The effect of effective microorganisms-4 (em-4) on biogas yield in solid-state anaerobic digestion of corn stover

L M Shitophyta*, G I Budiarti, Y E Nugroho and M Hanafi
Department of Chemical Engineering, Faculty of Technology Industry, Universitas Ahmad Dahlan, 55191, Yogyakarta, Indonesia

*luksi.mulia@che.uad.ac.id

Abstract. Biogas production from various organic wastes such as corn stover can be used as an alternative fuel. Corn stover is one of the agricultural wastes that are widely generated in Indonesia. It contains cellulose which has the potential to be used as raw material for producing biogas. The biogas production process was carried out in solid-state anaerobic digestion (SS-AD), i.e., a biological process that occurs naturally by a microorganism that breaks down molecules of organic material with a total solid content greater than 15%. This research was aimed to investigate the effect of EM-4 concentration on biogas yield. The volatile solids (VS) reduction was also measured in this study. The results of the study showed that EM-4 concentration had a significant effect on biogas yield (p < 0.05). The positive linear relationship was found between EM-4 concentration and biogas yield. The highest biogas yield of 597.98 L/kg VS was obtained at EM-4 15%. The main source of biogas production during SS-AD of corn stover was the reduction of VS.

1. Introduction
The use of fossil fuels has adverse impacts on environmental conditions such as emissions of greenhouse gases into the atmosphere and the accumulation of carbon dioxide which causes global warming [1]. Renewable energy is being developed to reduce the consumption of fossil fuels. One of the renewable alternatives is biogas [2]. Biogas is operated under anaerobic digestion (AD) which degrades organic materials into methane by microorganisms [3]. The anaerobic digestion process also aids to diminish the emission of greenhouse gases, eutrophication, and exhaustion of dissolved oxygen [4]. Biogas is mainly comprising of methane, carbon dioxide, and slight amounts of other gases that are generated on the fermentation process in the absence of oxygen [5]. The raw materials of biogas can be obtained from agricultural wastes such as corn stover. Corn is available abundantly in Indonesia [6].

Corn stover belongs to lignocellulosic biomass. Solid-state anaerobic digestion (SS-AD) is recommended to produce biogas using biomass with a high total solids (TS) content. SS-AD or dry fermentation is conducted at TS content ranging from 15% to 35% [7]. SS-AD has some advantages such as smaller digester, high solid loading with TS content of 15-35%, free of floating and stratification, and minimum energy for stirring [8]. Nevertheless, a high content solid of lignocellulose on SS-AD can cause an increase in volatile fatty acids (VFA) [9]. VFA accumulation affects the methanogen activity which leads to a process failure [10].

The digestion of lignocellulosic biomass occurs slowly because the microbes that digest biomass only come from the decomposed organic material. Therefore, the inoculum is needed to help the
degradation process. Inoculum is an effective parameter for SS-AD [11]. Inoculum has a role to carry the microbes, the nutrients and the water by recirculation [12]. The improvement of microbial efficiency can be done by adding Effective Microorganism-4 (EM-4). The EM-4 consists of 90% Lactobacillus sp. can accelerate the degradation of organic materials [13]. Hence, this research was aimed to investigate the effect of EM-4 on biogas yield during SS-AD.

2. Material and methods

2.1. Feedstock and inoculum
Corn stover as feedstock was dried and chopped into 1-2 cm then stored at room temperature.

2.2. Solid-state anaerobic digestion
Corn stover and the EM-4 were mixed and loaded into 2 L digester. Water was added to adjust the TS content of 22%. The effects of EM-4 concentration of 0%, 5%, 10%, and 15% were studied on the performance of SS-AD. This research was conducted at room temperature. Biogas volume was measured every 2 days by the water displacement method.

A sequence of biogas production methods can be seen in figure 1.

![Biogas production flow chart.](image)

Figure 1. Biogas production flow chart.

3. Results and discussion

3.1. Effect of EM-4 on biogas yield
Biogas yield was presented as daily and cumulative biogas yield during 30 days of SS-AD. Figure 2 shows, biogas production was started on day 2 for EM-4 of 0%, 5%, 10% and 15% with the biogas yields of 1.55 L/kg VS, 4.55 L/kg VS, 8.52 L/kg VS, and 13.64 L/kg VS, respectively. Biogas yield attained a peak yield on day 12 for all of the EM-4 concentrations. Afterward, biogas production decreased gently until no biogas produced.
Figure 2. Daily biogas yield on variations of EM-4 during 30 days of SS-AD.

As demonstrated in figure 3, biogas production increased with the addition of EM-4.

Figure 3. Cumulative biogas yield on variations of EM-4 during 30 days of SS-AD.

The higher of EM-4 concentrations the greater of biogas yield. This condition happened because more microorganisms were able to degrade a lot of organic materials. Furthermore, EM-4 contains lactic acids which can accelerate the fermentation [14]. The microorganisms in EM-4 can complete a delignification, reduce the degrees of polymerization and cellulose and the hydrolysis of hemicellulose [15]. The highest of EM-4 of 15% produced the highest of biogas yield of 362.39 L/kg VS.

