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Review: Biogas Production from Cow Dung and Its Potential in Indonesia

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ABSTRACT

Cows are ruminant livestock used as a source of food and the economy. Besides that, cows also produce waste, namely cow dung. If cow dung piles up in the open and spreads, it will carry by rainwater to lower places, which can cause soil and air pollution. To reduce cow dung waste can be used as a substrate in an anaerobic digester to produce biogas. Important factors that can affect the biogas rate include pH, temperature, Total Solid (TS) and Volatile Solid (VS) content, and the C/N ratio. The yield of biogas can be optimal with pretreatment and co-digestion. The potential for cow dung can generate electricity of 5,580 kW per day from 18 million head of cattle.

Keywords: *Anaerobic digester, Biogas, Cow dung*

1. INTRODUCTION

Cows are livestock that is raised to meet food sources such as meat and milk. In addition to producing meat and milk, cows also produce cow dung. Cow dung is the solid waste from cattle farming and in the process of disposal, it is often mixed with urine and gases, such as methane and ammonia.

Biogas also reduces methane emissions which would have otherwise escaped from landfills or manure piles. Using this methane as a fuel dramatically reduces its climate impact by converting it to CO_2, which is 34 times less potent as a greenhouse gas.

2. THE CONTENT OF COW DUNG

Discharged cow dung into the environment without treatment will pollute the air, water, and soil, causing pollution. Cow dung is a substrate that is considered the most suitable source of bio-gas production because cow dung (substrate) contains methane-producing bacteria found in the stomachs of ruminant animals (Indra, 2008). The composition of cow dung which has generally been studied can be seen in Table 1.

Table 1. Composition of Cow Dung

Parameters	Composition	Reference
pH	7.35	(El-Haddad, et al., 2014)
Moisture content (%)	60	
Dry matter (%)	40	
Ratio C/N	21.5:1	
Total Solids (%)	11.7	
Volatile Solids (%)	83.7	(Nasir, et al., 2014)
Total Solids (g/L)	108.9	
Volatile Solids (g/L)	91.3	
Ammonia-Nitrogen (g/L)	2,733.3	
Chemical Oxygen Demand (COD)(g/L)	2,654.5	

Cow dung can cause soil, water, and air pollution if not treated or stored well. The higher value of Chemical Oxygen Demand (COD) will decrease the amount of oxygen dissolved in the water because microbes in the process of oxidation or decomposition of organic and non-organic materials require oxygen. The decrease in dissolved oxygen levels will also interfere with the respiration process of aquatic organisms. Dissolved oxygen levels in the waters are strongly influence by aeration process. Aeration is the process of transferring oxygen to water. The process will be disrupted if the water turbidity is too high. High turbidity will disrupt the oxygen regeneration process in groundwater due to blocked sunlight, so the photosynthesis process is inhibited (Saputra, 2017) and pathogenic microorganisms, namely Salmonella sp. will affect health.

In addition, cow dung left in the open produces gases includes ammonium, hydrogen sulfide, CO_2, and CH_4. These gases, apart from being greenhouse gas, also cause unpleasant odors and human health problems (Widyastuti et al., 2013). Therefore, processing cow dung is needed, so it can be useful and not generate problems for the environment and health.

3. MASS BALANCE

A cow with a weight of 454 kg can produce 30 kg of feces and urine waste every day (Fathurrohman, et al., 2015). A high potential for animal dung waste is because the average production of beef cattle dung in Indonesia is 25 kg per head per day. With a population of beef cattle in 2013 of 16607000 heads, it will produce 415175 tons of fresh animal dung per day (Peraturan Menteri Pertanian Republik Indonesia, 2011).

In research (Wahyuni, et al., 2018) Manures which produce by two cows can result on average is 0.4 m3 biogas/day and equivalent to electrical energy equal to 1.88 Kwh/day. The potential for gas produced and the conversion of biogas into energy are listed in Table 2.

