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Anaerobic Digestion of Aerobic Pretreated Organic Waste

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ABSTRACT

Anaerobic digestion is a biotechnology that can be used to convert various biodegradable organic materials into methane-rich biogas fuel. The anaerobic digestion of municipal solid waste and sewage sludge is a process that has become a promising technology in waste management throughout the world .Digestion occurs in a four-step process: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Hydrolysis is the rate limiting step in the anaerobic digestion. Composting and anaerobic digestion (AD) are seen as the most favored options to deal with organic fraction of municipal solid waste (OFMSW). Both treatment options reduce the environmental burden and enable the generation of a nutrient rich fertilizer. Thus, the objective of this study is to analyze the effect of rotary drum pretreatment (pre-composting) on mesophilic anaerobic digestion of a mixture of vegetable waste and dairy sludge. Aerobic pretreatment prior to anaerobic co-digestion of fruit waste, vegetable waste, yard waste and cow dung. Aerobic pretreated organic waste was investigated using biogas plant inoculum in batch reactors at mesophilic condition. Effect of pretreatment on biogas production and TS and VS reduction was studied using batch anaerobic tests. At a F/M ratio of 1, there were a biogas production, TS and VS reduction of 465mLgVS^{-1}, 52.4% and 57.2% respectively for pretreated mixture and 340mLgVS^{-1}, 47.6% and 51.3% respectively for mixture without pretreatment. At F/M ratio of 0.5 there were a biogas production, TS and VS reduction of 325m LgVS^{-1}, 44.9% and 48.7% respectively for pretreated mixture and 275m Lg VS^{-1}, 41.1% and 46.4% respectively for mixture without pretreatment.

Keywords: Anaerobic, digestion, pretreated, organic wast

1. INTRODUCTION

Solid Waste Management (SWM) is an issue as production of Solid Waste is increasing due to the increase in population and rapid urbanization. Municipal Solid Waste Management (MSWM) is a challenging problem for developing countries. In India, the collection, transportation and disposal of solid waste is normally done in an unscientific manner. Uncontrolled dumping of wastes on outskirts of towns and cities has created serious environmental implication in terms of ground water pollution and contribution to global warming. An effective system of solid waste management is the need of the hour and should be environmentally and economically sustainable.

OFMSW of MSW is biodegradable as the moisture content present in it will be around 85-90%. Incinerating MSW generates the air pollutants such as nitrogen dioxide, sulfur dioxide and greenhouse gases and dumping it without pretreatment pollutes water by generating leachates. Also dumping of MSW causes breeding of mosquitos and rodents.

Today's waste management policies worldwide is to reduce the stream of waste going to landfills and to recycle the organic materials and the plant nutrients back to the soil. Using OFMSW for the producing of methane and energy using AD has received increasing attention in recent years. AD is nothing but decomposition of organic matter in the absence of free oxygen and involves several anaerobic microbes. Biogas production potential of AD makes it a promising solution for producing renewable energy from OFMSW. These technologies can maximize recycling and recovery of waste components. Among biological treatments, anaerobic digestion is frequently the most cost effective, due to the high energy recovery linked to the process and its limited environmental impact. The anaerobic digestion of OFMSW yields much better results in thermophilic temperature conditions than in mesophilic temperature conditions (Ivet Ferrer et al., 2008, Baoning Zhu *et al*., 2008).

A given amount of volatile solids of a particular waste can be converted to a maximum amount of biogas at a given temperature provided optimum conditions are prevalent. Evidently, AD has a great future amongst the biological technologies of sludge treatment in view of biogas generation as well as reducing solids mass. However, the low overall biodegradation efficiency of the sludge solids and long retention times (20-30 days) result in only moderate efficiencies. In anaerobic digestion, the biological hydrolysis is identified as the rate-limiting step. Most soluble organic materials which can be converted into biogas are produced during hydrolysis process. Consequently, the biogas production depends for the most part on the biodegradability and hydrolysis rate (Zhang Hanjie *et al*., 2010).

