Stabilization of 1:1 ratio of Buffalo Dung and Water in CSTR for Anaerobic Co-digestion of Banana Plant Waste and Buffalo Dung

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***Abstract*: In a number of regions in Pakistan, crop residues are leading to a solid waste problem. The waste from Banana plants is one of them as it has absolutely no use and is directly burnt. Also, the ineffective management of waste of animals may lead to a number of environmental problems. Therefore, the anaerobic co-digestion of crop residues along with animal waste can prove to be a suitable way for utilizing the crop residues and animal waste and convert them into renewable energy. In this study, stabilization of 1:1 ratio of Buffalo Dung and water was carried out in CSTR for HRT of 20 days in order to analyze its methane potential by measuring the steady conditions of the digester on daily basis. The steady state condition of the digester was tested by frequently examining the slurry for pH, total alkalinity (TA) and volatile fatty acids (VFA). The pH was maintained by adding $Ca(Oh)_2$ until the pH was stabilized. Throughout the study it was thoroughly observed that gas was being produced and also it was observed that with the increase of pH, the TA increased and VFA decreased. The study also revealed the increase in Total Alkalinity and decrease in Volatile Fatty acids lead to stabilization of the slurry because the VFA/TA ratio is required to be less than or equal to 0.5 for stabilization. The best results were observed at the pH 8.6 on which the VFA/TA ratio was 0.31. Further in this study, different organic loading rates containing banana plant waste and buffalo dung will be added to get the optimum results.**

***Keywords*: Anaerobic Co-Digestion, Banana Plant Waste, Buffalo Dung, CSTR**

I. INTRODUCTION

A number of Asian countries are facing an uphill battle for sustainablewaste management due to the growing waste generation [1].Methane production from agricultural waste has become increasingly important in latest years, as it provides significant number of environmental advantages.[2] In quite a number of regions of our country Pakistan, the crop residues including cotton gin waste, canola straw, waste from banana plants, cotton stalks, rice straw and sugar cane trash cause a solid waste issue. [3] Additionally, Animal waste is also one of the most usual organic substances taken in consideration or use for biogas generation. The animal waste is not properly or ineffectively managed in Pakistan that may lead to environmental problems and hazards, such as pollution of water, GGH emissions etc [4]. The biogas production by the anaerobic digestion of animal waste is one of the most feasible ways to get energy from it. The manure can be used as an efficient biogas producer, rich fertilizer, a disinfectant and an insect repellant. [5] Our country Pakistan consists of almost 70 million (70 M) numbers of the cattle and the buffalos. The quantity of biogas that can be generated from these animals is almost 20,000 million m^3/year. The energy produced in the form of biogas from the waste of the animals can prove to be a great help in managing the energy crisis faced by Pakistan. [6] The Process of Anaerobic Co-digestion (AD) of the wastes from crops along with the animal waste could prove to be a feasible and suitable way for discarding the increasing waste of the crops and may lead to the proper and effective management of animal waste. [7]

The financial ability of an effective and proper AD process does not relate to the operating and investment price of the biogas plant, but it also significantly depends on the optimizing the plant parameters. To operate the Continuous Anaerobic Digestion plant, OLR (organic loading rate) and HRT (the hydraulic retention time) are two of the most important and main parameters. The OLR is basically the amount of the organic material added in a day per volume of the reactor. This quantity or mass of the organic material is mostly indicated by VS (volatile solids). [8] Production of methane is significantly dependent on the loading rate. Therefore, in order to get greatest yield from the particular AD reactor size, the loading rate is to be kept greatest, but with more addition or concentration of the OLR, the AD process may be disturbed due to the formation of the VFA (volatile fatty acids) that may result in the reduction of pH within the digester which is not favorable for the anaerobic digestion process. Due to this reason, the OLR needs to be optimized. HRT is the optimized time during which the material that is fed remained in the reactor. The decrease or reduction in the HRT, escalates the danger of disturbing the population of bacteria that is already active. Also, the greater the HRT, the greater the price or the capital cost of the AD process. Therefore, as its necessary to optimize the OLR for AD process, HRT also needs to be optimized to keep the operation efficient and manageable of the AD plant. [9] But in this study, the focus is only kept on optimizing the OLR.