Table 2. Conversion of biogas into other energy

No	Utilization	Energy 1m^3 biogas
1	Ligthting	Lamp of 60-100 watt for 6 hours
2	Cooking	Cooking 3 recipes of food for 5-6 people
3	Horse Power	Running a motorcycle 1 hp for 2 hours
4	Electricity	4.7 Kwh electric energy

4. BIOGAS

One of the alternative energy is the utilization of biogas energy. Biogas can be categorized as bioenergy, because the energy comes from biomass. Biomass is a relatively young organic material derived from living things or cultivated products and industrial wastes (agriculture, plantations, forestry, animal husbandry, and fisheries). Disadvantages of biogas are biogas goes through many refining processes and yet contains a number of impurities, biogas is unstable, and not attractive on large scale (Bhardwaj & Das, 2017)

Biogas contains methane (CH_4) as the main product, carbon dioxide (CO_2) as the main by-product, and small amounts of other gases (such as carbon monoxide (CO), hydrogen (H_2), ammonia (NH_3), hydrogen sulfide (H_2S), etc.) (Karellas, et al., 2010). The percentage of gas in biogas depends on the biogas feedstock. Existing biomass such as kitchen waste, cow dung, crop waste, and residues or organic waste from industrial and municipal wastes contribute to several potential sources for biogas generation. AD's main products are biogas and slurry. Biogas has been declared an alternative to gasoline and diesel.

5. STAGES OF BIOGAS FORMATION

The process of anaerobic digestion proceeds through four successive stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. The process of anaerobic digestion depends on the interaction between various microorganisms capable of carrying out the four stages (Verma, 2002) as shown in the Fig. 1.

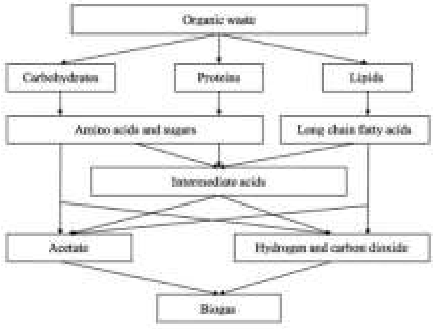

Fig. 1. Stages of biogas production process (Gupta, et al., 2016)

The initial mechanism in the anaerobic digestion process is hydrolysis. At this stage, there is a breakdown of complex organic compounds that are difficult to dissolve, such as polysaccharides, fats, and proteins into simple molecules that are easily soluble, such as sugars, amino acids, and fatty acids. Certain substrates, such as lignin, cellulose, and hemicellulose, may be difficult to degrade, and inaccessible to microbes due to their complex structure; Enzymes are often added to enhance carbohydrate hydrolysis (Lin et al, 2010). In general, hydrolysis has an optimum temperature between 30-50°C and an optimum pH of 5-7 (Azman, 2016). The hydrolysis process is performed by obligate anaerobic bacteria, facultative anaerobic bacteria. During anaerobic fermentation, energy is produced by fermentation or anaerobic respiration with a terminal electron acceptor other than oxygen, depending on the organism and growth conditions, such as Staphylococci, Corynebacterium, and Listeria (James & C. Jeffrey, 2007).

Acidogenesis is the process of converting simple molecules that are easily dissolved, such as amino acids, sugars, and fatty acids into short-chain organic acids or Short Chain Fatty Acids (SCFA), such as butyric acid and propionic acid. At this stage, the materials formed in the hydrolysis stage, such as sugars, long-chain fatty acids, and amino acids are used as substrates. One of the important products of amino acid breakdown is the production of ammonia from deamination at high enough concentrations, which is known to be an inhibitor of anaerobic digestion (Park, et al., 2014). In addition, if the dissolved sugar content available in the digester has a high concentration, the acidogenesis process can also produce alcohol (Darwin, 2019). The acidogenic stage includes many different fermentative genera and species; among them are Clostridium, Bacteroides, Ruminococcus, Butyribacterium, Propionibacterium, Eubacterium, Lactobacillus, Streptococcus, Pseudomonas, Desulfobacter, Micrococcus, Bacillus and Escherichia (Anderson, et al., 2003).