Pretreatment enhances sludge digestion and the rate and quantity of biogas generated, thereby reducing the retention time requirement from 15 to 25 days to approximately 7 days (Allan Elliott et al., 2007). Pre-treatment methods may also be applied to increase the digestibility of the organic solids and increase the efficiencies of anaerobic digesters. Thermal, chemical, biological and mechanical processes, as well as combinations of these, have been studied as possible pre-treatments cause the lysis of or disintegration of sludge cells permitting the release of intracellular matter that becomes more accessible to anaerobic microorganisms. A pre-composting stage may be used to obtain a slight degradation of organics to prevent fast acidification during anaerobic digestion. Previous studies have also shown that a rotary drum reactor (RDR) process provided an effective means for separating the organics from MSW using a combination of mechanical forces and biological reactions AD can be carried out in mesophilic and thermophilic conditions. Thermophilic conditions have certain advantages over mesophilic conditions for digesting the organic wastes separated from MSW, such as faster degradation rate, higher biogas production rate, lower effluent viscosity, and higher pathogen destruction (Baoning Zhu *et al*., 2008).

Capela et al(1999) did a study on the anaerobic digestion of pulp mill sludge with precomposting stage as pretreatment. There were higher methane yield and higher solid reduction in the case of treated sludge than untreated sludge.Anaerobic digestion is a multistage process in which hydrolysis is the first step. During hydrolysis, complex insoluble substrate macromolecules such as polysaccharides are hydrolysed into smaller units by a large number of microbial species that act in concert synthesizing and secreting different hydrolysing enzymes(cirne et al,2007). Ajay S Kalamdhad et al(2008) designed a rotary drum composter and studied the composting process in the rotary drum composter

Engelhart et al did a study on the anaerobic digestion of mechanically pretreated sewage sludge. There was a 25 % increase in volatile solids reduction.

Romero et al studied the effects of biological pretreatment, on organic matter solubilization from organic fraction of municipal solid waste.

The main objective of this study is to employ aerobic pre-composting process as a pretreatment technology for enhancing the biogas production in anaerobic digestion of OFMSW and cow dung.

2. MATERIALS AND METHOD

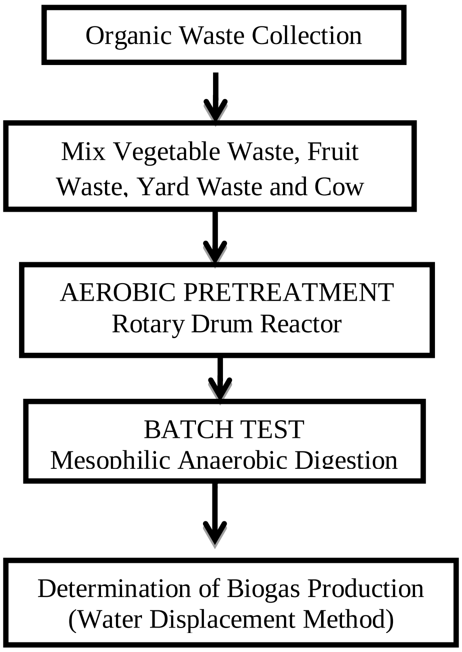

Figure 1. Flow chart shows the materials collection and method adopted in this study

2.1 Collection of Feed Stock Materials and Inoculum

Fruit waste and vegetable waste were collected from market, yard waste was collected from household garden, cow dung was collected from cattle dairy. Inoculum was collected from gobar gas plant. The wastes were tested for moisture content, total solids, volatile solids, total organic carbon and total kjeldahl nitrogen. Inoculum was tested for moisture content, total solids, volatile solids and pH.

2.2 AEROBIC PRETREATMENT

Rotary Drum Method

Aerobic pretreatment was done for one day using fabricated rotary drum reactor. Composting facilities are aerated or unaerated and covered or not covered. Composting methods include passive piles, windrow composting, static piles, and in-vessel composting. In-vessel composting refers to a diverse group of methods that confine the composting process within a container, building, or vessel and uses a combination of forced aeration and mechanical turning to speed up the composting. Compared to windrow and aerated pile methods, these systems require less labor and land area and offer potentially better odor control, faster composting (in a matter of days as opposed to weeks), and consistently good compost. The key factor of succesful co-digestion is that the balance of macro and micro nutrients can be assured by the co-substrate. To perform the aerobic pre-composting pretreatment a lab scale rotary drum composter of 25L capacity was used. The dimension of drum used is 0.4m in length and 0.3m in diameter and the drum is made up of plastic. The drum is mounted on four steel bearings which revolves around two steel rods and the steel rods are mounted on wooden stand. Fruit waste, vegetable waste, yard waste and cow dung were mixed in the ratio of 1:1:1:0.5 wet mass basis. The mixture of fruit waste, vegetable waste, yard waste and cow dung was loaded up to 50% volume to give good aeration and the drum is rotated manually for 10 times at regular intervals for a day.

