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EFFECT OF EFFLUENT IN CONTINUOUS TYPE ANAEROBIC DIGESTION

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ABSTRACT

The anaerobic digestion (AD) of biomass feed materials like Prosopis juliflora pods (PJP), dry leaves (DL), water hyacinth (WH), and cow manure was investigated in a batch and continuous type of digestion. The daily biogas yield and the composition of biogas and the cumulative biogas yield were evaluated for each experiment. The batch experiment was conducted to find the hydraulic retention time of the feed materials. The continuous digestion was conducted under three different phases. The first phase was batch digestion for startup the experiment, the second phase was to continuously feed the materials without microorganism and the third phase was continuously fed the materials with the effluent filtrate. For an HRT of 50 days, the average biogas production of 13.2 l/day was shown by the batch experiment. The average biogas production of 19.7 l/ day was shown by the continuous type of digestion third phase in 40 days. Moreover, it showed the highest biogas composition (CH4:75.73% and CO2:24.08%). However, the second phase performed worst in the average biogas production (9.4 l/day) in 20 days and the biogas composition (CH4:69.58% and CO2:29.06%). After stabilization (from the 15th day) of the third phase, experiment feed materials with effluent filtrate gave the maximum average biogas yield (23.2 l/day). Overall these studies show that the addition of effluent filtrate with the feed material can be a promising technique for improving biogas production.

Key words: Anaerobic digestion; co-digestion; batch; continuous; biogas; methane.

INTRODUCTION

In the source of renewable energy is one of the eco-friendliest energies. In today scenario of energy harnessing of renewable potential in an effective manner is becoming a need of the era. It can mitigate the negative environmental due to fossil fuel impact and also gives the sustainable power supply (Tripathia et al., 2016). Biomass contains a complex mix of H_2, O_2, C, and N_2. It is obtained from dead or living plants and also a by-product of crop production, agro-based industry, and wood (Kumar et al., 2015). Hydrogen, electricity, ethanol, the steam, methane, heat (via burning), and methanol can be produced by converting the biomass into a variety of energy forms. Methane is comparatively a clean fuel, the increased use of vehicles makes way for trend and also in industrial applications, power generation, and appliances. Thermal gasification or biological gasification process is used to produce the methane from the biomass (commonly referred to as AD) (Chynowetha et al., 2001). Animal manures and sewage are treated by anaerobic digestion can be used for many years. A high range of urban activities, agricultural, and industrial generated deposit are suitable for anaerobic treatment (Emberga et al., 2012). Methane-rich biogas is converted from organic matter as a renewable energy is known as anaerobic digestion (AD). It can be subdivided into the solid-state AD, liquid AD, based on the total solids (TS) content of feed stocks used in digester operations. To treat animal manure, the traditional technology is widely used to operate at TS ranging from 0.5% to 15 % with food waste, sludge, and sewage and liquid anaerobic digestion (Xu et al., 2014).

Simultaneous AD of multiple organic wastes in a single digester called co-digestion. It is used to yield more biogas production difficult or low yielding digest materials. Wu et al. (2010) had described that by adding agricultural remains in the co-digestion process with swine manure will improve the total biogas yield. A novel membrane bioreactor configuration, the addition of up to 5 g /l of D –Limonene and to hydrolyze microcrystalline cellulose has the ability to overcome an inhibition problem. And also, it proved to have a good ability to sequentially convert it into methane. It is containing both free and encapsulated cells that work simultaneously (Wikandari et al., 2014). The performance of both batch and continuous digesters were using an apple waste (AW) and swine manure as a mixture, It has been evaluated by Kafle and Kim. There will be a positive synergetic effect are the outcomes of the continuous test when the AW content in the feed was increased, and also negative synergetic of AW increases from 33% to 50%, due to the drop in pH and accumulation of TVFA (Kafle and kim., 2013). Zhang et al. proposed that the high concentrations of cationic elements and waste oil, form the inhibition in anaerobic digestion of food waste. This failure is prevented by a dual solid-liquid (ADSL) system. The total methane yield was obtained in ADSL (13.6%) was compared with raw food waste system (Zhang et al., 2013). A novel alternate feeding mode was introduced by Wang et al., and the successful operation of food waste/FM/chicken manure was proved to obtain a maximum biogas production (Wang et al., 2014). Stable and preferable methane yield of 223 ± 7 ml/g VS added and the OLR of 4 g VS/l/d were showed in the result of anaerobic co-digestion of corn stover and chicken CSTR (Li et al., 2014).

