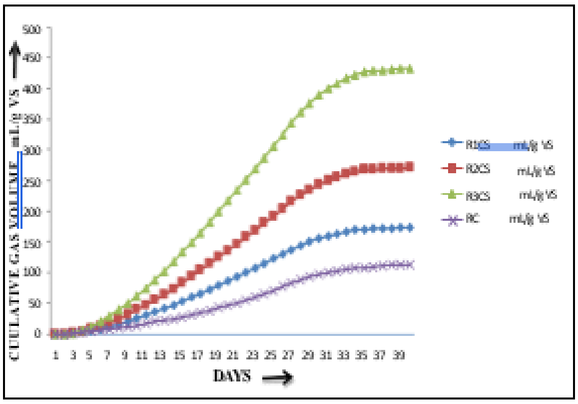


Fig 6-Variation of pH for untreated Cow Dung and Sheep Dung as Inoculum

Fig 7-Cumulative gas production with Cow dung and sheep dung as inoculum

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The profile of pH over the length of the absorption time frame at inoculums fixation 30% (R3CS) under room temperatures is appeared in Figure 06. The outcomes demonstrated that the pH esteems appeared to change with activity time in a similar path in all examples; as observed, the pH began from a similar starting pH (6.5 – 7.3), Dropped from the outset incompletely because of the heterogeneity particles, resulting hydrolysis measure happened in the reactors and the unpredictable unsaturated fats (VFA) gathering, particularly during the initial three days. In any case, all the pH expanded following 7 days' tasks, and stretched around 6.72 to 7.12.

A figure 6, 7 shows the pH for reactors and total cumulative biogas readings (RC, R1CS, R2CS, and R3CS). The reactors RC, R1CS, R2CS, and R3CS were worked with inoculums convergence of 0%, 10%, 20%, and 30% of the heaviness of substrate. The impact of various convergences of inoculums blending proportion on methane creation is appeared to be 76%. The explanation behind picking this proportion is to adjust between the nourishments to microscopic organisms. In the event that food less or more the requirements sum, the creation might be diminishing. On the off chance that the microscopic organism's proportion (i.e., microorganisms/food proportion) is not exactly the best proportion establishing, this may case fermentation proportion which repress the action of microbes. Be that as it may, if the case is converse this make substrate inadequate to improve microorganisms action and hence lessen methane creation. The pH was continually checked and variety in pH was seen in all the three cases with R1CS indicating more articulated impact. The pH was adjusted to 7.12-7.15 in R3CS by adding 4M-$NaHCO_3$ arrangement at time. The adjustment in pH at Reactors was appeared in Figure 06.

By comparing all those aspects in using different inoculums the best gas production and volume reduction is CD and SD (Mixed inoculum) as 30 % replacement in OSW gives better result in Batch reactors.

D. Performance study of VAD in Cow dung and sheep dung as mixed inoculum:

Based on the performance of mono inoculums and mixed inoculum. The C dung gives the best result in cumulative gas production. In mixed inoculums cow dung and sheep dung gives the better performance in cumulative gas production and VS degradation. So compared to all the mono inoculums and mixed inoculums, Cow dung and sheep dung gives the best result. Then that optimized inoculum of 30% inoculum of cow dung and sheep dung should be used in the vertical anaerobic digester. In an anaerobic framework, the acetogenic microorganisms convert natural issue to natural acids, potentially diminishing the pH, lessening the methane creation rate and the general anaerobic assimilation measure except if the acids were immediately devoured by the methanogens. pH in the scope of 6.8 to 7.4 should be kept up in the anaerobic assimilation measure, which is the ideal reach for methanogens development. A reduction in pH was seen during the initial not many long periods of assimilation because of the high unstable unsaturated fats development; consequently, the pH was acclimated to 7 utilizing 4M-NaOH solution. The biogas creation happens at pH (6.9-7.4) with most extreme estimation of (468.2 ml/gVS) as appeared in Figures 09 to 11. The methane substance of the biogas produced from the reactors was in the scope of 57–63% during the initial 2–4 days of the absorption and stayed in the scope of 62–69% for the excess time frame.[12] . The biogas creation was slowly reduced after 50 days because of absence of measure of substrate. The variation of pH, daily gas production, cumulative gas production, temperature, moisture content percentage as shown in the figure 8. 9, 10, 11 & 12.

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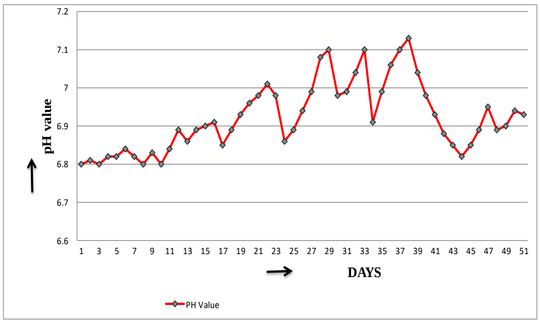

Fig 08-Variation of pH for untreated Cow Dung and Sheep Manure as Inoculum in VAD

