Stabilization & Optimization of Sewage Sludge in CSTR for Anaerobic Co-digestion of Banana Plant Waste & Sewage Sludge

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***Abstract*: In Pakistan waste generation is a rising issue. As Pakistan is an agricultural country so it contributes about 57 % of crop waste in total waste generated annually. Huge amount of crop residues such as banana plant waste are generated and they are wasted without any use. Generally, there is no any use of Banana plant waste (BPW) in Pakistan. Almost 100 % of BPW is burnt without being utilized. The crop residue can be used in order to overcome the issue of energy crisis as well. Therefore, the anaerobic co-digestion of Banana plant waste with sewage sludge is the most suitable way to utilize both the crop residue and sewage sludge for fulfilling the needs of energy. As biogas is the best source of renewable energy that leaves a safer impact on the environment. A study was conducted where Sewage sludge was stabilized in CSTR in order to maximize the energy potential and analyze its energy potential for using it further for methane enhancement by measuring the steady conditions of digester on daily basis by pH, Alkalinity, Volatile fatty acids, Moisture content, Volatile solids, Total solids etc. Throughout the study it was observed that Methane was generated & sewage sludge was stabilized at the conditions when pH was at range of 8 - 8.3, Alkalinity was 3000 - 4000 mg/l $CaCO_3$ while VFA to TA ratio was less than 0.5. Hence the results showed that sewage sludge has the potential of producing methane if steady conditions are maintained. Once the material is stabilized it would be further used for production of biogas by optimization of different ratios of banana plant waste & sewage sludge in order to enhance methane production & to obtain the best ratios (conditions) at which maximum methane would be produced.**

***Keywords*: Anaerobic Co-digestion, Banana plant waste, Biogas, Sewage sludge**

I. INTRODUCTION

In history of human agriculture Banana is the oldest crops which is grown. Banana (Musaceae) is cultivated mainly in the tropical countries regions and it is an essential crop in fruits for the food industry due to its valuable contributions. The by-products produced from it are a great source of precious raw material for industries by recycling this waste from agriculture. This activity helps and prevents in loss of available biomass and the environmental issues that occur. [1] Banana is the 4th largest crop in the world. In 2010 the total production of banana was estimated about 102.1 million tons while Asia records for 61 % of production of bananas & the biggest producer of bananas is India worldwide. There are total 34,800 hectares of banana crops and about 32,200 hectares of banana are grown in Pakistan's province Sindh and it produces about 127.4 thousand tons of banana. [2]

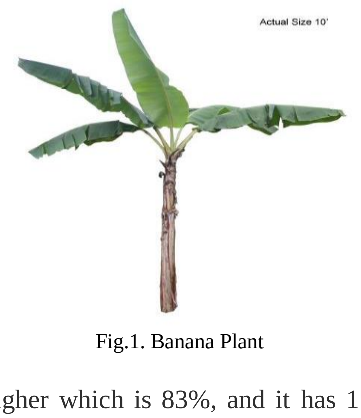

Fig.1. Banana Plant

In waste banana stem the organic content is quite higher which is 83%, and it has 15-20% (w/w) of lignin and cellulose content & because of this it has sheath like texture. [3] This study will discuss about the energy potential of banana plant waste (BPW) as a novel source of biomass. Banana plant waste (BPW) is selected for this study because of its highest growth rates, its availability & its carbon ratio and keeping this fact that it only stands fruit only once in a lifetime. BPW is exceedingly mismanaged crop residue as it is directly burnt in open atmosphere without utilizing it for any other use. According to fact & figures, In Pakistan 1261.848 kt/ha of BPW will be generated while in Sindh the generation rate will be 1167.572 kt/ha. Currently there is no any use pf Banana plant waste (BPW) in Pakistan. Almost 100 % of BPW is burnt without being utilized. [4]

