Biogas from Mesophilic Anaerobic Digestion of Cow Dung Using Silica Gel as Catalyst

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Abstract

Biogas originates from bacteria in the process of biological breakdown of organic material under anaerobic conditions. A research work was conducted to investigate the production ability of biogas from mesophilic anaerobic digestions of cow dung (CD) using silica gel as catalyst. Two laboratory scale digesters were constructed to digest cow dung, where one set-up was used for digestion of cow dung without catalyst and the other set-up was used for digestion with catalyst. The digesters were made of glass conical flask of 1-liter capacity each. Cow dung was used 390 gm and water was used 310 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 digesters were operated at ambient temperatures of 27 – 31°C. The total gas yield was obtained about 27.3 L/kg CD for digestion without catalyst and about 30.5 L/kg of CD for digestion with catalyst. The retention time was about 76 days for both the digestions. The gas yields were compared with the previous work of mesophilic digestions of cow dung without catalyst of operating temperatures 18 – 28°C.

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1. Introduction

Anaerobic digestion is a biological process that happens naturally in which anaerobic bacteria decompose organic matter in environments with little or no oxygen and produces biogas. Biogas can used for cooking, heating, cooling,

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lighting, generating electricity etc. [1]. The key by-product of anaerobic digestion is digested solid which is rich in nitrogen and can be used as a fertilizer. The composition of biogas mainly depends on feed materials and biogas generally comprises of 55-65% methane, 35-45% carbon dioxide, 0-3% nitrogen, 0-1% hydrogen, and 0-1% hydrogen sulfide [2]. By anaerobic digestion 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 [3]. 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 [4]. Anaerobic digestion is in principle possible between 3°C and approximately 70°C. Differentiation is generally made between three temperature ranges: the psychrophilic temperature range lies below 20°C, the mesophilic temperature range between 20°C and 40°C, and the thermophilic temperature range above 40°C [5]. Patel et al. [6] studied the effect of silica gel as one of the adsorbents in an effort to improve the anaerobic codigestion of water hyacinth and cattle dung. Desai and Madamwar [7] used silica gel as one of the adsorbents for improving the efficiency of anaerobic digestion of a mixture of cheese whey, poultry waste and cattle dung. For improving anaerobic digestion of water hyacinth and cattle dung temperature was optimized in the range 20 to 65°C by Madamwar et al. [8]. Desai et al. [9] reported that with the increase of temperature from 20 to 40°C gas production from anaerobic digestion of cattle dung, poultry waste and cheese whey was increased with a higher methane percentage. Patel and Madamwar [10] studied the effect of temperature in the range of 25 to 55°C on total gas production from acidic petrochemical waste water. Salam et al. [11] investigated the production ability of biogas from cow dung at ambient temperatures in the range 18–28°C. Ukpai and Nnabuchi [12] investigated the anaerobic digestion of cow dung for generating biogas while slurry temperature was maintained between 22 and 36°C.

The scope of this investigation was to conduct research in the laboratory scale to produce biogas from mesophilic anaerobic digestion of cow dung using silica gel as a catalyst.

2. Materials and methods

2.1. Source of cow dung and slurry preparation

The cow dung (CD) for this research work was collected from the area inside Chittagong University of Engineering and Technology campus. The total solid content of cow dung was determined by heating cow dung at 115°C in oven for 42 hours. And the total solid (TS) content was found to be 14.38%. Normally total solid content of fresh cow dung varies between 15 – 19% [13]. For preparing the slurry 8% of total solid content was maintained by adding water. Solid contents in the range 7 – 9% were considered to be optimum by many researchers [8, 14–16]. For each experiment 700 gm slurry was prepared from 390 gm of cow dung and 310 gm of water. For anaerobic digestion with silica gel 2.8 gm silica get was added into the slurry.

2.2. Experimental set-up and procedure

Two experimental set-ups were made to investigate the production of biogas from the anaerobic digestion of cow dung using silica gel as catalyst. Where one set-up was used for anaerobic digestion with silica gel (WSG) as catalyst and the other was used for anaerobic digestion without silica gel (WOSG). The set-ups were placed in the Heat Engine Laboratory of Mechanical Engineering department of CUET. The digesters made of glass conical flask of 1 liter capacity was used for each set-up. The schematic diagram of the set-up is shown in Fig.1. The digesters were connected with displacement tank / gas collector and water collector. As methanogenic micro-organisms are very sensitive to temperature fluctuation the digesters were kept in the containers and covered with rice husk to keep the digesters temperature stable. Plastic pipes were used to connect the digesters and the displacement tanks. 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 fitted air tight in the displacement tank and inserted up to bottom part of it. Digestion was done at ambient temperature. During the investigation the volume of the produced gas was measured with the help of water displacement method [11], considering the volume of the produced biogas was equivalent to the displaced water in the water collector. The digesters were operated in batch mode and fed manually. At the time of experiments, these were ensured that the digesters were fully gas tightened.
3. Results and discussions

Data were taken for collected gas and room temperature for the digestion set-ups between 18/05/2011 and 02/08/2011. Figure 2 shows the total gas yields for both anaerobic digestions of cow dung with (WSG) and without silica gel (WOSG) catalyst. The ambient temperatures during the data taking period varied between 27 and 31°C,

![Diagram](image)

