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Co-Digestion of MSW for Efficient Biogas Production

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I. Introduction

The major problem in today's scenario is the global depletion of energy supply due to the continuing over-utilization. As per estimation in few years we will be run out from fossil fuels **[1]**. It is therefore important to explore new potential sources of energy **[2]**. India is a tropical country and its temperature condition is very suitable for the fermentation of organic materials throughout the year. Therefore, there is a great prospect of biogas to be used as an alternative source of energy in India.

AD is one of the most promising uses of biomass wastes because it provides a source of energy while simultaneously resolving ecological and agrochemical issues **[3]**. The value of supplement is not reduced by the anaerobic fermentation of manure **[4]**.

The major advantages are enhanced biogas production, better digestibility, arising from availability of additional nutrients, as well as a more efficient utilization of equipment and cost sharing **[5]**. Studies have shown that co-digestion of several substrates, for example, cow manure, poultry waste, pig waste and plantain peels, spent grains and rice husk, and cassava peels, sewage and brewery sludge, among many others, have resulted in improved methane yield by as much as 60% compared to that obtained from single substrates **[6]**.

Biogas production takes into consideration a large variety of substrates, animal and plant wastes **[7]**. In these studies, the rate of biogas production was found to depend on several factors such as pH, temperature, C: N ratio, retention time, etc. Co-digestion of OFMSW with cow manure and poultry waste can improve the methane production of anaerobic digestion processes **[8]** and has been recently reviewed **[9]**. The co-digestion of cattle manure with MSW **[10]** has also been shown to enhance methane production. The present study was undertaken to evaluate co-digestion of organic waste of MSW and animal manure.

1.1 Biomass

Biomass has been defined as organic matter formed by photosynthetic capture of solar energy and stored as chemical energy, which includes agricultural crops and wastes, animal wastes, forest and mill residues, wood and wood wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.

II. Methodology

2.1 Anaerobic digestion of municipal solid waste and co-digestion with manure

Anaerobic digestion of the organic fraction of municipal solid waste (OFMSW) co digestion with cow manure and poultry waste. This was carried out in two mesophilic (35^{o}C) wet digestion treatment systems. Initially only OFMSW digested S_1 setup and OFMSW co-digested with cow manure in S_2 setup then we take OFMSW co-digested with poultry waste in S_3 setup and then OFMSW co-digested with cow manure and poultry waste, at a hydraulic retention time (HRT) of approximate 4-5 days. Over a period of 6 weeks adaptation of the co-digestion process was established to an OFMSW: manure. The pH raised to a value of above 7 and the reactor showed stable performance with high biogas yield and low VFA levels.

2.2 Materials for designing and development of digester

i) Digester: 4 batch type airtight plastic bottles, Capacity – 500 ml

ii) Gas Container: one liter High-density glass container for contains the biogas.

iii) Substrates: The substrates used as feed stock materials for the generation of biogas in the Takshshila institute campus were OFMSW which contains market and household wastes including vegetables, fruits and kitchen wastes. MSW are collected from different areas in the city.

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iv) Inoculums: The inoculums for mesophilic incubations were collected from the pilot scale mesophilic anaerobic treatment plant based on cow dung and MSW.

v) Plastic tubes: 0.5 inch

vi) Measuring jar: 1000 ml

2.3 Analytical Methods

The study was conducted in Takshshila institute of technology & sciences campus. The methods used in this study are described here under:

2.3.1 Materials/Instruments

The following materials/instruments were used for the purpose of this research: weighing balance (Systronics), gas chromatography (CHEMITO), pH meter (Systronics), a mercury in glass thermometer (range $0^{O}C$ to $100^{0}C$), Borosilicate Desiccators, silica glass crucibles, oven, grinding mill, temperature controlled water bath, water troughs, graduated transparent glass gas collectors, tap water, rubber cork, connecting tubes and biogas burner fabricated locally for checking gas flammability.

2.3.2 Biomethanation unit

It consists of a temperature controlled thermo bath which is maintained at $35^{0}C$ if possible. It can accommodate 4 biodigester. Each biodigester is connected to a graduated gas collector by means of a connecting tube. A stand holds all the gas collectors. Biogas evolved is collected by downward water displacement method. Plastic water basins are used for water sealing

2.4 Solids Analysis

Total solid (TS) and volatile solid (VS) were analyzed for OFMSW, poultry waste, cow dung and primary sludge according to standard methods (APHA, AWWA and WPCF).

