

POTENTIAL OF LIVESTOCK MANURE FOR COAL ACTIVATION

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ABSTRACT

The natural methane formed by bacteria in anaerobic conditions is known as biogenic gas. Gas trapped in coal, formed through thermogenesis as well as biogenesis known as coal-bed methane (CBM). The availability of organic material as decomposition of this material into methane is continuously required for the production of methane in the coal aquifer. The aim of this research was to investigate whether or not cattle feces bacteria were able to grow and produce methane in coal. Parameters measured were Volatile Fatty Acids (VFA) and the production of biogas, such as nitrogen, hydrogen, carbon dioxide, and methane. Explorative method was used and data obtained was analyzed by descriptive approach. The results showed that the bacteria found in the feces survived in the coal and produce biogas. On day 2 when the process was at the acidogenesis phase, it produced VFA with the largest component of acetic acid. Acetic acid would undergo decarboxylation and reduction of CO₂, followed by reactions of H₂ and CO₂ to produce methane (CH₄) and carbon dioxide (CO₂) as the final products.

Key words: Methane, CBM, bacteria, livestock feces

INTISARI

Metana yang secara alami terbentuk oleh bakteri dalam kondisi anaerobik dikenal dengan nama gas biogenik. Gas yang terperangkap dalam batubara, terbentuk melalui thermogenesis serta biogenesis dikenal dengan gas metana batubara (GMB). Ketersediaan bahan organik sebagai bahan dekomposisi metana diperlukan secara terus menerus untuk produksi metana di akuifer batubara. Tujuan dari penelitian ini adalah untuk mengetahui apakah bakteri feces ternak dapat tumbuh dan menghasilkan metana dalam batubara. Parameter yang diukur adalah *Volatile Fatty Acids* (VFA) dan produksi biogas, diantaranya nitrogen, hidrogen, karbon dioksida, dan metana. Metode eksploratif digunakan dan data yang diperoleh dianalisis dengan pendekatan deskriptif. Hasilnya menunjukkan bahwa bakteri yang ditemukan di feces ternak dapat bertahan di batubara dan menghasilkan biogas. Pada hari ke 2 pada fase acidogenesis, VFA yang dihasilkan memiliki komponen asam asetat terbesar. Asam asetat akan mengalami dekarboksilasi dan reduksi CO₂, diikuti oleh reaksi H₂ dan CO₂ untuk kemudian menghasilkan metana (CH₄) dan karbon dioksida (CO₂) sebagai produk akhir.

Kata kunci: Metana, CBM, bakteri, kotoran ternak

INTRODUCTION

Biogas in general consists of methane (CH₄), carbon dioxide (CO₂), hydrogen (H₂) and small amounts of other gases. Methane (CH₄) is a gas that can be used as an alternative and environmental friendly energy source. Recently, non-conventional energy sources, such as coal-bed methane have been widely utilized. In Indonesia, several types of coal, namely Anthracite, Bituminous, Subbituminous, and Lignite have been utilized as sources of energy (Tim Kajian Batubara Nasional, 2006). Lignite found in the largest number has low heating characteristic. In order to sustain its utilization, this material need to be further processed by using methane-forming microbes (methanogens) derived from cattle feces in a digester scale. Methanogens, especially methanogens

fermenting cattle's manure, obtain their nutrition from manure which contains macronutrients, such as carbon, hydrogen, nitrogen, oxygen, phosphate and sulphate needed in large quantities by these microbes. Manure also contains micronutrients, such as Fe, Zn, Bo, Mn, Cu and Mo which are needed by the body in small amounts. In the engineering process, the methanogen obtain their nutrients from artificial media in accordance with the need to grow and gas production. Cattle feces still contain microorganisms which can be reduced over anaerobic degradation or biogas process to prevent environmental pollution. It is an alternative source of organic material that can be utilized to maintain the continuity of coal-bed methane production. Coal-bed methane (CBM) is a natural gas (hydrocarbons) with methane as the main element, occurs naturally in coal forming process. Coal

Tabel 1. Average Volatil Fatty Acid

Sample	C ₂	C ₃	iC ₄	nC ₄	iC ₅	nC ₅
Bbkf-1	21.29 ±10.24	6.72±3.87	1.37±0.82	4.51±2.76	2.20±1.35	0.78±0.26
Bbkf-2	17.14±9.35	3.52±1.82	1.97±1.28	5.61±3.46	1.98±1.16	0.76±0.43
Bbkf-3	22.18±11.97	2.62±1.09	1.67±0.97	4.81±3.12	1.86±0.82	0.65±0.32

Note : Bbkf-1, Bbkf-2, and Bbkf-3: coarse coal + mixture of cattle feces and water (triplication) obtained from Hungate tube.

has pores through which the gas flows. Coal fractures formed as a result of dehydration and tectonic pressure will accompany the coal maturation process (Saghafi, 2001; Karimi, 2005). The purpose of this research was to investigate whether or not the cattle feces bacteria were able to grow and produce methane in coal.