Acetogenesis is the process of digestion of SCFA into acetic acid. In this process, acetogenic bacteria (acettobacterium sp.) also produce hydrogen and carbon dioxide. The microorganisms used in this stage are homoacetogens that produce acerare using hydrogen and carbon dioxide as substrates and syntropic acetogens that produce acetate and hydrogen through the oxidation of Volatile Fatty Acids (VFA), such as propionate and butyrate.

The final stage in the anaerobic digestion process is methanogenesis. The methanogenesis stage converts the products of the acetogenesis stage (acetic acid, carbon dioxide, hydrogen) into methane gas and carbon dioxide. The formation of methane gas with hydrogen and carbon dioxide by anaerobic microorganisms is called hydrogen methanogenesis. Parameters that affect the growth of methanogenic microorganisms are changes in pH, temperature, oxygen contamination, and other chemical compounds such as ammonia, calcium, and magnesium in the anaerobic digester. These bacteria can only grow and develop at a pH of 6.5-8 (Cheng, 2010).

Anaerobic digestion converts these substrates into biogas, containing about 40-70% methane and other gases, mainly carbon dioxide 25-55%, and traces of nitrogen 0-5%, hydrogen 0-1% and hydrogen sulphide 0-3% (Wellinger, et al., 2013)

6. FACTORS AFFECTING OF BIOGAS PRODUCTION

6.1 Moisture Content

The water content of the substrate affects the anaerobic digestion process. The highest methane yields have been reported at 60-80% humidity (Gashaw, 2014). The process of anaerobic digestion is influenced by the air content. High water content can dissolve organic matter that is easily degraded (Khalid, et al., 2011). In the study (Hernandes-Berriel, et al., 2008), 70% water content produced 83 ml CH_4 per gram of dry matter, while 80% water content produced 71 ml CH_4 per gram of dry matter.

6.2 Total Solid (TS) and Volatile Solid (VS)

Total solids (TS) include organic and inorganic matter. The percentage of volatile solids (VS) present in the substrate is directly proportional to the yield of methane (Moody, et al., 2009). Solid content is the total amount of fermentable substrate present in one unit volume of slurry. Higher dry solids content, especially lignocellulosic content, affects the hydrolysis process (Nizami, et al., 2009).

In research (Orhorhoro, et al., 2017), a high total solid content resulted in decreased biogas production, a content of 10.16% TS with 91.10% VS resulted in optimum biogas production. (Yavini, et al., 2014), 9% TS content resulted in optimum biogas production in each digester of 317.9; 423.2; 542.6 ml. It was concluded that the increase in TS decreased the substrate content which reduced the level of microbial activity so that biogas production decreased.

6.3 C/N Ratio

The C/N ratio is the ratio of the mass of Carbon (C) to the mass of Nitrogen (N) in a substance. If the carbon content is too high, the composting process will take a long time, conversely, if the nitrogen content is too high, the composting process will take place quickly, however, some of the nitrogen will be released/evaporated into the air (Chandra, 2020). Carbon and Nitrogen are macromolecules which have structural and functional roles in bacteria. Carbon such as CO_2 or other organic forms such as glucose are used by microbes as the main constituent of cellular material. Nitrogen such as NH_3, NO_3, N_2 functions as a constituent of amino acids, nucleic acids nucleotides, and coenzymes (Todar, 2020). The C/N ratio of cow dung is 26.50 (Sanjaya, et al., 2015). Optimum C/N ratio of raw materials at 25-30 (Haque & Haque, 2006). C/N ratio of 25:1 compared to a C/N ratio of 15:1 and 40:1 produces the most optimum biogas production, which is 23 cm^3 on day 28 (Widadri, et al., 2019).

When the C/N ratio is too high, the biogas yield is not optimal because acidogenic bacteria consume nitrogen faster than methanogenic bacteria. However, the lack of carbon types causes a decrease in acid formation, nitrogen accumulates in the form of ammonium ions (NH_4) which increases the pH (Yen & Brune, 2007) and adversely affects biogas production.

6.4 pH

The process of hydrolysis and acidogenesis can take place optimally at a pH of 5.5 – 6.5 and the process of methanogenesis can take place at a pH of 6.5 – 8.2. Lime or sodium (bicarbonate or hydroxide) are often added to the digestive tract to raise the pH because methanogenic microorganisms cannot grow and work under acidic conditions. The optimum pH for anaerobic digestion is around 7.2 and 8.2 to produce stable methane gas (Abdelgadir, et al., 2014).