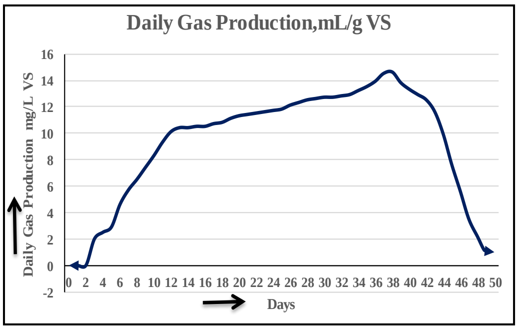

Fig 09-Daily gas production for Cow Dung and Sheep Manure as Inoculum in VAD

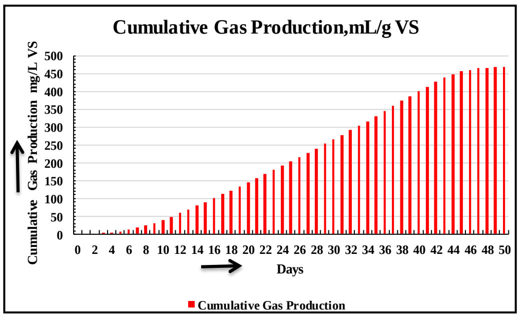

Fig 10-Cumulative gas production for untreated Cow Dung and Sheep Manure as Inoculum in VAD

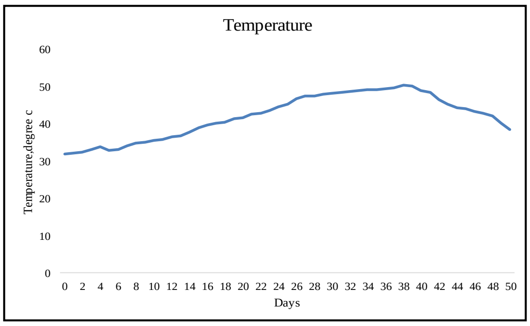

Fig 11-Temperature measurement for untreated Cow Dung and Sheep Manure as Inoculum in VAD

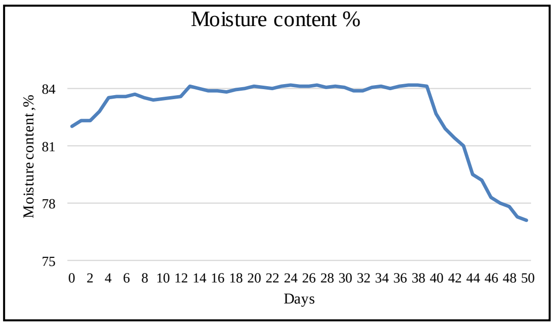

Fig 12- Moisture content for untreated Cow Dung and Sheep Manure as Inoculum in VAD

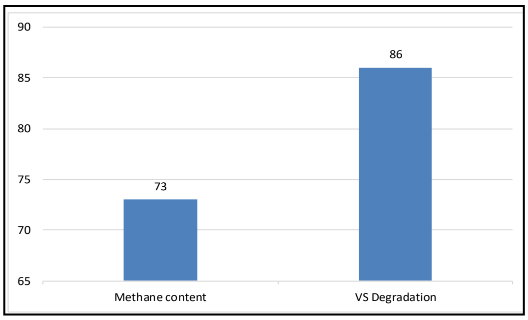

Fig 13- Methane content and VS degradation for untreated Cow Dung and Sheep Manure as Inoculum in VAD

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E. Comparative process efficiency

The rundown of execution of batch reactors referring to the characteristics of starting and prepared substrate, it was seen from Figure 5 &7, that the methane substance of the biogas made from the reactors was in the extent of 52 to 56% in control reactor and that CD and SD produces the 86 % of CH_4. From the results, it was seen that most limit methane substance of the biogas created was occurred for mixed inoculums of CD and SD. The extension in CH4 obsession may have been achieved by the development of trimmings containing a great deal of adequately biodegradable substances [13]. The cumulative gas production in cow dung & sheep dung has produced more gas when compared to cow dung as inoculum. The VS degradation also increases in mixed inoculum of cow dung and pig dung when compared to all the mono inoculums and mixed inoculums. It will in general be seen; that the fundamental piece of substrate debasement occurs up to a period of estimated 50 days in VAD. The methane yield % was more in the Untreated cow and sheep dung inoculum reactors that is a typical biogas creation obtained during anaerobic ingestion; contains methane (75-86%), carbon dioxide (20-25%), some inactive gases (N2, H2, CO, and O2) and Sulfur blends has found by using gas chromatography. The CH4 structure (86%) recovered in this experiment. The moisture content was found to be 82% in starting of digester, which will increases to 84.15% at the end of 39th day and further it reduces unto 77.10% at the end of 50th day .over a period of 50 days of retention period of pH as shown in the figure 12.

Maximum permissible retention period has attained at methanogenesis is around higher in effluent from hydrogen genic operations than the single methanogenesis process. This is because the retention period of hydrogen genic operations is substantially shorter than that of solubilizing operations, while achieving almost the same levels of overall removal efficiency [14].

IV. CONCLUSIONS

The purpose of this study is to enhance the extraction of biogas and VS degradation from segregated Municipal organic solid waste with optimized inoculums. The cumulative gas production in cow dung (30%) as inoculum was found to be 427.7 mL/g VS, which is higher than the other mono inoculums in layered technique over a period of 40 days. The cumulative gas production from reactor digested with cow dung and sheep dung (30%) as mixed inoculum was found to be 432.9 ml/g VS, Which gives the best result when compared to all other mixed inoculums over a retention period of 40 days in the batch process. After the completion of digestion process in batch reactor with mono and mixed inoculums, mixed innoculum of Cow dung and sheep dung(30%) addition seems to record the best degradation results. The optimized mixed inoculum(Cow & Sheep Dung) with MOSW substrate was used to analyse the performance of the vertical anaerobic digester (VAD). The VAD is run for a retention period of 50 days in anaerobic condition. The cumulative gas production was found to be 468.2 ml/g VS of biomass and the methane content was 73% in the biogas produced. The percentage degradation of volatile solids was 86 % over a retention period of 50 days. The percentage degradation of VS and maximum gas production was achieved within the shorter retention period using layered inoculum technique than the conventional anaerobic digestion process.

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