2.4.1 Fermentation Slurry

Organic waste of MSW on collection was chopped to small sizes of about 2 cm, and then Organic waste of MSW was then ground to fine particles using a grinding mill. To study the anaerobic co-digestion of Organic waste of MSW with poultry waste and cow dung, the experimental setup of 4 batch digesters S_1,S_2,S_3, and S_4.Biomethanation of the digesters were carried out with a retention time 55 days in the mesophilic range (30-40^{o}C).

2.4.2Anaerobic Process

The schematic diagram of the overall process is shown in Fig 3.3.1. The reactor had total Volume of 500 ml batch type. When the hydraulic Retention time (HRT) of the reactor was 4-5 days, and solid retention time (SRT) was 50 Days, the organic loading rate (OLR) from 300g With Cow manure and poultry waste seeding with 100g fresh digested sludge of Cow manure. At temperatures of the acidogenic and methanogenic reactor were maintained at $35^{o}C$-$45^{o}C$. In order to investigate the effects of co-substrate and stage of digestion on biogas production and the performance of the system was investigated.

2.4.3 Effect of Microorganism Seeding on the Start-up of the AD

Although anaerobic microorganisms acclimatized to MSW can be good inoculums for a fast start-up of the operation at the initial stage, the waste sludge of the activated sludge process was used as seeding inoculums to avoid possible infection by pathogenic microorganisms from other cow manure treatment plants. During the start-up period, the organic loading rates of both acidogenic and methanogenic reactors were with 5 days hydraulic retention.

2.4.4 C: N: P ratio

Fermentable carbohydrate, nitrogen, phosphorous and other nutrients such as sodium, potassium, calcium, magnesium, iron and sulfur are needed for normal growth of bacteria involved in anaerobic wastewater treatment. Therefore, it is important to ensure that during the anaerobic treatment nutrients required for biomass to grow are sufficient.

III. STUDY VARIABLES

- Hydrolysis rate in neutral and different acidic level of solution (using of different acid concentrations with time variation).
- Biogas production at optimum solid retention time.
- Characterization of the waste before and after digestion pH, TS, moisture content, VS, Total Nitrogen, C/N ratio.

3.1 Study design

The experimental is designed for digestion of organic waste, Cow dung, Poultry and water. Amount and quantity of biogas, varies with the variation of mix ratio of the feed stocks. The temperature should be 30-45^{o}c.

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3.2 Sample analysis

Optimization design conditions employed in the study:

3.2.1 Hydrolysis/pretreatment stage

- Micro aerophilic (slightly aerobic) conditions in the digester to facilitate the rate of liquefaction.
- Different acid concentration to pretreatment of the OFMSW with time variation.

3.2.2 Operation of the Reactor

Feeding unit: The feeding of OFMSW was after size reduction of particles to less than 25 mm and mixed with water to have a ratio of 1kg to 2.5-3 l, the reactor was kept for 4-5 and days for hydrolysis.

3.2.3 Methanogenic stage

A batch anaerobic reactor under mesophilic condition ambient temperature was used for a digestion period of 55 days. The biogas production process was done, i.e., hydrolysis, acidification and methanogenesis process foroptimal growth of non-methanogenic and methanogenic bacteria. Volume of biogas production was determined by water displacement.

3.3 Experimental Setup

Experiments were carried out in 500 ml airtight cylindrical anaerobic digester at ambient temperature and 100 ml airtight container to keep the temperature at ambient state to determine biogas production from different mixing factor of OFMSW, cow manure (CM) and poultry waste (PW). In all Experimental setup of feeding ratio is of OFMSW, CM and PW in digester are follows.

Photograph 1: Experimental Setup 1

IV. Biogas Production

The gas off-take from each reactor is taken to a volumetrically calibrated collector vessel operating by water displacement. A constant head, liquid seal device ensures that the gas pressure in the reactor is maintained at a constant value throughout the test run. The collected gas can be exhausted from the vessel and the volume re-filled with water during a run without breaking the liquid seal. The pressure create through the balloon at one end of the pressure glass tube and gas container collect the gas at the other end of the glass tube.

V. Results And Discussion

This chapter deals with the results obtained on the experimental scale of anaerobic digestion of cow manure and poultry waste. The characteristics of the wastes are presented. The result shows the anaerobic digestion process as an efficient technology for the OFMSW with CM (Cow manure) and PW (Poultry waste) co-substrate. The some problems introduce in the world due to high quantity of OFMSW, cow manure and poultry waste.

5.1 Results and discussion on the experimental work

The experiments were conducted in AD i.e. the hydrolysis of OFMSW by using different acid concentration for several days and gas production and organic solid reduction from AD system using substrate mixing factor OFMSW, CM and PW.