This research was made to evaluate the effect of effluent filtrate with feed materials on continuous type anaerobic digestion. This is analyzed in terms of daily biogas yield cumulative biogas yield and biogas composition. The first experimental test was carried out in anaerobic digestion of the mixture of PJ pods, DL, WH and CM in a batch mode. The second experimental test was carried out in a continuous mode of operation, using the mixture of PJP, DL, and WH. The continuous mode was conducted by three phase and each phase differs by the feed materials (phase I: batch digestion, phase II: only PJP, WH, and DL, and phase III: PJP, WH, DL, and effluent filtrate).

MATERIALS AND METHODS

Materials: the various feed materials used in this research was PJP, DL, WH, and CM. All the feed materials were taken from the college campus and nearby village. Then the feeds (except manure) were sun-dried and air tight plastic bags are used to store the materials. The particle size of the feed materials was reduced in the blender by crushing.

Experimental Setup: The digester used for experiments is a 25 L plastic tank. The digester consists of feed inlet at the top of the digester and the slurry outlet on the bottom side of the digester. The heating rod and temperature controller were placed in the water jacket. The digester is sealed and connected with a pipe for the collection of biogases. The other end of the pipe was connected to a water displacement system consisting of an inverted 20-liter plastic tank, in which the amount of water in the tank is replaced by the gas collected. Prior to operation, the anaerobic conditions of the

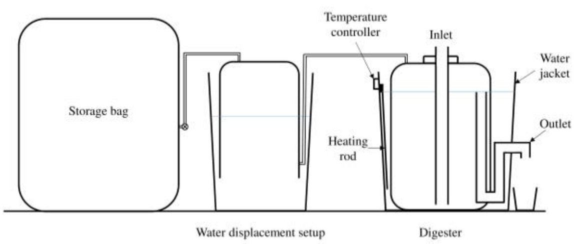

Fig. 1. Experimental setup

Fig. 2. The photographic view of experimental setup

reactors are ensured. The temperature of the digesters will be maintained at 35 ± 2 ºC with the help of temperature controller. The batch experiment was terminated, when there is no significant gas production was observed. The fig .1. and fig.2. represent the line diagram and the photographic view of the experimental setup.

Analytical methods: The total solid and volatile solid of the samples were measured by the standard methods (APHA 1998). pH meter was used to measure the pH. (Eliot LI 120). Elementary Vario EL III Carbon-Hydrogen-Nitrogen analyzer is used to analyze the C, H_2, and N_2. The water displacement method is used to measure the daily biogas production. Biogas composition is analyzed by (GC – 2014, Shimadzu in Japan) Gas chromatography with N_2 as a carrier gas.

Experimental methods: The amount of CM added to the equal amount of crushed feed materials (PJP, DL, and WH) mixed with the tap water to form a feed slurry. The feed materials are initially loaded into the batch reactor for experimentation. The experiments were terminated when there is no significant gas production was observed. The biogas production was measured every day.

The continuous digestion had conducted in three different phases. The first phase was started in a batch mode with an initial organic loading of 5 % TS. After digestion for 40 d, no apparent biogas production was produced. Then we start up the second phase by loading with the prepared feed materials once a day, without the addition of extra microorganism (CM). No higher OLR was conducted based on the previous results of batch digestion tests. After 20 days of phase II experimentation, we started the phase III experimentation. During the third phase, we added the feed materials with effluent filtrate as a microorganism. The biogas production was measured every day. The pH value of the effluent was measured on an alternate day. The biogas composition was tested in every 10th day. The whole system ran for more than 100 days.

Table I: Characteristics of feed materials

Properties	PJ pods	DL	WH	CM
Moisture content/%	7.78	8.61	10.91	78.86
TS/%	92.2±0.4	91.39±1.2	89.1±0.3	21.14±0.6
VS/%	90.9±0.3	89.7±1.06	79.6±0.2	16.15±0.4
VS/TS/%	98.57	98.15	89.33	76.4
C/%	42.06	39.57	33.57	30.99
H/%	6.73	5.91	5.82	-
N/%	2.35	1.49	1.55	1.93
C/N	17.89	26.55	21.65	16.05

RESULTS AND DISCUSSION

Characterization of the feed materials: Table I shows the characteristics of feed materials. The moisture content of the DL and GC are low compared to other materials. The materials in this study had a wide range of TS and VS content. The PJP had high carbon content value of 42.06%. The other materials have the C/N ratio in the optimal range of 15 to 30. The digester influents had maintained the TS less than 5%. So that only the material can easily flow in the continuous type digester. Add tap water in the feed materials that helped to prepare the feed slurry for anaerobic digestion.