In order to utilize these crop residues, they can be used to overcome the issue of energy crisis as well Therefore, in this study the anaerobic co-digestion of Banana plant waste along with sewage sludge is the most suitable way to utilize both the crop residue and sewage sludge for fulfilling the needs of energy. As sewage sludge consists of solids & liquid constituents that undergoes treatment for separation. As the handling methods and techniques of disposal for the constituents removed from treatment is of immense concern as they are produced in large quantity. If there is no any method for disposal of sludge, then water protection concept will fail. A method that fulfills the needs of efficient recycling without compromising the health of humans and the supply of toxic substances to the environment is known as Sustainable sludge handling [7]. In order to utilize the sewage sludge, it can be co-digested with any other substrate for anaerobic co-digestion to produce renewable energy source. Therefore, in this study the anaerobic co-digestion of Banana plant waste along with sewage sludge is the most suitable way to utilize both the crop residue and sewage sludge.

II. MATERIALS & METHODS

A. Collection of Samples

Banana plant waste & Sewage sludge samples were collected for experimental work. Banana plant waste was collected from the rural areas of Hyderabad & sewage sludge was also collected from Hyderabad city which was then transported to the Institute of Environmental Engineering and Management, MUET, Jamshoro.

B. Stabilization of Sewage sludge in CSTR

Sewage sludge was stabilized in CSTR at HRT of 20 days in order to prepare activated sludge for further process of batch reactor. A ratio of 1:1 of sewage sludge & water was used in the CSTR reactor. The capacity of the reactor is 5 L. The reactor was filled up to 4 L in order to leave small space for gas formation. The reactor was in process for about 20 days in which the sewage sludge was activated & became rich in microorganisms. Methanogens were highly activated in these 20 days. On regular basis from reactor 200 ml of slurry was discharged & was also fed with 200 ml slurry made of sewage sludge & water. The discharged slurry was used for different testing in the laboratory in order to check its characteristics on daily basic which includes pH, Volatile fatty acids (VFA), Alkalinity, Moisture content, Total solids, Volatile solids etc. The achieved results are discussed in the results portion.

C. Preparation of Samples

Banana plant waste was cut into pieces & left in open for drying for some weeks. As Banana Plant Waste was dried it was grinded to ≤ 1mm size in blender mill. Sewage sludge was used fresh & tested for its characteristics including Moisture content (MC), Total solids (TS) & Volatile solids (VS). Dried banana plant waste & grinded powder of BPW is shown in Fig. 2 and 2.1, respectively.

Fig. 2 Dried BPW

Fig. 2.1 Powder BPW

D. Analytical Methods

Different parameters like pH, Moisture content (MC), Total Solids (TS), Volatile solids (VS), Volatile fatty acids (VFA), Alkalinity (TA) etc were analyzed on daily basis during stabilization of sewage sludge & also before preparation of batch. According to APHA (American Public Health Association) standard method, each & every parameter was analyzed for this study. Obtained results are discussed in results section.

E. Preparation of Batch Experiment

In order to optimize different ratios of Banana plant waste and Sewage sludge, the batch experiment was conducted as shown in the Fig. 3.1. The different optimized ratios of BPW and SS were used. In all the batch assays the pH was kept constant. The size of the BPW was kept less than 1mm. The pH was maintained at 7.5.Six different ratios of BPW and SS were carried out on the basis of volatile solids, which are 0:100, 20:80, 40:60, 60:40, 80:20 and 100:0. From obtained results of batch the best ratio of the BPW to SS was selected for maximum methane generation.

F. Preparation of Batch Assays

In order to prepare batch assays, Manual Methane Potential Test System (MMPTS) was utilized as per the laboratory setup to measure the methane gas production as shown in figure 3. The setup followed the conventional method of measuring methane potential tests. The data was collected on daily basis manually.