**Fig. 1.** Schematic diagram of the experimental set-up for anaerobic digestion of cow dung.

**Fig. 2.** Total gas yield from anaerobic digestion of cow dung.

**Fig. 3.** For both the cases the gas productions were found to be started from the 5th day. The gas production continued up to 76th and 77th days for WOSG and WSG respectively. The total gas yield for digestion without silica gel catalyst was found to be 27272 ml/kg CD and for digestion with silica gel catalyst was found to be 30528
ml/kg CD. An increase of 11.94% total gas production for using silica gel catalyst was observed. Patel et al. [6] used up to 6 gm/liter of silica gel for anaerobic digestion of mixture of water hyacinth and cow dung and reported increase of gas production for digestion with silica gel. The authors found maximum gas production of 1.35 l/l of digester/day for 1 gm/liter silica gel compared to 1 l/l of digester/day gas production from digestion without silica gel. Desai and Madamwar [7] also reported increase of gas production from digestion of mixture of cow dung, poultry waste and cheese whey with silica gel. They found 4 l/l of digester/day gas production from 4 gm/liter silica gel compared to gas production of 2.2 l/l of digester/day from digestion without silica gel. Fig. 2 also shows total gas production from anaerobic digestion of cow dung from earlier work where ambient temperatures varied between 18 and 28°C, Fig. 3 [11]. Total gas productions at lower range of ambient temperatures were reported to be significantly lower. At 18 to 28°C ambient temperature range total gas productions from two digesters were reported to be 10447 and 13139 ml/kg CD [11]. Ukpai and Nnabuchi [12] reported total gas generation of 7312 ml/kg CD from anaerobic digestion of cow dung while slurry temperature was maintained between 22 and 36°C. The optimum mesophilic temperature at which the micro-organisms which take part in methane fermentation lies between 35 – 40°C [17]. Figure 4 shows the daily gas production for both digestions of without silica gel and with silica gel. No significant differences were shown from the two digestions for daily gas production. For digestion without silica gel maximum daily gas production of 1346 ml/kg of CD was obtained on the 14th day. For digestion with silica gel the maximum daily gas production of 1244 ml/kg CD was obtained on the 34th day. In the last part of the digestion processes daily gas production from WSG were found to be more than those from WOSG. For WOSG digestion the daily gas production from 56th to 76th days varied between 0 to 308 ml/kg CD. Whereas for digestion WSG the daily gas production from 56th to 77th days varied between 27 to 769 ml/kg CD.

Fig. 3. Ambient temperatures during anaerobic digestion of cow dung.
4. Conclusions

The effect of silica gel catalyst on anaerobic mesophilic digestion of cow dung was investigated using batch type 1 liter digesters. Digestions were done at ambient conditions of temperature 27 – 31°C. An increase of 11.94% total gas production for using silica gel catalyst was observed. Total gas productions at higher range of ambient temperatures were reported to be significantly higher.

References

[1] J. Balsam, D. Ryan, Anaerobic digestion of animal wastes: factors to consider, www.attra.ncat.org/utra-pub/PDF.anaerobic.pdf, 2006.
[2] P. Milono, T. Lindajati, S. Aman, Biogas production from agricultural residues, The First ASEAN Seminar-Workshop on Biogas Technology, Working Group on Food Waste Materials, 1981, pp. 52–65.
[3] U.S. Environmental Protection Agency, Web: www.epa.gov/methane/ (01 April 2011).
[4] J. Mata-Alvarez, S. Macé, P. Llabrés, an overview of research achievements and perspectives, Bioresource Technology, 2000, 3–16.
[5] Information and Advisory Service on Appropriate Technology (ISAT), Biogas Digest, Volume 1, Biogas Basics, Germany.
[6] V. Patel, A. Patel, D. Madamwar, Effects of adsorbents on anaerobic digestion of water hyacinth–cattle dung, Bioresource Technology, 40 (1992) 179–181.
[7] M. Desai, D. Madamwar, Anaerobic digestion of a mixture of cheese whey, poultry waste and cattle dung: a study of the use of adsorbents to improve digester performance, Environmental Pllution, 86 (1994) 337–340.
[8] D. Madamwar, A. Patel, V. Patel, Effect of temperature and retention time on methane recovery from water hyacinth–cattle dung, J. of Fermentation and Bioengineering, 70(5) (1990) 340–342.
[9] M. Desai, V. Patel, D. Madamwar, Effect of temperature and retention time on biomethanation of cheese whey–poultry waste–cattle dung, Environmental Pollution, 83 (1994) 311–315.
[10] H. Patel, D. Madamwar, Effects of temperature and organic loading rates on biomethanation of acidic petrochemical wastewater using an anaerobic upflow fixed-film reactor, Bioresource Technology, 82 (2002) 65–71.
[11] B. Salam, S. Biswas, T.K. Das, Biogas from thermophilic anaerobic digestion of cow dung (RE-003), Intl. Conf. on Mechanical Engineering (ICME 2011), 2011, Dhaka, Bangladesh.
[12] P.A. Ukpai, M.N. Nnabuchi, Comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 litres biogas digesters, Advances in Applied Science Research, 3(3) (2012) 1864–1869.
[13] M. Shyam, A biogas plant for the digestion of fresh undiluted cattle dung, Boiling Point, No 47, Autumn 2001, 33 – 35.
[14] A. Santana, B. Pound, The production of biogas from cattle slurry, the effects of concentration of total solids and animal diet, Trop Anim Prod, 5(2) (1980) 130–135.
[15] B.Z. Zennaki, A. Zadi, H. Lamini, M. Aubinear, M. Boulif, Methane fermentation of cattle manure: effects of HRT, temperature & substrate concentration, Tropicultural, 14(4) (1996) 134–140.
[16] I.J. Otaraku, E.V. Ogedengbe, Biogas production from sawdust waste, cow dung and water hyacinth–effect of sawdust concentration, Intl. J. of Application or Innovation in Engineering & Management, 2(6) (2013) 91–93.
[17] A. Mazumdar, Consolidation of information, Biogas handbook, General Information Programme and UNISIST, United Nations Educational, Scientific and Cultural Organization, Paris, 1992.