MATERIALS AND METHOD

This preliminary study was conducted in order to acquire bacterial consortia with the ability to activate coal and produce methane from livestock wastes, such as cattle feces. Cattle feces were utilized as bacteria sources, while coal was utilized as microbial culture media. Coal used for activation was a mixture of subbituminous and bituminous in two forms, namely fine and coarse coal. Exploratory study with descriptive approach was used in the study, with treatments of: fine coal + water (Bbh); fine coal + mixture of cattle feces and water (Bbhf); coarse coal + mixture of cattle feces and water (Bbkf); and coarse coal + water (Bbk). These treatments were placed in 3 different digesters, namely 30 ml Hungate tube, 600 ml bottles, and 30 liter drums with triplicates. Each treatment is using ratio of 1:1 based on its digester optimal capacity, for example in drums: 10 kg coal in 10 kg of water and cattle feces mixture. The parameters measured were biogas production including nitrogen, hydrogen, carbon dioxide, and methane. Observations on the formation of volatile fatty acids (VFA) using GC were also conducted from Hungate tube on the day 2 with triplicates.

RESULTS

The biogas formation process in digesters occurred in three stages, namely Hydrolysis, Acidogenesis, and Methanogenesis. In the hydrolysis stage, complex molecules are degraded into simpler molecules. This will be followed by acid production by bacteria which modify short compound produced in the hydrolysis phase into simple organic acids such as acetic acid, H₂ and CO₂.

Table 1 show the average acetic acid production which is higher than other volatile fatty acids, suggesting that the potential for methane formation is very high or about 70% of methane is formed from acetic acid, while the remaining is formed from hydrogen and carbon dioxide. The average % mol of hydrogen produced in the digesters is shown in Table 2.

Tabel 2. Average H₂ Production in Several Digesters (% Mol)

Treatment	Hungate Tubes	Digester 600 ml	Digester 30 litre
Bbhf	-	0.0276±0.0165	-
Bbkf	-	0.5911±0.0135	2.33±0.28
Bbk	-	-	1.23±0.15
Bbh	-	0.7076±0.9256	-

Note:

Bbhf = fine coal + mixture of cattle feces and water
 Bbkf = coarse coal + mixture of cattle feces and water
 Bbk = coarse coal + water
 Bbh = fine coal + water

The digesters were also found to produce CO₂ and N₂ and the average amounts of these gas produced in each digester are presented in Table 3 and 4, respectively.

Tabel 3. Average CO₂ Production in Different Digester (% Mol)

Treatment	Hungate Tubes	Digester 600 ml	Digester 30 litre
Bbhf	0.23149±0,05876	26.5847±7,6633	-
Bbkf	0.26046±0,07163	28.178±8,3571	38.75±2,99
Bbk	0.2528±0,00541	3.495±0,6594	1.84±0,77
Bbh	0.38600±0,10770	2.9931±0,6816	-

Note:

Bbhf = fine coal + mixture of cattle feces and water
 Bbkf = coarse coal + mixture of cattle feces and water
 Bbk = coarse coal + water
 Bbh = fine coal + water

Tabel 4. Average N₂O Production in Different Digesters (% Mol)

Treatment	Hungate Tubes	Digester 600 ml	Digester 30 litre
Bbhf	0.9499±0,02118	26.0906±22,37	-
Bbkf	0.10004±0,00369	25.2413±17,33	14.02±9,58
Bb+water	0.09689±0,04865	96.3597±0,71	97.73±0,86
Bb+water	0.06966±0,023155	95.167±1,92	-

Note:

Bbhf = fine coal + mixture of cattle feces and water
 Bbkf = coarse coal + mixture of cattle feces and water
 Bbk = coarse coal + water
 Bbh = fine coal + water

The averages methane production in various digesters observed in this study are shown in Table 5. Treatment of mixture of fine coal and cow feces (Bbhf) showed methane production in all digester. It means methanogenic bacteria grew in coal media and produce methane.

