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BIOGAS FROM THERMOPHILIC ANAEROBIC DIGESTION OF COW DUNG

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ABSTRACT

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic conditions. Biogas is one of the most important alternate sources of conventional energy. The production of biogas not only reduces the use of fossil fuels but also reduce the release of methane through microbial activity to the atmosphere. A research work was conducted to investigate the production ability of biogas from thermophilic and mesophilic anaerobic digestions of cow dung (CD). Three laboratory scale digesters were constructed to digest cow dung, where two set ups were used for mesophilic digestion and the other set up was used for thermophilic digestion. The digesters were made of glass conical flask of 1-liter capacity each. Cow dung was used 311 gm and water was used 389 gm in each experiment. In the slurry, total solid content was maintained 8% (wt.) for all the observations. The digesters were fed on batch basis. The mesophilic digesters were operated at ambient temperatures of 18 – 28^oC and thermophilic digester was operated at 50 – 56^oC. The highest total gas yield was obtained about 13.2 L/kg CD for mesophilic digestion and about 11.4 L/kg of CD for thermophilic digestion. The retention time was about 60 to 65 days for mesophilic digestion and 58 days for thermophilic digestion. From the investigation, it was found that using thermophilic digestion gas production started after 2 days but for mesophilic digestion it took 22 days to start biogas generation.

Keywords: Biogas, Anaerobic, Thermophilic, Cow Dung.

1. INTRODUCTION

Anaerobic digestion (AD) is a complex biological process in which anaerobic bacteria decompose organic matter in environments with little or no oxygen. The products of anaerobic digestion are biogas and digested substrate, commonly named digestate, and used as fertilizer in agriculture. The biogas generally composes of 55-65% methane, 35-45% carbon dioxide, 0-3% nitrogen, 0-1% hydrogen, and 0-1% hydrogen sulfide [1]. By AD process the significant methane emission resulting from the uncontrolled anaerobic decomposition of organic waste into atmosphere would be stopped, where methane is over 20 times more effective in trapping heat in the atmosphere than carbon dioxide [2]. Moreover, production of biogas will reduce the use of fossil fuels, thereby reducing the carbon dioxide emission. This is thus in accord with Kyoto Summit agreement [3]. Anaerobic digestion is in principle possible between 3^oC and approximately 70^oC. Differentiation is generally made between three temperature ranges: the psychrophilic temperature range lies below 20^oC, the mesophilic temperature range between 20^oC and 40^oC, and the thermophilic temperature range above 40^oC [4]. Production of biogas from municipal wastes, different animal manures, water hyacinth, agricultural waste etc. using thermophilic digestions were reported by different researchers. To optimize the temperature on methane recovery from anaerobic digestion of water hyacinth-cattle dung Madamar et al. [5] reported 60^oC to be optimum for thermophilic digestion and they also reported that thermophilic operation performed better than mesophilic operation. Their finding was supported by the work of Pfeffer [6] for municipal refuse. Ahring et al. [7] demonstrated that an increase in the operational temperature of a single-stage digester treating cattle manure from 55^oC to 65^oC did not affect the hydrolysis/fermentation but reduced the final methane yield. Nielsen et al. [8] demonstrated the possibility to improve the anaerobic degradation of cattle manure when applying 68^oC pretreatment before a traditional 55^oC digestion. Nielsen et al. [9] studied the possibility of improving a two-stage (68^oC/55^oC) thermophilic anaerobic digestion concept for treatment of cattle manure. Liu et al. [10] investigated thermophilic anaerobic digestion of dairy cattle manure and co-digestion of garbage, swine manure, and dairy cattle manure, where the reactors were maintained at the temperature of 53^oC.

The scope of this present investigation was to conduct research work in laboratory scale to produce biogas from thermophilic and mesophilic anaerobic digestion of cow dung.