In this setup the glass bottles of 500 ml were used as the reactor. The batch assays were kept at a temperature of 37 ℃as it is the ideal temperature for methanogenic microorganism. The reactors in the batch were filled with duplicate ratios of BPW & SS. There were total 6 ratios selected from literature review. The ratios were R1 (0:100), R2 (20:80), R3 (40:60), R4 (60:40), R5 (80:20), R6 (100:0) of Banana plant waste (BPW) & Sewage sludge (SS) respectively. In each bottle BPW & SS was added as per the ratio specified. Each reactor was filled with 5 g VS of BPW & SS along with 100 g of Inoculum. There were total 14 reactors in number among which 12 reactors were filled with the ratios & each ratio was in duplicate. While the remaining 2 bottles were filled with 100 ml of inoculum & tap water only in order to measure the gas production of inoculum only. After the inoculum & substrate were added in each reactor it was filled up to 400 ml with tap water. As the batch assays were completely filled, they were sealed & connected to the DC motor. All reactors were kept in the water bath & connected & started. The batch anaerobic co-digestion was in operation for 30 days. The CO_2 produced in the reactors were removed from biogas by contacting the produced biogas with the solution of 3 M sodium hydroxide (NaOH).

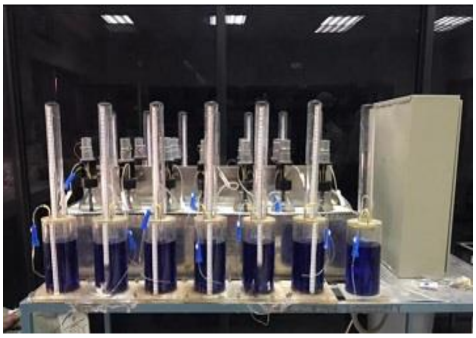

Fig. 3 BMP Setup

Fig. 3.1 Preparation of Batch assays

III. RESULTS

A. Stabilization of Sewage Sludge in CSTR

Sewage sludge was stabilized in CSTR at HRT of 20 days in order to prepare activated sludge for further process of batch reactor. The slurry was used for different testing in the laboratory in order to check its characteristics on daily basic which includes pH, Volatile fatty acids (VFA), Alkalinity (TA), Moisture content (MC), Total solids (TS), Volatile solids (VS) etc. The pH increased from 7.92-8.4, whereas TA was increasing on daily basis & VFA was decreasing. Both these conditions were required for proper anaerobic digestion process. Due to the increase in TA and decrease in VFA the VFA to TA ratio was also reduced to almost 0.01 from 1.14 as it is required to be less than 0.5. The favorable conditions of the reactor helped in increasing the gas production during stabilization period. The results of each parameter are shown in the graphs below.

