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To Investigate the Recycling of Organic Matter in Food Waste by Anaerobic Digestion

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Abstract—*Food waste is single largest category of municipal solid waste in India. 1,00,000 MT of Municipal Solid Waste is generated daily in India of which of which 50% is food waste (FW) . Waste quantities are increasing and municipal authorities are not able to upgrade or scale up the facilities required for proper management of such wastes. Diverting food waste from landfills prevents uncontrolled emissions of its breakdown products, including methane—a potent greenhouse gas. Anaerobic digestion is a suitable alternative to dispose food waste since it contains 80% moisture contents. Separation of municipal biological waste from municipal solid waste can reduce the stress on traditional disposal facilities. The study was divided into two parts. In the 1st stage anaerobic digestion was done by mixing the FW, calculated amount of waste activated sludge (WAS) and water. An airtight setup was constructed which consisted of a cylindrical jar, a thermometer, compressor pipe, a valve and a gas collection bag. Methane was generated after a certain amount of time. The 2nd stage was focused on acceleration of methane generation. In order to achieve this, digestion was done with two different mixture. One digestion unit consisted of FW, WAS and dairy manure and other consisted of poultry waste instead of dairy manure. Methane generation was early in this stage as compared to stage 1. List of experiments included pH, Moisture content, COD, TS, VS, C/N ratio and Alkalinity.*

Keywords*: Food waste, Methane, Anaerobic digestion, Waste activated sludge, poultry waste, Dairy manure*

1. INTRODUCTION

Solid Waste is the discarded or the unwanted material in the form of garbage or refuse resulting from industrial, commercial, mining and agricultural operations, and from community activities. This solid waste is categorized as Municipal Solid Waste, Construction and Demolition Waste, Hazardous Waste, abandoned vehicles, etc. Municipal Solid Waste generation is at ever-increasing rate with the increase in economic prosperity and urban population [1]. 1,00,000 MT of Municipal Solid Waste is generated daily in India of which of which 50% is food waste [2].

Collection in India is mainly done on house-to-house basis which is a problem in waste management. Awareness is being created for its proper management but is confined to some regions. Source segregation is encouraged, however the objectives are not achieved as in many cases segregated waste is mixed again at the time of transportation and disposal. Norms are not followed during the transportation of waste. There are health issues associated with improper management of food waste [2]. Exposure to decaying organic waste can cause skin problems and even breathing difficulties. Airborne mould spores from it can lead to allergic reactions, asthma attacks, hayfever like symptoms and itchy skin lesions. One common health hazard associated with it is aspergillomas-fungal balls that fix themselves inside lung [3]

Food waste is usually incinerated with other municipal wastes but since in contains high amount of moisture, it may lead to the production of dioxins. In recent years, food waste generally ends up in the landfill. The main component of food waste is organic material which is easy to transform into contaminants, causing serious effects on the surrounding environment. Moreover, FW landfill is proven as a key factor contributing to global climate change [4].

Food waste is usually incinerated with other municipal wastes but since in contains high amount of moisture, it may lead to the production of dioxins. Incineration of food waste is not a suitable option as it has upto 80% moisture content [5]. Furthermore, each tonne of food waste causes 4.5 ton of CO2 emissions [6]. In recent years, food waste generally ends up in the landfill. The main component of food waste is organic material which is easy to transform into contaminants, causing serious effects on the surrounding environment. Moreover, food wate landfill is proven as a key factor contributing to global climate change. Landfills laden with food waste will result on production of methane thus adding to greenhouse gasses [7]. Composting can be done but requires a decent amount of land.

The best suitable option to treat and dispose food waste is its anaerobic digestion. Anaerobic digestion is a suitable alternative to dispose food waste since it contains 80% moisture contents. Separation of municipal biological waste from municipal solid waste can reduce the stress on traditional disposal facilities. Anaerobic digestion has been recognized as environmentally friendly technology to convert organic solid waste such as animal manure, food waste, and organic fraction of MSW into renewable energy in biogas form [8]. Anaerobic

digestion is a series of bioconversion processes that transform organic compounds, especially biomass wastes, to methane biogas (a mixture of approx. 60% CH_4 and 40% CO_2). However, digestion process tends to fail, when one readily degradable organic matter is used as sole substrate without external nutrients and buffering agent [9]. The main objectives of anaerobic digestion have been to stabilize and sanitize the sludge and to remove the organic pollutants from the influents, with relatively little focus on biogas production.

2. MATERIALS AND METHODS

Experimental Apparatus:

The study used batch process. It consisted of a cylindrical jar made of plastic as the main unit of the digester. A digital thermometer was attached near to its bottom. On the top of the cylindrical vessel there was a compressor pipe which had its one end fixed to jar and other end to a gas valve. The gas valve was used to control the flow of gas generated. To collect the gas generated in the digester, a gas collection bag was used. The effective volume of the digester was 3L. The digester is physically stirred twice a day. The study was divided into two stages, 1st stage consisted of generation of biogas and 2nd stage consisted acceleration of biogas generation.