2. MATERIALS AND METHODS

2.1 Sources of Cow Dung and Slurry Preparation

The cow dung for this research work was collected from the local area around Chittagong University of Engineering and Technology (CUET). The total solid content of cow dung was considered to be 18% (wt.) [11]. To optimize the gas generation, total solid content in the slurry was maintained 8% (wt.) [11, 12]. For each experiment slurry of 700 gm amount was prepared from 311 gm of cow dung and 389 gm of water.

2.2 Experimental Set-up and Procedure

Three experimental set ups were constructed to investigate the production of biogas from the anaerobic digestion of cow dung. Where two set ups were used for mesophilic digestions and the other was used for thermophilic digestion. All the set ups were placed in the Heat Engine laboratory of Mechanical Engineering department of CUET. Three digesters made of glass conical flask of 1 liter capacity was used for each setup. The schematic diagram of the setup for thermophilic digestion is shown in Fig. 1. The digesters were set-up with other equipments such as displacement tank / gas collector, water collector and hot water bath. For thermophilic digestion the digester was kept into a thermostated water bath to maintain the temperature of the slurry from 50^{o}C to 56^{o}C. A plastic pipe was used to connect the digester and displacement tank. The gas produced in the digester passed through the pipe to the displacement tank. Another plastic pipe was used to take the displaced water from the displacement tank to the water collector which was fitted air tight in the displacement tank and inserted up to bottom part of it. For mesophilic digestion no water bath was used. So the digestion was done at ambient temperature. During the study the volume of the produced gas was measured with the help of the water displacement method [13, 14], considering the volume of the produced biogas was equivalent to the displaced water in the water collector. The digester were operated in batch mode and fed manually. At the time of experiments, it was ensured that the digesters were fully gas tightened.

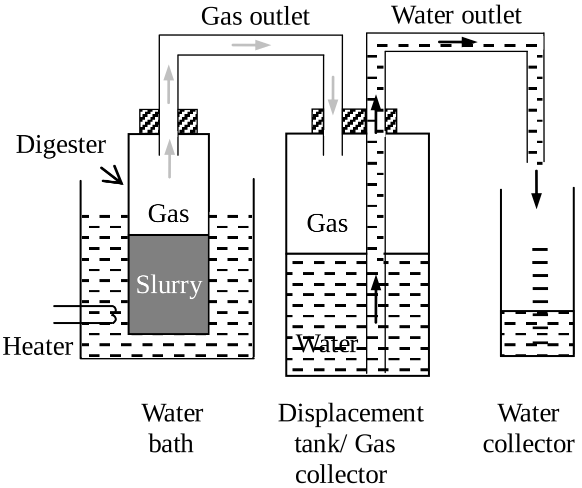

Fig 1. Schematic diagram of the experimental set-up for thermophilic anaerobic digestion

3. RESULTS AND DISCUSSION

Data were taken for gas collection, room temperature, and bath temperature for three digestion set ups. The experiments were conducted between 25/01/2010 and 04/04/2010. Figure 2 shows the total gas yields for both mesophilic and thermophilic anaerobic digestions. For the mesophilic digestions the gas productions were found to be started from 22nd day for both the set ups and productions continued up to 60th to 65th days. As the experiments were started in the winter and ambient temperature was at psychrophilic range (<20^{o}C) for few days, the starts of gas production were delayed for mesophilic digestions. For the thermophilic digestion the gas producion started on the 3rd day and it continued till 58th day. The total gas yield for mesophilic-1 was found to be 13193 ml/kg of CD and for mesophilic-2 this amount was 10447 ml/kg CD. For thermophilic digestion the total gas yield was found to be 11431 ml/kg CD. Figure 3 shows the daily gas production from both mesophilic and thermophilic anaerobic digestions. It is clear that for mesophilic-1 digestion the gas production rate increased from 37th day with the maximum gas production of 879 ml/kg CD per day was observed on the 56th day. For mesophilic-2 digestion, the maximum gas