In previous literature or studies, no any study was found related to the anaerobic co-digestion of BPW (banana plant waste) along with BD (buffalo dung) in Continuous Stirr Tank Reactor (CSTR). Therefore, this study was done to optimize the OLR for the AD process using the banana plant waste and the buffalo dung as substrates. The process of optimization was regularly carried out as continuous experiments in Continuous Stir Tank Reactor. Initially, the substrate (1:1 ratio of water and BD) was stabilized for HRT of 20 days during which pH, Moisture Content, Volatile Solids, Total Alkalinity, Volatile Fatty Acids and Gas Generation was continuously measured.

II. MATERIALS & METHODS

A. Collection of Samples

To carry out the experimental work, it was mandatory to collect the BPW samples and BD. Therefore, BPW was collected from the Hyderabad district rural areas and BD was collect from the Jamshoro Railway crossing, which was then transported to the IEEM department, MUET, Jamshoro to begin the study.

B. Substrate Characteristics

The substrate was the buffalo dung for stabilization and for OLR optimization it was (BD) and (BPW). The moisture content percentages (MC%), total solids percentages (TS%) and the volatile solids percentages (VS%) were checked regualrly as per standard methods of (APHA, 1998), whereas the checking of pH was carried out by using the H^+ ion sensitive pH meter. The characteristics of the substrate used are given in Table 1.

Table 1. Characteristics of the substrate used

Feedstock	*Moisture Content* (%)	*Total Solids* (%)	*Volatile Solids* (% TS)
BD	80.50 ± 0.5	19.50 ± 0.5	70.05 ± 1
BPW	6.56 ± 0.5	93.44 ± 0.5	89.08 ± 1

C. Anaerobic Digester

Anaerobic digester used in this study is the Continuous Stirred Tank Reactor (CSTR). The digester is a round container, and has the volume of 5 liters in total, out of which the volume used for working is 4 liters and the remaining 1 liter is the head-space. The digester is made as the triple shell digester. The inner shell is filled with the material (substrate) and the shell which is in middle is filled with the heated water. The water is heated with the help of the electric element which is of 0.5 kilowatt (kW) and is moved around with the help of the pump. The middle shell is wrapped with insulation of glass wool just to reduce the loss of heat.

Fig. 1 (a): CSTR setup

Fig. 1 (b): The Reactor

D. Slurry preparation and N_2 Purging

In order to initiate the work, slurry (mixture of Water and BD) was prepared with 1:1 ratio. The reactor was filled with this slurry up to the working volume i.e. 4 liters and then N_2 gas was purged in the reactor for 5 minutes to generate anaerobic environment.

E. Stabilization of CSTR

As soon as the slurry (mixture of BD and water) was filled in the CSTR upto the working volume i.e. 4 liters, the reactor was then connected with CO_2 absorption jar which was a drum type wet gas meter. For mixing of substrate, the stirrer was adjusted at rpm of 60. The timer of the stirrer was kept to 2 minutes and 30 minutes for mixing and resting times, respectively. The digester was charged on a daily basis with the slurry of buffalo dung and water and the ratio of the slurry was constantly kept at 1:1 till the stabilization was achiever i.e. for HRT of 20 days

The stabilized condition of the reactor was regularly tested by examining the digestate (slurry taken out) for pH, volatile fatty acids (VFA) and total alkalinity (TA). The process of Anaerobic Digestion is stable at pH in the range of 6.5 to slightly alkaline (Stronach*et al.*, 1986); TA in the range of 2000 to 18000 mg of $CaCO_3$ per liter (Cuetos*et al.*, 2008; Gelegenis*et al.*, 2007); and the ratio of VFA to TA of less than or equal to 0.5 (Lin *et al.*, 2009). The pH was checked with an H^+ ion sensitive electrode, whereas the TA and VFA were investigated with titration and distillation processes respectively according to the Standard Methods (APHA, 1998).