Batch digestion: The batch digestion, the mixture of PJP, DL, WH, and CM are used to evaluate the anaerobic digestion process. Fig.3. shows the daily biogas production in batch digestion. From this graph, we observed that many peaks had recorded in daily biogas production curve at different time period. This is due to the mixture containing the different mixture of materials and various degradation period of each material, based on the fiber, cellulose, and hemicellulose available in the materials. The highest daily biogas production was recorded on day 18 (27.5 l/day). The average biogas production is found to be 13.2 l/day for a period of 50 days. Comparison between 50 days HRT period and 40 days HRT period, the 40 days HRT period gave the maximum average biogas yield 15.7 l/day. The graph clearly showed after 40 days of digestion the daily biogas yield curve decreased. 4.1 l/day average biogas production had recorded in the digestion period of 41 to 50. Therefore we had selected 40 days HRT period for the continuous digestion. The cumulative biogas production has recorded 661 liters in 50 days. Moreover 74.997 % methane and 25% CO_2 content present in the biogas

Continuous digestion: Based on the aforementioned information, 40 days of HRT period is enough continuous digestion. Therefore, after the completion of startup batch test the digester had fed by 0.575 l of slurry on each day. Fig 4. Shows the biogas composition in continuous digestion. The first phase of an experiment the digester loaded with the feed material with CM to start up the digestion. The average biogas production of 14.6 l/day and biogas concentration of methane 75.93% and CO_2 23.77% were observed in phase I. After 35th day the biogas production was slowly decreased. In the second phase of an experiment, the digester is loaded only

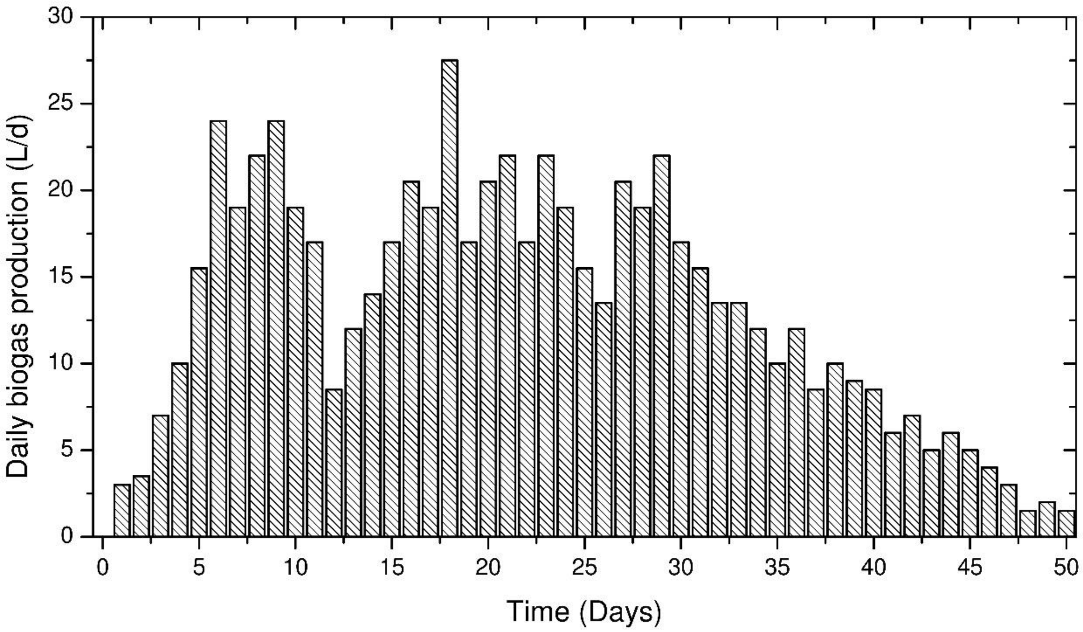

Fig.3. Daily biogas production in the batch digestion

with feed material. The graph shows that the biogas production was decreasing in the second phase of digestion and there is less significant biogas production. The average biogas production in the second phase of digestion is 9.4 l/day. In the second phase of digestion, there is no microorganism present in the feed materials. Therefore, the reaction speed reduced, and the biogas production also reduced. During this time the effluent pH value also decreased as shown in fig. 6. The methane composition in the biogas also started to decrease (75.93 to 69.52%).