(Nkodi, et al., 2020), concluded that pH affects microbial growth during the anaerobic process. A pH below 6.0 inhibits the activity of methane bacteria, 6.8 is the optimum pH to increase the yield of biogas from cassava peels and cow dung as co-substrates. High pH values lead to instability of anaerobic digestion due to the fast conversion rate of ionized ammonia nitrogen to free ammonia nitrogen. To limit the inhibitory effect of free ammonia nitrogen on the anaerobic digestion process, it is advisable to keep the pH value close to 7 (Rajagopal, et al., 2013). pH influences the chemical balance of NH_3, H_2, S, and Volatile Fatty Acids (VFA) which can inhibit the activity of microorganisms. If the pH value is below 7.0, the yield of methane can be inhibited perhaps because the alkalinity is not sufficient to support the production of volatile fatty acids, inhibiting methanogenic activity (Cerón-Vivas , et al., 2019)

6.5 Temperature

Anaerobic digestion can ideally be carried out at almost any temperature conditions. Anaerobic microorganisms ideally grow and work at temperatures of 30 – 40°C for mesophilic microorganisms (Escherichia coli) and 45 – 65°C for thermophilic microorganisms (Archaea). Thermophilic digester has advantages like exhibiting higher biogas production, pathogen destruction and substrate degradation while mesophilic is much easier to maintain and more stable (Vindis, et al., 2009). Anaerobic digestion at mesophilic temperatures is more stable, microorganisms have greater tolerance to changes in environmental conditions with less energy consumption. While in thermophilic conditions, the degradation process takes place more quickly with large energy consumption. As a result, the growth rate is high, but the mortality rate is higher than in mesophilic conditions (Abdelgadir, et al., 2014).

6.6 Starter

The starter is a supporting part of biogas production. Starters or biological agents are used to accelerate the reforming process of organic matter. The starter commonly used in biogas production is cow's rumen. The presence of bacteria in the large intestine of ruminants helps the fermentation process so that the process of forming biogas in the digestive tank can be carried out more quickly. However, if the dirt will be directly processed in the digester tank, it is necessary to clean it first. The dirt must be clean of straw and other foreign materials to prevent the formation of foam (Sufyandi, 2001).

(Putri, et al., 2012), biogas production from cow manure with the addition of a starter in the form of a rumen ratio of 1:2 produces the most optimum biogas, namely 3500 ml compared to pure cow manure which is only 1000 ml. (Arifan, et al., 2021), 2000 ml of biogas production from cow dung using anaerobic digestion, with the addition of 70% cow dung, 15% chicken manure, and 15% tofu liquid waste increased biogas production to 3251.5 ml. (Mukti, et al., 2021), concluded that biogas made from vegetable waste alone is effective enough to be used as a solution to the energy crisis problem (to replace Liquefied Petroleum Gas (LPG) gas to be precise) because quite a lot of methane is produced. However, if you want to be an innovation for the success of village development, biogas from household waste (vegetable waste) can be used by adding cow manure as the main ingredient. So that methane is produced in large quantities according to the amount of material used.

7. TYPES OF DIGESTER

7.1 Fixed dome digesters

Fixed dome plants are usually called "Chinese" digesters. The fixed dome generator is built underground with the main material being bricks and the top is a gas storage dome shown in Fig. 2. The Chinese fixed dome digester is often the design of choice because of its reliability, low maintenance requirements and long lifetime (Parawira, 2009)

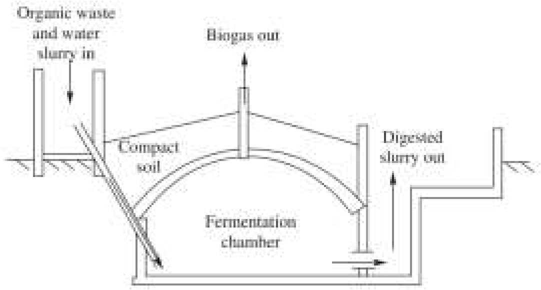

Fig. 2. Fixed dome digesters (Gautam, et al., 2009)