Fig. 2 (a): Total Akalinity Setup

Fig. 2 (b): VFA Distillation setup

Fig. 2 (c): pH meter used

F. Start of Organic Loading Rate

After the steady condition of the digester was achieved, the first OLR addition of the Banana Plant Waste (BPW) with the Buffalo Dung (BD) was started. The first OLR that was used in this study was (2.66 gVS/L-day). Therefore, in order to make the slurry of required OLR, the banana plant waste and buffalo dung ratio was set to be 40:60 based on VS and previous studies. The HRT was set to 40 days for OLR (20 days for stabilization and 20 days for loading rate settlement). On the pre-fixed HRT of 20 days and already specified volume of the digester i.e. 4L, the total volume of inlet and outlet slurry was calculated to be 200 mL according to equation # 1.

$$HRT = V/Q \qquad (1)$$

$$Q = V/HRT$$

$$Q = 4000mL / 20 \text{ days}$$

$$Q = 200 \text{ mL/day.}$$

G. Measurement of Methane

The Bio-gas commonly consists of (CO_2) and (CH_4). In order to get only methane in the setup for this study, the biogas generated in the AD reactor was at first passed through a jar known as absorption jar which is filled with a solution of 3M NaOH to absorb CO_2. The methane produced was measured with the help of a wet gas meter which is drum type as shown in Fig 3.

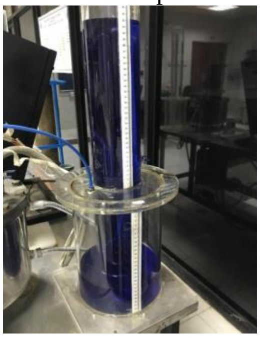

Fig. 3: Absorption Jar

III. RESULTS

A. Stabilization Results:

The pH, Total Alkalinity (TA), Volatile Fatty Acids (VFA) and their ratio i.e. VFA/TA of the digestate from the stabilization of water and buffalo dung for the retention time (HRT) of 20 days is represented in Fig. 4(a) to 4(d). For the stabilization of the reactor to get required pH, TA and VFA values, a mild alkali Calcium Hydroxide $Ca(OH)_2$ was being added daily in small quantities to maintain the pH and get required results. The pH increased from 7.6-8.6, increasing the TA and decreasing the VFA which are both required for proper and maintained process of anaerobic digestion. Owing to the increase in TA and decrease in VFA the VFA to TA ratio was also reduced to almost 0.31 from 1.5 as it is required to be less than 0.5 as mentioned by Lin (Lin *et al.*, 2009). The favorable conditions of the reactor helped in increasing the gas production during stabilization period.