The third phase of an experiment the digester loaded with the feed material with the addition of effluent 35th day the biogas production was slowly filtrated. After the addition of effluent filtrate, the rate of reaction was improved. So that the biogas production was increased. The graph shows that the graph shows that the biogas production was biogas production was improved from the 61st day decreasing in the second phase of digestion and to the 75th day. Moreover, after 75th day the biogas production was stabilized and the yield varying in the range between 20 to 25 l/day. The average biogas production in the second phase of digestion is 19.7 l/day. After the 15th day of the third phase, continuous digestion gave the average biogas yield of 23.2 l/day. The biogas composition value also improved from the second phase to the third phase

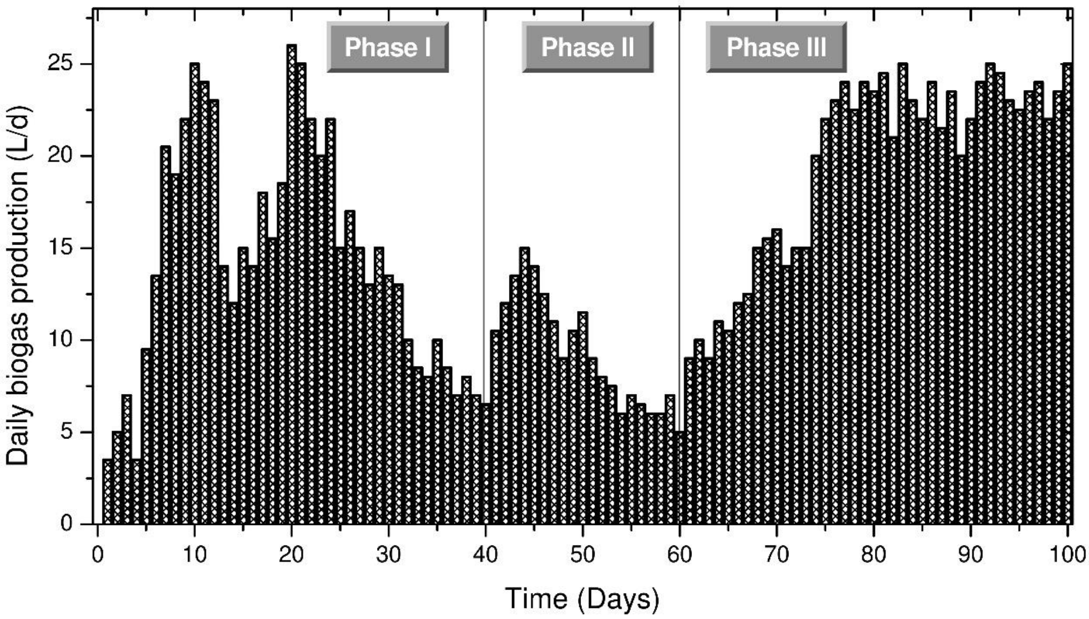

Fig. 4. Daily biogas production in the continuous digestion

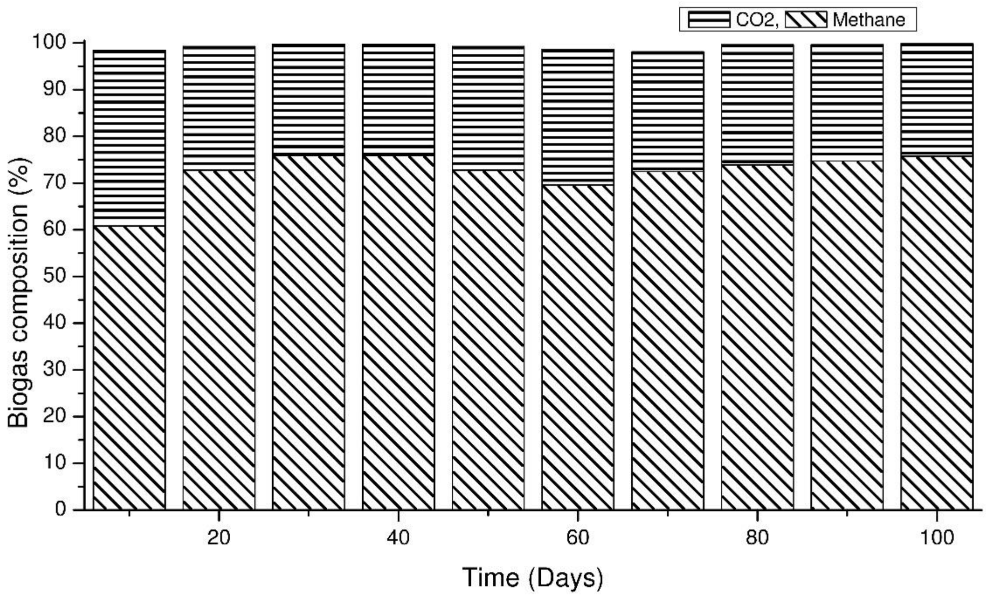

Fig. 5. Biogas composition in the continuous digestion

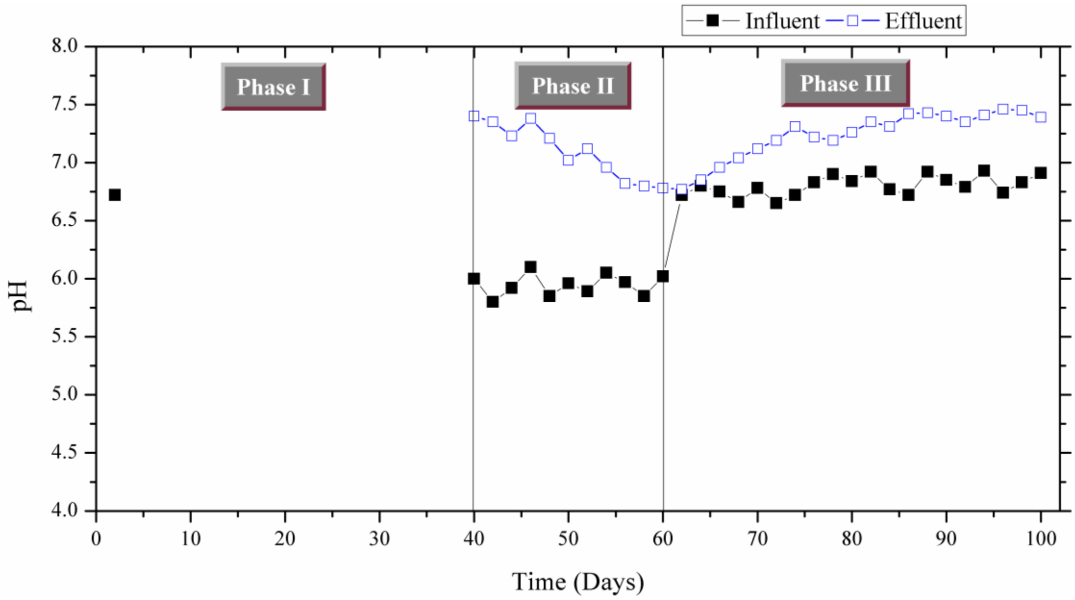

Fig.6. pH variation in the continuous digestion

and it's shown in fig. 5. The methane composition in the biogas increased from 69.52% to 75.73%. Fig.6. shows the pH variation in the continuous digestion. The second phase experiment the pH value of the influent is low compared to the other phase influent. Continuously adding this low pH feed, it affected the reaction rate. So that the pH of the effluent is found to decrease, and low biogas yield was recorded. To get maximum biogas production in the AD with an optimal range of pH was 6.5–7.5. All microbially mediated substrate conversion processes were subjected to inhibition by extremes of pH (Liu et al., 2008). A dramatic change in pH, low methane yield and subsequently causing reactor failure and inhibiting methanogenic bacteria was the result of an accumulation of total VFAs during AD (Cui et al., 2011). The third phase of the experiment with the addition of effluent filtrate with feed materials adjusted the pH of the influent and slowly stabilize the reaction and improve the biogas production.

CONCLUSION

This study examined the anaerobic digestion of biomass materials using batch and continuous operation. The batch digestion gave the better biogas yield up to 40 days to the value of 15.7 l/day. The second phase of continuous digestion, the biogas production was decreased due to the insufficient amount of microorganism. After the addition of effluent filtrate with feed materials, the effluent filtrate improved the biogas yield. After stabilization of the third phase of the experiment, we found the highest average biogas production (23.2 l/day). From this study, it was suggested that the addition of effluent filtrate in the feed material influent is good for biogas production.

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