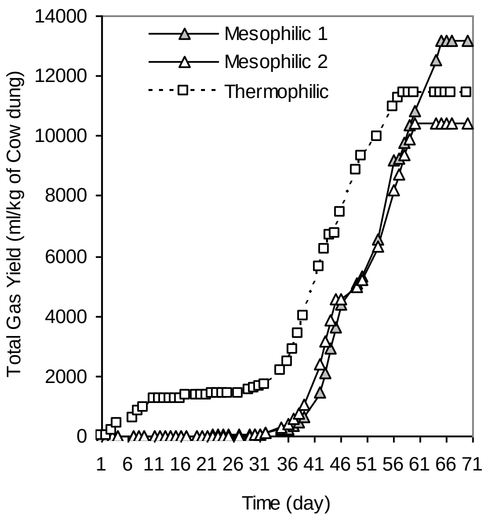

Fig 2. Total gas yield from anaerobic digestion

production was found to be 756 ml/kg CD per day on the 43rd day and the gas production rate was found to be increased from 36th day. On the other hand, for thermophilic digestion the maximum gas production rate was found to be 707 ml/kg CD per day on 46th day. Figure 4 shows the room temperature and bath temperature variations during the total experiment period. Mesophilic digestions were done at room temperature. At the beginning of experiments the room temperature was 18^{o}C, and it was gradually increased to 28^{o}C on 65th day (30/03/2010). The effect of room temperature on gas generation from mesophilic digestion can be explained from Fig. 3. On 22nd day the room temperature was 22^{o}C. And this temperature reached at this level on 20th day. For thermophilic digestion temperature varied between 50^{o}C to 56^{o}C. But for four days (9th – 12th days) bath temperature was 60^{o}C and above. The maximum bath temperature was 65°C. From 13th to 27th day there was no significant gas generation. Gas generation started again from 29th day and continued till 58th day.

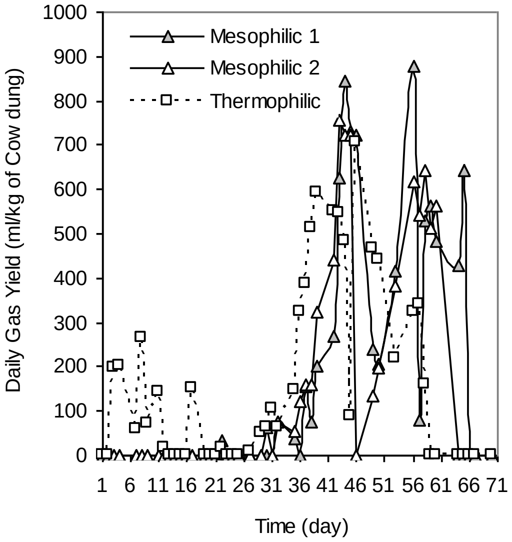

Fig 3. Daily gas yield from anaerobic digestion

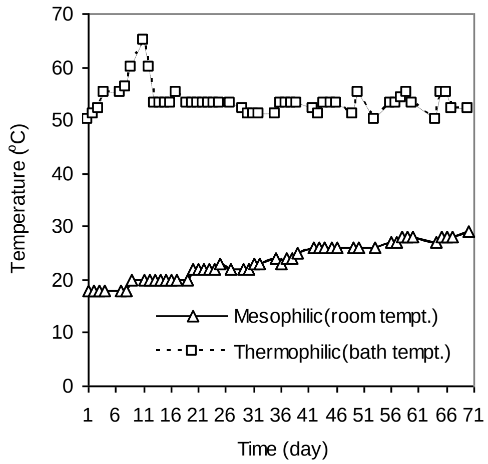

Fig 4. Digestion temperatures for mesophilic and thermophilic digestions

4. CONCLUSIONS

Anaerobic mesophilic and thermophilic digestions of cow dung for producing biogas were investigated using one liter digester. The highest total gas yield was obtained about 13.2 L/kg CD from mesophilic digestion. The total gas yield of 11.4 L/kg of CD was obtained from thermophilic digestion. For mesophilic digestion the gas production started on 22nd day, for thermophilic digestion it started on 3rd day. Since thermophilic digestion needed extra energy to maintain the bath temperature more work should be done with proper temperature control of the water bath before concluding regarding the suitability of thermophilic digestion method in Bangladesh.

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