3.2. Effect of EM-4 on pH

Figure 4 compares the pH in the digester before and after digestion. The addition of EM-4 concentrations decreased the final pH values. This state happened because the EM-4 has an acid pH. The lower final pH was observed in the digester with a higher EM-4 concentration.
The pH change at the variation of EM-4.

Figure 4. The pH change at the variation of EM-4.

The final pH was lower than the initial pH because there was a higher acid concentration which leads to a pH drop in the digester [16]. A pH reduction indicated the degradation of organic compounds. At the fermentation step, the pH always dropped because microorganisms converted organic matters into organic acids.

3.3. Volatile Solids (VS) reduction

The volatile solids reduction can be seen in Figure 5. The highest of EM-4 concentration of 15% generated the highest of VS reduction of 34%.

Figure 5. The VS reduction (%) during 30-day SS-AD of corn stover.

The VS reduction represented the number of organic materials that can be converted into biogas by methanogens, so the higher VS reduction, the higher conversion of biogas. In other words, the VS reduction was equal to the biogas yield.

4. Conclusions

The enhancement of biogas yield was observed with an increase of EM-4 of 0% to 15%. The highest EM-4 of 15% generates the highest biogas yield of 597.98 L/kg VS. The VS reduction has a relationship with the biogas yield. The greater VS reduction is equivalent to higher EM-4 concentration. An increase of EM-4 concentration reduces the final pH in the digester.

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References

[1] Darwin, Cheng J J, Liu Z, Gontupil J and Kwon O 2014 Anaerobic co-digestion of rice straw and digested swine manure with different total solid concentration for methane production Int J. Agric. Bio.l Eng. 7 79–90

[2] Winquist E, Rikkonen P, Pyysainen J and Varho V 2019 Is biogas an energy or a sustainability product? - Business opportunities in the Finnish biogas branch J. Clean. Prod. 233 1344–1354

[3] Liu Y, Fang J, Tong X, Huan C, Ji G, Zeng Y, Xu L and Yan Z 2019 Change to biogas production in solid-state anaerobic digestion using rice straw as substrates at different temperatures Bioresour. Technol. 293 122066

[4] Kainthola J, Kalamdhad A S and Goud V V 2019 A review on enhanced biogas production from anaerobic digestion of lignocellulosic biomass by different enhancement techniques Process Biochem. 84 81–90

[5] Alkhalidi A, Khawaja M K, Amer K A, Nawafleh A S and Al-safadi M A 2019 Portable biogas digesters for domestic use in Jordanian Villages Recycling 4 1–10

[6] Shitophyta L M and Maryudi 2018 IOP Conf. Ser: Mater. Sci. Eng. vol 345 (Riau: IOP Publishing) p1–6.

[7] Kougiас P G and Angelidaki I 2018 Biogas and its opportunities — A review Front. Environ. Sci. Eng. 12 1–12

[8] Zhou Y, Li C, Nges I A and Liu J 2017 The effects of pre-aeration and inoculation on solid-state anaerobic digestion of rice straw Bioresour. Technol. 224 78–86

[9] Ning J, Zhou M, Pan X, Li C, Lv N, Wang T, Cai G, Wang R, Li J and Zhu G 2019 Simultaneous biogas and biogas slurry production from co-digestion of pig manure and corn straw: Performance optimization and microbial community shift Bioresour. Technol. 282, 37–47

[10] Rouches E, Escudie R, Latrille E and Carrere H 2019 Solid-state anaerobic digestion of wheat straw: Impact of S/I ratio and pilot-scale fungal pretreatment Waste Manag. 85 464–476

[11] Zhang J, Luo W, Wang Y, Li G, Liu Y and Gong X 2019 Anaerobic cultivation of waste activated sludge to inoculate solid state anaerobic co-digestion of agricultural wastes: Effects of different cultivated periods Bioresour. Technol. 294 122078

[12] Suksong W, Mamimin C, Prasertsan P, Kongjan P and Thong S O 2019 Effect of inoculum types and microbial community on thermophilic and mesophilic solid-state anaerobic digestion of empty fruit bunches for biogas production Ind. Crops Prod. 133 193–202

[13] Irawan D and Suwanto E 2016 Pengaruh EM4 (Effective Microorganisme) terhadap produksi biogas menggunakan bahan baku kotoran sapi TURBO 5 44–49

[14] Sanjaya I G M 2012 Biokonversi Sampah Organik Pasar Menjadi Biogas Menggunakan Starter Effective Microorganisms ( EM4 ) Sains dan Mat. 1 17–19

[15] Herawati D A and Wibawa A A 2010 Pengaruh Pretreatment Jerami Padi pada Produksi Biogas dari Jerami Padi dan Sampah Sayur Sawi Hijau Secara Batch J. Rekayasa Proses 4 25–29

[16] Shitophyta L M, Budiyono and Fuadi A M 2015 B Int. Conference of Chemical and Material Engineering(IICCME) (AIP Publishing) vol 1699 pp. 1–8