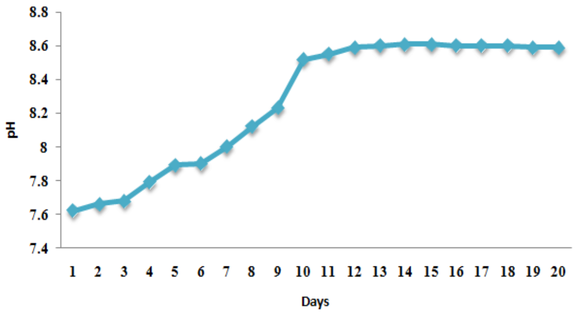

Fig. 4 (a): pH throughout stabilization period

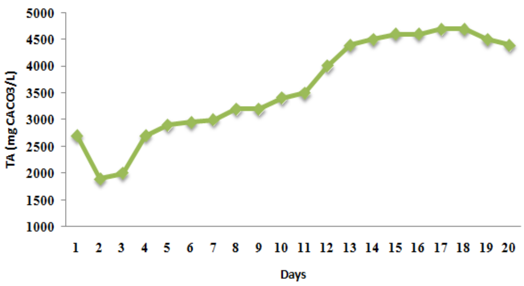

Fig. 4 (b): Total Alkalinity throughout stabilization period

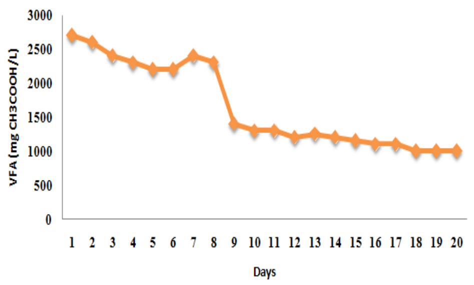

Fig. 4 (c): Volatile Fatty Acids throughout stabilization period

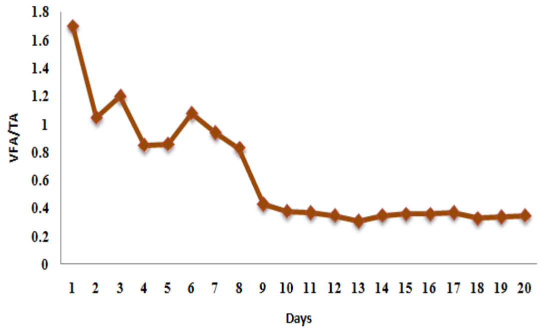

Fig. 4 (d): VFA/TA throughout stabilization period

B. OLR 1 results:

After stabilization was achieved, first OLR of the study i.e. 2.66 gVS was started for HRT of 40 days. The pH, TA, VFA and VFA/TA ratio was stabilized enough showing the steady state of the reactor as shown in Figs 5(a) to 5(d). The little bit variation might be due to the regular addition of substrate into the reactor i.e. 200 mL daily. Conditions were maintained by addition of small quantity of $Ca(OH)_2$ whenever required (when TA decreased or VFA increased).