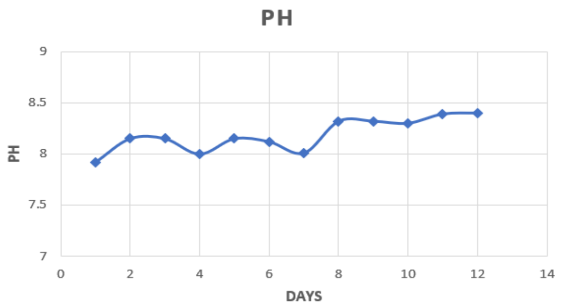

Fig. 4. pH

Fig. 4.1 Total Alkalinity

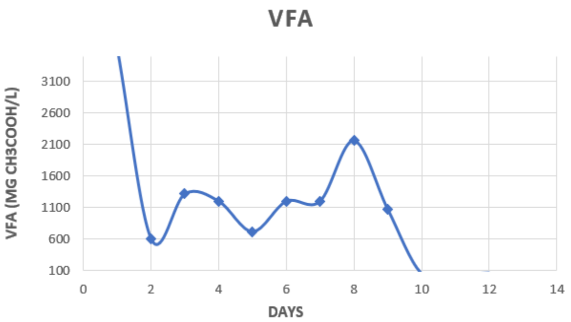

Fig. 4.2 Volatile Fatty Acids

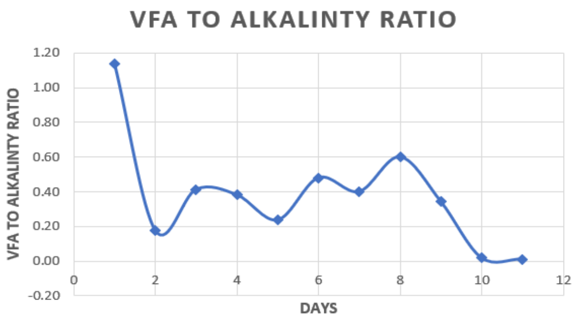

Fig. 4.3 VFA TO TA Ratio

B. Best Optimized Ratio of BPW to SS

There were total 6 different ratios optimized for selection of best ratio for methane production. The optimized ratios of BPW to SS were 0:100, 20:80, 40:60, 60:40, 80:20, and 100:0. The cumulative methane productions & gas flow rate of different banana plant waste to sewage sludge ratios are shown in Fig. 5 & 5.1 respectively. The maximum cumulative methane production was observed as 5950.4 for ratio R1 (0 BPW & 100% SS) followed by 5825, 4616.7, 4187.65, 3783.05, 3346.45 for ratios R4, R3, R6, R2 & R5 whereas the highest gas flow rate was observed as 456.25 NmL for ratio R3 (40 % BPW and 60% SS) followed by 443.9, 440.3 369.3, 329.25 &321.85 for ratios R6, R2, R1, R4 and R5 respectively as shown in graph 5. Whereas the methane produced from inoculum was 147.6 NmL. Finally, it was observed that the maximum methane production was achieved from R3 which was selected as best ratio by the co-digestion of banana plant waste and sewage sludge.

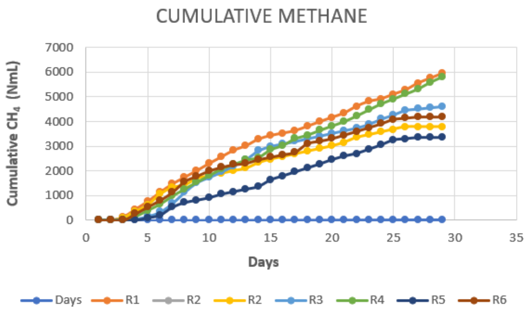

Fig. 5 Cumulative Methane Production from different ratios of BPW to SS

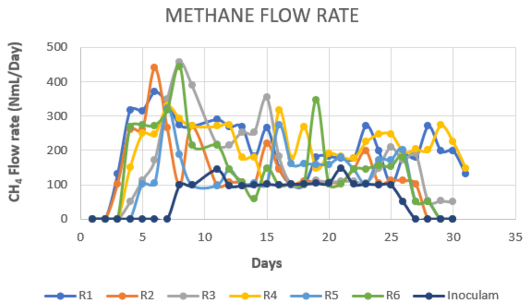

Fig. 5.1 Methane Flow rate from different ratios of BPW to SS

IV. CONCLUSIONS

The aim of this study was to stabilize the sewage sludge & select the best optimized ratio for methane production through anaerobic co-digestion of banana plant waste (BPW) & sewage sludge (SS). There were 2 main objectives of this study which were the stabilization of sewage sludge (SS) for methane enhancement & optimization of different ratios of BPW to SS were co-digested for best optimum results. The maximum cumulative methane production was observed as 5950.4 Nml for R1 whereas maximum gas flow rate was observed as 456.25 NmL for R3 (40:60) ratio on the basics of volatile solids. From this study it was concluded that banana plant waste is feasible feedstock which can be used in anaerobic digestion for biogas production. It is renewable source of energy, cheaper and easily available & In order to utilize these crop residues, they can be used to overcome the issue of energy crisis as well Therefore, in this study the anaerobic co-digestion of Banana plant waste along with sewage sludge is the most suitable way to utilize both the crop residue and sewage sludge for fulfilling the needs of energy.

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