Feedstock and Feed Mixtures:

The FW was collected from Manipal Institue of Technology (MIT) Food Court which is situated inside the campus. The food court caters a mix of food items which includes veg and non-veg items. It order to carry out proper digestion food items such a chicken bones, egg shells, potatoes and other food materials having similar physical characteristics were avoided. As there was no segregation, the day of food waste collection was selected to be Tuesday. Vegetarian food was served for the lunch and food waste (FW) mostly contained rice. FW was minced into pieces with diameter less than 1 cm using food processor, and then it was kept in the refrigerator until used. FW was mixed well before the digestion reaction. The collected FW had a moisture content of 67.45% and 32.54% Total Solids. The FW was broken down and added with water such that the final concentration of total solids is 10%. In 1st stage study the slurry of FW was mixed with waste activated sludge (WAS). The WAS was collected from a treatment plant which is also inside the campus. Three trials were conducted with different FW slurry and WAS mixtures mixed on 10:90, 40:60 and 50:50 basis. In 2nd stage of study, two different mixtures were prepared. One consisted of FW slurry, WAS and dairy waste which was mixed at 40:40:20 (D1). Other consisted poultry waste in place of dairy waste is which the mixing ratio was 30:30:40 (P1).

Operating Conditions:

As the collection of FW and WAS was done, they were kept in a refrigeration unit which was maintained at a temp. of 4°C. During the period of study, the digester was kept outside under sunlight so as to increase the temperature inside the digester. This period is important since bacteria's start their activity under a certain range of temperature. In order to restrict the exchange of heat with the surrounding environment, a digestion unit was kept in an enclosed chamber of thermocol. Thus the temperature was maintained in range of 25°C to 35°C.

In the anaerobic digestion process, the parameters that indicate stability are pH, alkalinity, Volatile Fatty Acids (VFA) and temperature in the digester. The pH of the methane bioreactor is usually controlled to a set point within the range of 6.5–7.5. During anaerobic treatment of organic solid wastes, a major pH drop in the digester is owing to the accumulation of VFA produced from the hydrolysis/acidogenesis of organic wastes.

Analytical Methods:

The pH and temperature are monitored using pH meter and digital thermometer respectively. Chemical oxygen demand (COD), TS, VS and alkalinity of the sample was determined according to standard methods (APHA, AWWA & WEF, 1998). Elemental composition of the sample was analyzed with an elemental analyzer.

Characteristics of Food Waste

PARAMETERS	RESULTS
P^H	6-6.5
Moisture content (%)	67-68
Total Solids (%)	32-33
Volatile Solids % (w.r.t. TS)	77.93
Fixed Solids %	31.62
COD (mg/L)	240
Alkalinity (mg/L as of $CaCO_3$)	3849
C (%TS)	46.11
N (%TS)	2.75
C/N	16.75

3. RESULTS AND DISCUSSION

In the 1st stage of study, 3 different mixtures were used the ratio being 10:90, 40:60, 50:50. Biogas was generated within 3 days of digestion but it mainly consisted carbon dioxide. This phase is known as hydrolysis. This hydrolysis step is catalyzed by the extracellular hydrolytic enzymes such as amylases, cellulases, xylanases, proteases, and lipases secreted by the hydrolytic bacteria. The resulting hydrolytic products are immediately fermented to short chain fatty acids, CO_2, and H_2 in smal proportion. The final phase of anaerobic digestion involves methanogens of the Archaea domain. Methanogens are strict anaerobes and produce CH_4 as the major end-product of their catabolism. Of these three trials conducted, methane of considerable amount was generated in 27 days by the mix 40:60. On the other hand, the 2nd stage of study generated methane at much faster rate. Mix D1 generated methane in 13 days while mix M1 generated methane in 15 days. The reason, generaly animals manures have relatively high water contents,

ranging from 75% (poultry waste) to 92% (cattle manure). Most of the animal manure is organic matter, with VS contents ranging from 72% (poultry manure) to 93% (cattle manure) of TS. Inorganic nutrients, including N, P and K, are rich in animal manures, especially poultry manure. Because most of the readily degradable substances, especially carbohydrates, have been digested and absorbed by the animals, animal manures have very little readily fermentable substrates. Additionally, animal manures have high concentrations of amino nitrogen such as urea and ammonia and a large pH buffering capacity against acids. Thus, the fermentative acidogenesis during AD of animal manures typically does not result in significant pH decline, but high concentrations of ammonia. Furthermore, animal manures contain large amounts of microbial microbial biomass, including bacteria and methanogens. Therefore, the optimum operating conditions and the corresponding performance of the digester indicate that the anaerobic digestion of FW with WAS aided either with daily manure or poultry waste is a good option for methane generation.

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