Optimization of Process Parameters to Generate High Quality Biogas from Mixed Organic Wastes

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Highlights

- Acidogenic reactors can generate biogas with 88% H_2 concentration from mixed organic waste.
- Mixed organic waste resulted in improved biogas production (90% CH_4) in a biphasic reactor system.
- High pressure AD with additive in biphasic system eliminates the need for biogas upgradation.

1. Introduction

Anaerobic digestion (AD) or biomethanation is a widely practiced method for the conversion of organic wastes to biogas which can be utilized for combined heat and power applications. AD is a complex microbial process which involves simultaneous activity and requires syntrophic effect of hydrolytic bacteria, acidogens, acetogens and methanogens for the generation of biogas as end product. The composition of biogas in general comprises of 60-62% CH_4, 30-35% CO_2 and other gases. Achieving high-quality biogas with more than 90% CH_4 concentration, to substitute the fossil fuel based compressed natural gas, the biogas has to be upgraded using purification techniques. However, the existing separation and purification techniques are cost-intensive. Therefore, this work develops a comprehensive process strategy involving the latest advancements of AD process for the generation of high-quality biogas directly from the reactor so that the necessity of external purification system can be eliminated. This study further emphasizes on optimizing various aspects of the AD and ensuring that the resultant biogas meets specific criteria for purity, energy content, and stability as per the Indian standards of compressed biogas (CBG). To achieve the aim of CBG quality directly from the reactor, different strategies have been considered in this study. The proposed strategies are high pressure anaerobic digestion (mono and co-digestion), dry anaerobic digestion, addition of materials (nanoparticles, micronutrients of nanoparticles, conductive materials, carbon sources etc.,), development of H_2 producing cultures, development of microbial cultures that are suitable for the conversion of CO_2 and H_2 to CH_4.

2. Methods

Raw material and Inoculum: Mixed organic wastes such as cooked food waste (CFW), cow dung (CD), press mud (PM) and vegetable waste (VW) was used as raw material in the present study. The acidogenic anaerobic mixed microbial consortia (AAMMC) and the methanogenic microbial consortia (MMC) was collected from an anaerobic digester treating food waste in CSIR-IICT and acclimatized with mixed organic waste at mesophilic temperature. To operate the two-stage anaerobic digester, acidogenic inoculum in the acidogenic reactor for H_2 production was developed and enriched in laboratory while the inoculum from an existing anaerobic digester was used in the methanogenic reactor. The AAMMC and MMC was initially characterized for pH, total solids (TS) and volatile solids (VS) which was found to be 6.5 and 7.1; 3.4% and 5.5%; 3% and 5 %, respectively.

Experimentation: Experiments were conducted in varying volumes of reactors demonstrating single and two stage AD as per the design of experiments represented in Figure 1. The substrates CFW (ground paste), PM, CD and VW were collected in required amount and made into slurry by diluting it with water to obtain a desired TS of 12 %. In single stage reactors of 0.5 and 1L, with 250 and 700 mL of active volume respectively, the reactors were inoculated with 30 % of anaerobic inoculum and 70 % of prepared CFW and VW slurry. The proportion of CFW and VW slurry was 1:1. Similarly, in reactors of 20 L volume with an effective volume of 14 L, the reactors were fed with 4.8 L of anaerobic inoculum and the remaining 9.8 L was slurry.

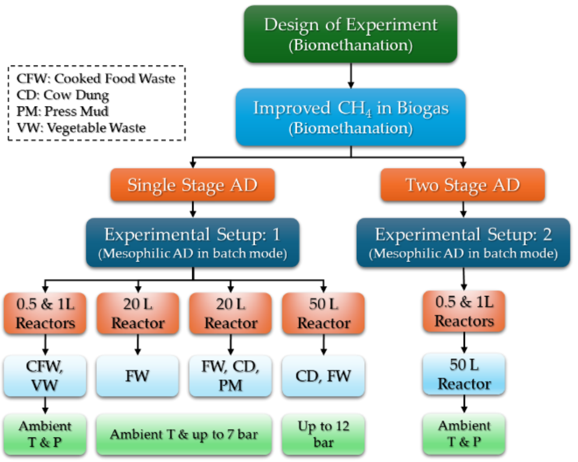

Figure 1. Design of experiments

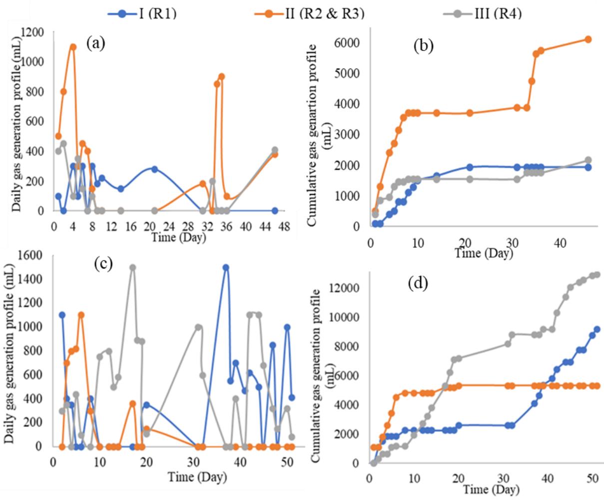

Figure 2. Daily and cumulative gas generation profile

3. Results and discussion

The performance of reactors R1, R2, R3 and R4 in terms of daily and cumulative biogas generation profile, is shown in Figure 2 (a) and (b). It is noted from the figure that the maximum cumulative biogas generation was observed in the interconnected reactor biphasic reactors R2 and R3 with a cumulative generation of 6110 mL and biogas yield of 379 mL/g $VS_{reduced}$ compared to the single phase acidogenic (R1) and methanogenic (R4) reactors. The performance of reactors L, M and N in terms of daily and cumulative biogas generation profile is shown in Figure 2 (c) and (d). It can be noted from the figure that the maximum cumulative biogas generation was observed in reactors L and N. Interestingly, maximum H_2 in gas generated from reactor M (gas produced from acidogenic reactor (L) manually injected)) reached 88 %, this indicates that the addition of BESA to the anaerobic cultures suppresses the activity of methanogens resulting in more H_2 and CO_2. The maximum CH_4 in biogas obtained from reactor N is 74 % at ambient temperature and pressure conditions.

4. Conclusions

The findings from this study illustrate that the maximum H_2 in biogas that can be achieved from single stage acidogenic reactors is 88 %. Further the pressure concept as well as the biphasic experimental set up proved to be promising in achieving improved CH_4 in biogas. Further, the maximum H_2 in gas that can be achieved from single stage acidogenic reactors is 88 %. In contrast, the biphasic reactors with CFW and in VW resulted in improved biogas production qualitatively and quantitatively.

References

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Keywords

Anaerobic Digestion; Biogas; Mixed Organic Waster; Biphasic Reactor