5.1.1 Only Organic waste of MSW as Fermentable Material: The Maximum gas production from only organic waste after digestion is 0.33 ml. The average digester temperature was about 35ºC. It shows that the hydraulic retention time for organic waste is about 55 days and gas production starts at the 4th day.

5.1.2 OFMSW with Cow manure as Fermentable Material: The maximum gas production from co digestion of OFMSW and cow manure is 0.35 ml. The average digester temperature was about 35ºC. It shows that the hydraulic retention time for cow manure is about 55 days.

5.1.3 OFMSW with Poultry Waste as Fermentable Material: The maximum gas production from OFMSW and poultry waste is 0.36 ml. The average digester temperature was about 35ºC. It shows that the hydraulic retention time for poultry waste is about 55 days.

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5.1.4 OFMSW, with Poultry Waste and cow manure as Fermentable Material: The maximum gas production from OFMSW, cow manure and poultry waste is 0.37 ml. The average digester temperature was about 35ºC. It shows that the hydraulic retention time for poultry waste is about 55 days and gas production starts at the 1st day.

The gas production in four slots of hydraulic retention time. In first period from 0-10 day's starting the gas production about 7% is produced. From 11-20 days gas production maximum about 27%. In the third period from 21-30 days the gas production is about 19%. From 31-40 days gas production increases slightly to about 23%. From 41-50 days gas production decreases to about 14%. Finally, from 55 days gas production reduces to about 1.95 % and gas production almost ceases after the 30thday.

5.2 Comparison of Results

Shows the total gas production from different fermentable materials. The average digester temperature for different fermentable materials is a little bit different, although constant digester temperature is desirable for proper comparison. This is due to the seasonal changes during the investigation procedure. The cumulative biogas production from only OFMSW is 2.656 ml/kg it means 0.026 m^3/kg, OFMSW with cow manure produced is 2.77 ml/kg it means 0.027 m^3/kg, and OFMSW with poultry waste produced is 2.862 ml/kg it means 0.028 m^3/kg and OFMSW with cow manure and poultry waste produced is 2.955ml/kg it means 0.029 m^3/kg.

5.3 Results and Discussion on Performance of hydrolysis stage

The outcome of the research carried out for the hydrolysis of OFMSW, CM and PW .The add to in soluble matter at the start of hydrolysis process depends on the nature of the substrate. It is very important to mention that the hydrolysis operation is vital for early volume reduction and degradation.

5.4 Results and discussion on methanogenic stage

The dissimilarity of biogas production with respect to Retention Time (RT), pH value, and Temperature in co-substance mix ratio OFMSW: CM: PW. Experimental setup (1), only OFMSW had biogas production potential estimated to be 2.656 ml/kg. Experimental setup (2), OFMSW: CM had biogas production potential estimated to be 2.77 ml/kg. Experimental setup (3), OFMSW: PW had biogas production potential estimated to be 2.862 ml/kg.

5.5 The variation of biogas with respect to Temperature, RT, pH value

(a) pH value Vs Retention Time

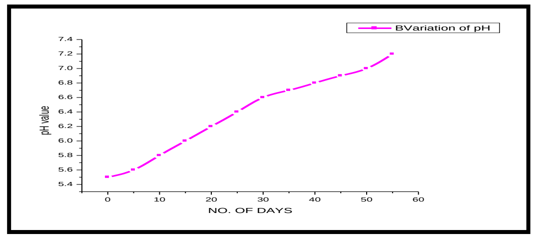

Fig 1. Variation of pH value w.r.t. Retention Time

(b) pH value Vs Biogas Production

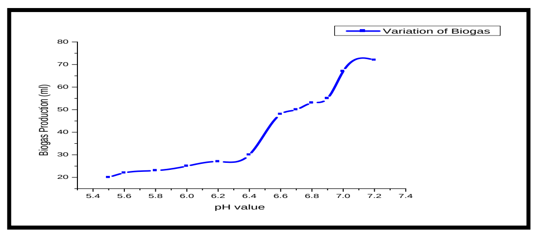

Fig 2. Variation of biogas production w.r.t. pH value

(c) Temperature Vs Biogas Production

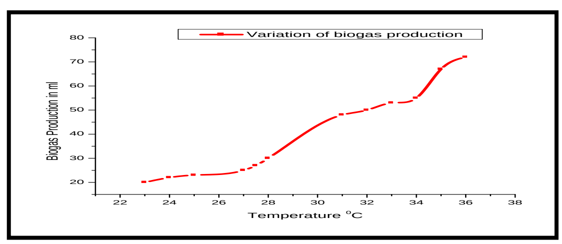

Fig 3. Variation of biogas production w.r.t. temperature

5.6 investigational consequences

The consequences shown after investigational work

(i) The digested loading with slurry form so do not lose Volatile solid.