7.2 Plug flow digesters

A plug flow digester is a long, narrow, insulated, heated tank made of concrete, and steel with a lid to capture the biogas shown in Fig. 3. The digesters operate at mesophilic or thermophilic temperatures (Ghosh & Bhattacherjee, 2013). The inlet and outlet of the digester are at opposite ends, mounted on the ground, while the rest of the digester is on the ground in an inclined position. The tilted position allows longitudinal perfection for both acidogenesis and methanogenesis, resulting in a two-phase system. To avoid rise temperatures at night and to maintain process temperatures, a gable or shed roof is installed above the digester which serves as day and night insulation (Rajendran, et al., 2012). Plug flow is designed for low cost and simple maintenance, in addition, this type of reactor is easily damaged, low gas pressure, and not environmentally friendly (Pérez, et al., 2014)

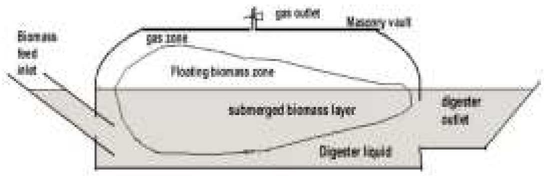

Fig. 3. Plug flow digesters (Chanakya, et al., 2009)

7.3 Floating drum digesters

This type of floating drum digester consists of an underground digester and moving gas holder shown in Fig. 4. This digester structure is separate for gas production and collection (Osei-Marfo, et al., 2018). According to (Bensah & Brew-Hamond, 2010) floating drum digesters are ideal for processing fibrous waste, for example from slaughterhouses, especially cow entrails, because the gas reservoir can be removed to remove the foam that forms at any time.

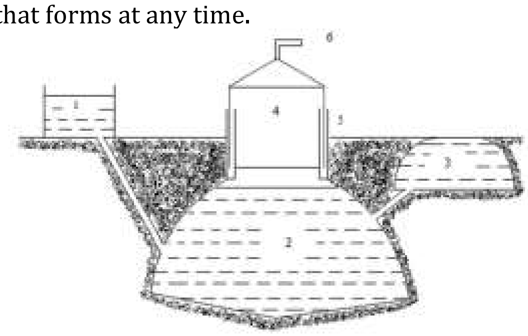

Fig. 4. Floating drum digester 1. Mixing tank with inlet pipe, 2. Digester, 3. Compensation tank, 4. Gasholder, 5. Water jacket, 6. Gas pipe (Arthur, et al., 2011)

8. STRATEGY TO INCREASE BIOGAS

The strategy to increase biogas was carried out because the factors affecting biogas production were not suitable which resulted in a decrease in biogas production. Using several new technologies, the quality of biogas can be improved and the range of applications can be increased (Kougias & Angelidaki, 2018). Technologies that can be carried out include pretreatment which includes physical, chemical, psychochemical, biological, and co-digestion (addition of other substrates) are listed in Table 3.

In physical pretreatment, reducing the particle size can increase the surface area of the biomass. This size reduction can increase the accessibility of the biomass and increase its susceptibility to microbial and enzyme attacks (Abraham, et al., 2020). Chemical pretreatments are classified into acid, alkaline, oxidative, and organosolvent treatments based on the type of chemical being used. Biological pretreatment is an environmentally friendly process compared to chemistry and physics, because it requires less energy and the process is used under mild conditions (Shresta, et al., 2017).