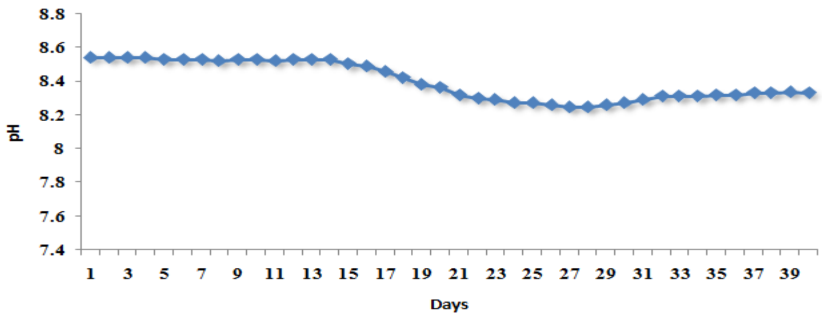

Fig. 5 (a): pH throughout OLR period

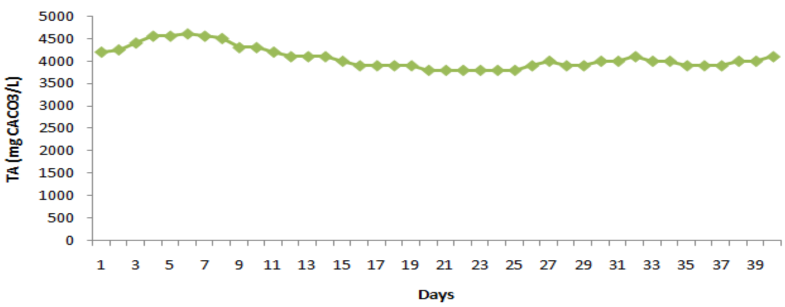

Fig. 5 (a): Total Alkalinity throughout OLR period

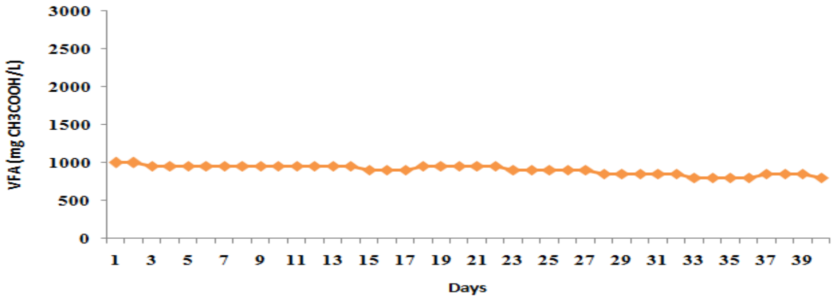

Fig. 5 (a): Volatile Fatty Acids throughout OLR period

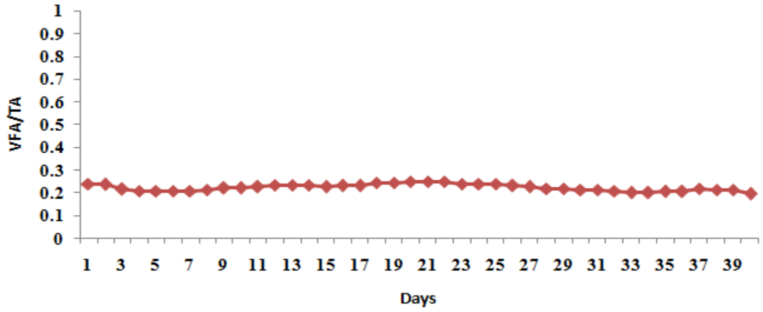

Fig. 5 (a): VFA/TA throughout OLR period

C. Methane Production

The overall methane produced during the stabilization and Organic Loading Rate Period for the HRT of total 60 days is shown in Fig 6 (a). The increase in the production of methane from almost 475 NmL to almost 848 NmL can be clearly seen due to the maintained and optimized parameters of the reactor and regular addition of the feedstock. The little dissimilarities that are shown in the figure may be because of the making of food for the microorganisms as the new substrate was added on daily basis.

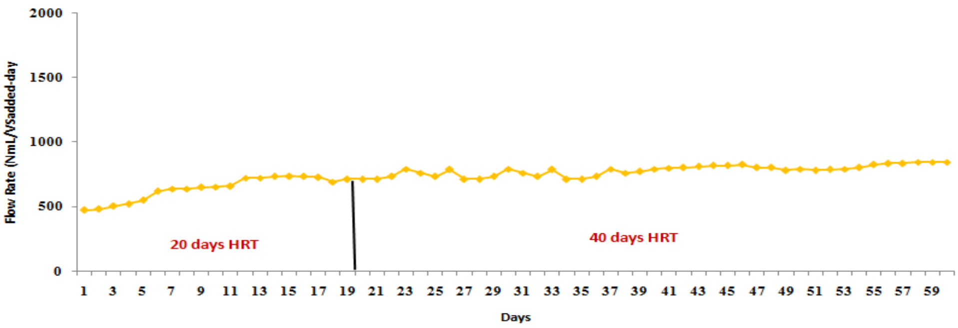

Fig. 6 (a): Methane Production

The cumulative methane produced from the digestate due to the co-digestion of BPW and BD at the OLR of 2.66gVS is represented in Fig. 6(b). The variation in the production of cumulative methane can be seen, which may be due to the swinging of the food being produced for the methanogenic microorganisms.

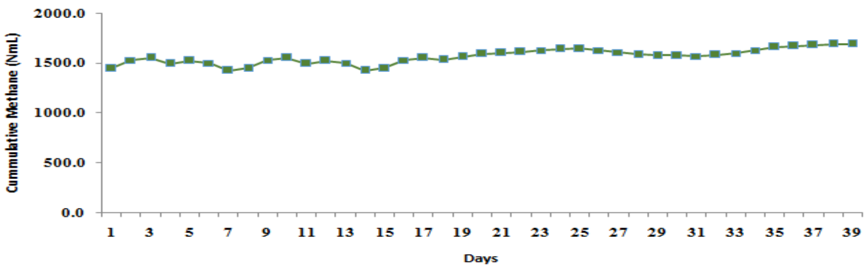

Fig. 6 (b): Cumulative Methane Production

IV. CONCLUSIONS

The aim of this study was to stabilize the 1:1 ratio of water and BD and startup the first Organic Loading Rate and observe the results through anaerobic co-digestion of BPW and BD. Also, the aim was to maintain the parameters such as pH, Total Alkalinity (TA), Volatile Fatty Acids (VFA) and VFA/TA ratio for the AD process. The pH was increased from almost 7.6 to 8.5 in order to increase the TA and reduce the VFA and VFA/TA ratio. The TA increased from 2000 to 4500 and was maintained in the duration of OLR i.e 40 days. Similarly, VFA was reduced from 2800 to 1000 and was in the similar range throughout OLR duration. The increase in TA and decrease in VFA caused the VFA/TA ratio to reduce from 1.8 to 0.2 which is the required parameter for proper anaerobic digestion process. The methane generation started from almost 475 NmL and reached to 848 NmL at the HRT of 60 days and this huge change is due to the maintained and stabilized parameters of the reactor which are the favored environment for the microorganisms to generate methane. Further, two more OLRs will be added to continue this study in order to optimize the OLR for anaerobic co-digestion of BPW and BD.

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