(ii) Reduce the environmental impact.

(iii) The obtained digested sludge for soil conditioner.

5.7 Rate of Biogas production

The production of biogas was observed and volumes of the biogas collected were recorded during the experiment period after 20 days, and the production of biogas was used mainly as an indication of optimum production and the Development of the digestion process.

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The daily biogas production rates from the digestions of OFMSW: CM: PW. The co-digestion of mix OFMSW: CM: PW produced biogas much faster and higher rate per reactor volume than the others co-digestion OFMSW: CM, and OFMSW: PW this maximum rate because mix feed substrate used for this case the readily start up time with digested sludge consume by methanogenic bacteria.

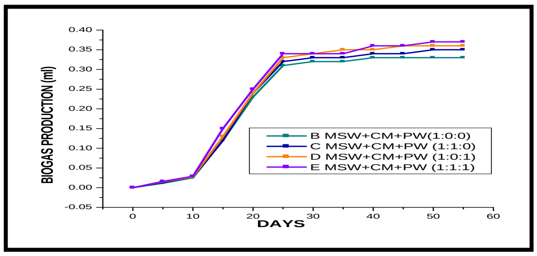

Fig 4. Daily biogas production

5.8 Identification of maximum mix ratio for highest biogas production

The mean cumulative biogas production for the digestion of OFMSW, CM and PW its co-digestion tests are shown in Fig. 5.4.2. In biogas production mixed digestion is better than digestion of substrates alone; it was observed in this experiment there is higher biogas production compare to mix of OFMSW: CM. Methane concentrations measured during the digestion period and mean values in different mix ratio are shown in table, A better methane composition with an average of 54% of mix of OFMSW: CM: PW.

The avg. value of C/N ratio of MSW, CM and PW are 40, 24 and 10 respectively. The optimum value of C/N ratio obtained by the mix Co-Substrate feeding stock. The pH value also affected the production of biogas in acidogenesis and methanogenesis stage. The OFMSW mix with CM and PW the better biogas production in 55 duration time at mesophilic temperature.

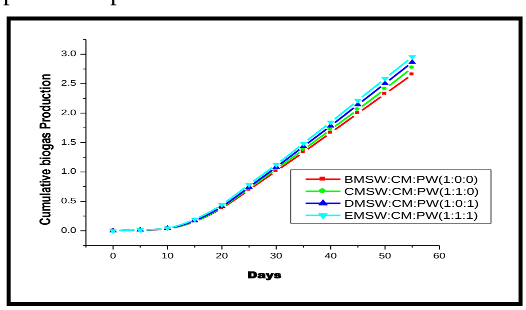

Fig 5. cumulative biogas production

5.9 Identification of maximum mix ratio for highest CH_4 production

Daily methane production rate, cumulative methane and methane content for the digestions mix of OFMSW: CM: PW and the maximum methane rate starting from the 12th, and reached a maximum methane yield from the 15th to 20th days of digestion. The peak methane rate from the digestion of mix of OFMSW: CM: PW.

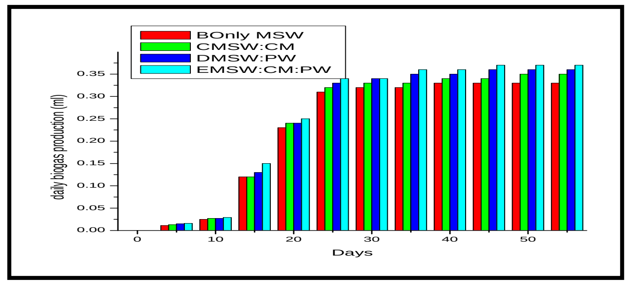

Fig 6. Daily biogas production rate from batch reactor (ml/day)

VI. CONCLUSION

The production of biogas from OFMSW with cow manure and poultry waste and methane composition of batch type experimental setup was carried out. In this experimental work the biodegradability of the MSW organic fraction has been studied with different organic fraction at mesophilic temperature. The qualitative and quantitative analysis reveals that CH_4 varied between 55%. AD and co-digestion of Organic Fraction of MSWs, CM and PW were investigated using anaerobic digestion. The biogas produced in the anaerobic co-digestion had a higher biogas rate and methane content than single substrate. The composition of biogas containing CH_4 - 56%, CO_2 – 33%, Calorific Value (CV) - 20 MJ/ m^3 for different mix ratio of OFMSW, CM and PW.

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