Table 3. Strategies for increasing biogas production

Method	Result	Reference
(Co-digestion) Cow dung - bagasse	The best combination to get the largest volume of biogas (from the first day to the 37th day) is the TS content of bagasse of 2.5%, cow dung of 10%, and water of 30% with a total volume of biogas produced as much as 26.57 L/Kg Substrate.	(Riyanta, et al., 2017)
(Co-digestion) Cow dung and horse dung	Comparison of cow dung (CD) and horse dung (HD), P1: 100% CD and P3: 50% CD - 50% HD P1 biogas production produced biogas of 6.3 L/gVS and P3 had the highest yield of 13.6 L/gVS.	(Alfa, et al., 2021)
(Pretreatment) Thermochemical pretreatment	Using HCl and NaOH with heating temperatures of 100 and 37°C at a certain time. Thermochemical pretreatment with 10% NaOH at 100°C for 5 minutes yielded 23.6% (361 mlCH_4/gVS) higher than control (334 mlCH_4/gVS).	(Passos, et al., 2017)
(Pretreatment) Biological pretreatment	The addition of a single dose of Aquasan® microbes at a dose of 10, 15, and 20 ppm. The yield of biogas with the addition of 15 ppm aquasan increased 55% from the control.	(Singh, et al., 2001)
(Pretreatment) Mechanical pretreatment	Using Mechanical Refining (MR) with particle size reduction, internal delamination, and external fibrillation. The results showed that AD manure with MR at 6k cycle (MR-6k) achieved higher cumulative biogas and higher methane volume and yield than AD unrefined manure (MR control). The cumulative gas volume and yield of MR-6k were 2342 mL and 1110.74 mL biogas/g VS for biogas, and 1289.29 mL and 611.47 mL CH_4/g VS for methane, respectively. Compared to the control MR, the cumulative gas volume and yield of MR-6k increased by 32.02 and 6.35% for biogas and 33.65 and 7.66% for methane, respectively.	(Zeng, et al., 2021)
(Pretreatment) Alkali pretreatment	Biogas production from wheat straw using NaOH (1.6%) at 30°C, 24 hours, methane yield 15% increase.	(Mancini, et al., 2018)
(Pretreatment) Irradiation pretreatment	Using Alkaline and microwave on biogas production from rice straw at 35°C, 66 days. Increase biogas production 25%	(Qian, et al., 2019)

9. BIOGAS POTENTIAL IN INDONESIA

The use of biogas from cow dung in Indonesia has the potential to generate electricity. According to the Central Agency on Statistics Indonesia, the cattle population in 2021 reached 18 million heads (Annur, 2022). With data in 2013, the cattle population reached 16607000 head of cattle, with a total of 415175 tons of dung per day. The total cow dung in 2021 is 450 tons or 450000 kg of cow dung.

In 1 kg of cow dung there is ± 0.24m^3 of biogas, so it can be seen that the potential for biogas in Indonesia is:

$$\textbf{Biogas potential} = \mathbf{0.24} \times \textbf{amount of cow dung}$$
$$\textbf{Biogas potential} = \mathbf{0.24} \times \mathbf{450000}$$
$$\textbf{Biogas potential} = \mathbf{108000m^3}$$

According to (Yulianto, et al., 2010) it is known that 1 m^3 of biogas can generate 1,24 kWh of electricity. so that for 114000000 m^3 of biogas it can generate the energy of:

$$\textbf{Amount of energy} = \textbf{amount of biogas} \times \textbf{energy per m}^3$$
$$\textbf{Amount of energy} = \mathbf{108000\ m^3} \times \mathbf{1.24\ kWh}$$
$$\textbf{Amount of energy} = \mathbf{133920\ kWh}$$
$$\textbf{Amount of energy} = \mathbf{5580\ kW}$$

So, theoretically the potential for biogas in Indonesia is 108000 m^3 with the potential for electrical energy that can be generated of 5580 kW.

10.CONCLUSION

Cow dung waste can be used as a substrate or inoculum for biogas production. Several factors that can affect the yield of biogas production are pH, temperature, Total Solid (TS) and Volatile Solid (VS) content, and the C/N ratio. Several ways to produce good and maximum biogas can be done in several ways, including using pretreatment and co-digestion. In mechanical pretreatment using Mechanical Refining (MR-6K) increased by 6.35%. In co-digestion, biogas production of pure cow dung is 6.3 L/g VS and cow dung + horse dung is 13.6 L/g VS. Indonesian cow dung is used as fertilizer. In addition, biogas from cow dung can be used as a power plant, whereas in Indonesia itself as many as 18 million cows can produce biogas of 108000000 m with potential electrical energy that can be generated of 5580 kW.

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