DISCUSSION

Methane is mostly formed by acetic acid accounted for 70%, while the remaining is formed by hydrogen and carbon dioxide. Table 1 shows higher production

Tabel 5. Average CH₄ Production (% Mol)

Treatments	Hungate Tubes	Digester 600 ml	Digester 30 litre
	%Mol-----		
Bbhf	0.0210±0,01935	47.2971±14,6953	-
Bbkf	0.0284±0,01107	45.9896±8,5612	43.64±10,01
Bbk	0.0263±0,0085	1.1323±0,7580	-
Bbh	-	0.1452±0,0482	-

Note:

- Bbhf = fine coal + mixture of cattle feces and water
- Bbkf = coarse coal + mixture of cattle feces and water
- Bbk = coarse coal + water
- Bbh = fine coal + water

of acetic acid than other volatile fatty acids which suggested the potential for methane formation. This stage has been considered as a significant factor that determines the speed of biogas production (Simamora, 1989). The bacteria that play a role in the acidogenesis stage are acidogenic bacteria, such as *Syntrophomonas wolfei*. These acidogenic bacteria produce acetic acid, propionic acid, butyric acid, hydrogen, carbon dioxide and small amount of formic acid, lactic acid, valeric acid, methanol, ethanol, butanediol, and acetone. Organic acids that are critical to methane production in methanogenesis is volatile fatty acids (VFA), which has been utilized to observe the performance of anaerobic digestion process (Dong-Jin *et al*, 2015; Liet *et al*, 2011; Raposo *et al*, 2009).

Hydrogen is needed by bacteria in the decomposition of organic matters during acidogenesis stage. Bacteria produce acids which modify H₂ and CO₂ into simple organic acids for methanogenesis (Wilkie, 2005). Methanogenic bacteria utilize H₂ produced by Protozoa and convert it into CH₄ (Kurihara, *et al*. 1978). No O₂ was detected in all treatments, indicating that anaerobic fermentation process occurred.

Carbon dioxide (CO₂) is the second largest gas from biogas. It is generated from bacterial activity in anaerobic process of organic matter decomposition (Ferry, 2015). In this research, carbon dioxide was needed by methanogens to support their growth, because in methanogenesis phase, carbon dioxide became important in the production of methane when other components in biogas formation depleted. Carbon, nitrogen, phosphorus, and sulphur are macronutrients that support the growth of microorganisms in the methane formation. CO₂ produced from decarboxylation of acetate will react with H₂ and produce methane (CH₄) and carbon dioxide (CO₂) as the final products (Szuhaj, 2006).

In coal-water mixture (Bb), N₂ dominated biogas composition, indicating that the stage occurred in this mix was still the hydrolysis stage. Decomposition of nitrates, nitrites or denitrification normally occurred in this hydrolysis stage. In this study, the outcome nitrogen did not meet the standards of biogas composition. This indicated that all stages were not completed. If nitrogen content is high, it would be consumed very quickly by methanogenic bacteria to meet their protein requirements, so that it will no longer react with residue of

organic carbon. This resulted in inhibition of methane production and led to reduced methane levels.

In methanogenesis stage, methanogenic bacteria slowly form methane in anaerobic conditions. The biogas formation lasts for 14 days at a temperature of 25°C in digester (Wiratmana *et al.*, 2012). Several bacterial genera involved in methanogenesis stage include *Methanobacterium*, *Methanothermobacter*, *Methanobrevibacter*, *Methanisarcina*, and *Methanosaeta* (Moris, 2011). These bacteria produce methane in two ways, namely by transforming acetic acid (about 70%) and about 30% by reducing carbon (Seadiet *et al.*, 2008).

Methane production in digester 600 ml was higher than that in drums. This condition is associated with stirring system where the drum was not equipped with a stirrer, while the Hungate tube and 600 ml digester could easily be stirred manually. In large digesters, stirring become very important. The purpose of stirring is to avoid the solid material from sedimenting on the base of the digesters. Mixing prevents sedimentation of particles, creates homogenous mixtures of substrates, and ensures all materials undergo anaerobic fermentation evenly. In addition, stirring can facilitate the release of gas produced by bacteria into the biogas reservoir. As suggested by Carlos Rica *et al* (2011), stirring systems are still one of the most critical biogas plant components due to floating or sedimenting substances.

CONCLUSION

Based on the results of this study, it can be concluded that anaerobic bacteria derived from feces of cattle can be grown in coal and have potential to produce *coal-bed methane (CBM)*.

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