2.3 BATCH TEST

Raw waste sample and pre-treated waste sample was collected. Innoculum was collected from gobar gas plant. The TS, VS, VS to TS ratio (VS/TS) and pH of the innoculum is measured.

Five 500mL conical flask with rubber stopper and each with a water displacement arrangement for measuring the biogas production were used as batch reactors namely B1,B2,B3,B4,B5. Reactor B1 was used for blank. Reactor B2 was used for sample without pretreatment and for F/M ratio of 0.5. Reactor B3 was used for sample without pretreatment and for F/M ratio of 1. Reactor B4 was used for sample with pretreatment and for F/M ratio of 0.5. Reactor B5 was used for sample with pretreatment and for F/M ratio of 1. Each batch reactor was filled with 125mL inoculum and required amount of waste sample and 120mL distilled water and for blank the reactor was filled with 125mL inoculum and 125mL distilled water. 250mL of each reactor was kept as working volume. F/M was calculated by dividing feedstock VS by inoculum VS. For F/M ratio of 0.5 reactor B2 was loaded with sample without pretreatment containing 1.05g VS and reactor B4 was loaded with pretreated sample containing 1.05gVs. For F/M ratio of 1 reactor B3 was loaded with sample without pretreatment containing 2.1gVS and reactor B5 was loaded with pretreated sample containing 2.1g VS.

2.4 ANALYTICAL METHODS

Sample Preparation

One litre of hot distilled water is added into 100 grams of each sample and shake for 24 hours in shaker. An aliquot of each is examined for total kjeldahl nitrogen (TKN), ion ammonia (NH_4^+), nitrate (NO_2^-), nitrite (NO_3^-), temperature, pH, dissolved oxygen (DO), BOD and COD. Laboratory works for all analytical measurements are in accordance with American Standard Methods (1995).

Total Solids

Twenty five grams of the sample is taken in a clean and weighed evaporating dish, dried at 103°C in a water bath and cooled in a desiccator. After cooling, the weight of the dish with the contents is noted. Calculation is done as follows.

$$\text{Total Solids } (\%) = \frac{(A - B) \times 100}{C - B}$$

Where,

A = Weight of the filter paper (g) + sample after drying (g)

B = Weight of the filter paper (g)

C = Weight of the filter paper (g) + wet sample (g)

Volatile Solids

Twenty five grams of the oven dried sample (105°C) is taken in a crucible and kept in a muffle furnace at 550°C for 1h. After cooling, the weight of the crucible is measured. Calculation is done as follows.

$$\text{Volatile Solids } (\%) = \frac{(A - D) \times 100}{C - B}$$

Where,

A = Weight of the crucible (g) + sample after drying (g)

B = Weight of the crucible (g)

C = Weight of the crucible (g) + wet sample (g)

D = Weight of the crucible (g) + dried sample (g)

Total Kjeldahl Nitrogen (TKN)

A known volume of the 35 ml is taken in a 500 mL Kjeldahl flask and 50 mL of the digestion reagent (potassium sulphate, copper sulphate and sulphuric acid) is added. The sample is digested for about two hours. After cooling, 200 mL of distilled water and 50 mL of sodium hydroxide- sodium thiosulphate solution are added and distilled. The distillate is collected in a beaker containing indicating boric acid solution and titrated against 0.2 N sulphuric acid till a pale lavender colour is produced. Calculations are done as below.

$$TKN\ (mg/L) = \frac{(A - B) \times 280}{35}$$

Where,

A = Volume of sulphuric acid used up for titrating sample

B = Volume of sulphuric acid used up for titrating blank

Total Organic Carbon (TOC)

Total Organic carbon is calculated by the following formula

$$\text{TOC } (\%) = \frac{VS(\%)}{1.8}$$

2. RESULTS AND DISCUSSIONS

Table. 1. Results of organic waste

Substrate	*MC* %	*TS* %	VS/TS %	C %	N %	C/N
Fruit Waste	67.52	32.48	88.3	44.4	2.09	21.24
Vegetable Waste	71.39	28.61	72.4	43	2.6	16.54
Yard Waste	10.16	89.84	67.92	61.8	0.85	72.7
Cow Dung	76.25	23.75	76.13	50.41	1.77	28.48

3.1 CHARACTERISTICS OF ORGANIC MATERIALS

The moisture content of fruit waste, vegetable waste, yard waste and cow dung were 67.52%, 71.39%, 10.16% and 76.25% respectively. Total solids of fruit waste, vegetable waste, yard waste and cow dung were 32.48%, 28.61%, 89.84% and 23.75% respectively. C/N ratio of fruit waste, vegetable waste, yard waste and cow dung were 21.24,16.54, 72.7 and 28.48 respectively. Moisture content, total solids, volatile solids, pH of anaerobic inoculum are 95.32%, 4.68%, 2.92% and 6.91%.(Table .1)

3.2 RAW AND PRETREATED WASTE MIXTURE

Moisture content, total solids, VS/TS ratio, Carbon, Nitrogen, C/N ratio of waste mixture without pretreatment were 53.48%, 46.515%, 76.19%, 49.938%, 1.9% and 26.28 respectively. Moisture content, total solids, VS/TS ratio, Carbon, Nitrogen, C/N ratio of waste mixture with pretreatment were 52.32%, 47.68%, 72.13%, 47.92%, 1.97% and 24.28. Temperature inside the reactor increased to 47ºC from 31ºC.(Table.2)

Table. 2. Results of Raw waste and pretreated waste

Waste type	MC %	TS %	VS/TS %	C %	N %	C/N
Raw Waste	53.48	46.51	76.19	49.9	1.86	26.82
Pretreated Waste	52.32	47.68	72.13	47.8	1.94	24.63

3.3 ANAEROBIC BATCH TEST

Table. 3. Remesults of organic waste without pretreatmentv and with pretreatment

Parameter	Without pretreatment		With pretreatment	
	F/M = 0.5	F/M = 1	F/M = 0.5	F/M = 1
Biogas yield ($mLgVS^{-1}$)	275	340	325	465
TS reduction (%)	41.1	47.6	44.9	52.4
VS reduction (%)	46.4	51.3	48.7	57.2
pH at the end of digestion	7.3	7.5	7.2	7.2

Biogas yield, TS reduction, VS reduction, pH at the end of digestion of the waste mixture without pretreatment and for F/M ratio of 0.5 were $275mLgVS^{-1}$, 41.1%, 46.4% and 7.3. Biogas yield, TS reduction, VS reduction, pH at the end of digestion of the waste mixture with pretreatment and for F/M ratio of 0.5 were 325mLgVS-1, 44.9%, 48.7%, 7.2. Biogas yield, TS reduction, VS reduction, pH at the end of digestion of the waste mixture without pretreatment and for F/M ratio of 1 were $340mLgVS^{-1}$, 47.6%, 51.3% and 7.5. Biogas yield, TS reduction, VS reduction, pH at the end of digestion of the waste mixture with pretreatment and for F/M ratio of 1 were 465mLgVS-1, 52.4%, 57.2%, 7.2.(Table.3)

For F/M ratio of 0.5, daily biogas yield reached the maximum of $80mLgVS^{-1}$ in the first and second days for pretreated waste mixture while the daily biogas yield reached the maximum of $40mLgVS^{-1}$ in the sixth day for waste without pretreatment. For F/M ratio of 1, daily biogas yield reached the maximum of $95mLgVS^{-1}$ in the first day for pretreated waste mixture while the daily biogas yield reached the maximum of $55mLgVS^{-1}$ in the first day for waste mixture without pretreatment.

For F/M ratio of 0.5, cumulative biogas production after 20 days of study was $325mLgVS^{-1}$ for pretreated waste mixture and $275mLgVS^{-1}$ for waste mixture without pretreatment. For F/M ratio of 1, cumulative biogas production after 20 days of study was $465mLgVS^{-1}$ for pretreated waste mixture and $340mLgVS^{-1}$ for waste mixture without pretreatment.

4. CONCLUSION

Anaerobic digestion is used to convert biodegradable organic materials into methane – rich bio gas. It is a renewable energy source.

Rotary drum reactor process could be used as an effective technology for pretreatment of organic materials in municipal solid waste prior to anaerobic digestion. A pre-composting stage is used to prevent fast acidification during anaerobic digestion. Pretreatment method is applied to increase the digestibility of the organic solids and increase the efficiency of anaerobic digesters.

The results of the study show that aerobic pretreated system is effective and efficient in the conversion of organic waste in to biogas.

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