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Evaluation of the Effectiveness of Corn Water Waste as an Additive in the Production of Cow Dung-Based Biogas Fuel

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ABSTRACT: *Biogas is a renewable energy source produced through the anaerobic fermentation of biomass such as cow dung, and this study investigates the effect of adding corn waste water to cow dung on the quality and quantity of biogas generated. Four treatment compositions were tested: A (cow dung: corn waste water = 1:1), B (1:2), C (1:3), and D (1:1) as a control using water, each repeated three times over a 30-day period. The results showed that composition A yielded the highest biogas volume among the corn waste water treatments at 1168.08 cm³ and the highest methane content at 49.76%, while composition B produced the lowest volume and quality at 791.21 cm³ and 23%, respectively. However, the control composition D outperformed all other treatments, producing the highest biogas volume of 1384.05 cm³ and the highest methane content of 52.82%, indicating that corn waste water may not be an effective co-substrate for enhancing biogas production from cow dung.*

Keywords: *Cow dung, biogas, corn waste, anaerobic fermentation*

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I. INTRODUCTION

As population and economic growth grow, energy demand will also increase. Therefore, alternative energy sources that are environmentally friendly and can be utilized efficiently are needed. This alternative energy source can be processed from livestock industry waste, one of which is cow dung. The cattle farming industry produces significant amounts of waste daily. According to data from the West Nusa Tenggara Province Animal Husbandry and Animal Health Service, in 2021 the cattle population in NTB reached 1,320,551 (Badan, 2022; Aulia, 2022). A cow weighing 454 kg can produce 30 kg of cow dung and urine per day (Fathurrohman, 2015). The sheer volume of cow dung results in a significant amount of waste. This waste can pollute the environment if not properly managed. Cow dung can be processed into alternative energy in the form of biogas. Biogas is a reliable alternative energy source that can be produced from organic materials such as animal manure, dry leaves, organic market waste, household wastewater, food industry waste, and other sources. The amount of biogas produced varies depending on the type of biomass or waste used (Saputra et al., 2023).

Biogas is a flammable gas produced through the fermentation of organic matter by anaerobic bacteria. While all types of organic matter can be processed to produce biogas, only homogeneous organic matter such as livestock manure and urine is suitable for use in biogas systems (Usman et al., 2020). Methane (CH_4) and carbon dioxide (CO_2) are the major constituents of biogas. The concentration of methane (CH_4) in biogas determines its energy content (calorific value). However, to improve the quality of the biogas produced, carbon dioxide (CO_2), hydrogen sulfide (H_2S), and water must be removed (Santoso et al., 2019).

Corn is a crucial commodity in West Nusa Tenggara (NTB). Data from the Department of Agriculture in 2022 indicates that corn production in NTB reached 1,839,898 tons in 2021. This data indicates that corn processing generates significant waste. In Indonesia, corn is used as a raw material for the food and beverage industry, as well as for flour, animal feed, oil, and other industries. Corn cultivation has been intensified in Indonesia to achieve food self-sufficiency (Wulandari and Jaelani, 2019). Corn is often processed into foodstuffs, such as fried corn, corn chips, corn flour, and other products. During this process, corn undergoes a nixtamalization process. Nixtamalization involves boiling corn with an alkali mixture (Zakiyah et al., 2022). The addition of alkali can remove the outer layer (pericarp) of corn (Safitri et al., 2019). The purpose of removing the husk on corn is to make the corn texture crispier and easier to process (Wahyuni, 2011). According to Shubhaneel et al. (2018), corn flour contributes 12% of total flour production where it experiences a growth of 5.5% annually.

The technology currently available in corn flour waste processing is not specific to the characteristics of corn liquid waste which is large in quantity, low pH, and solids that are easily degraded in the environment.

The potential for processing corn liquid waste into biogas is as in the research of Valero et al. (2020) who conducted a laboratory-scale study on the potential for methane gas production from corn liquid waste using the micro aeration method (adding a small amount of air to an anaerobic environment) with a mixture of 30 g/L deep soil, 300 g/L cow manure, 150 g/L pig manure, 1.5 g/L Na2CO3, and 1 L of tap water. The results of the study showed that the micro aeration method increased the percentage of acetic acid and butyric acid for the methanogenic process by 62%. The results of methane production showed a 55% higher methane gas production. The purpose of this study was to determine the effect of the composition of the addition of corn liquid waste on cow dung biogas production based on the quality and quantity of biogas. Corn liquid waste is expected to be able to improve the quality and quantity of biogas from cow dung. There has been no specific research studying the effect of using corn waste water as an additional material in the process of fermenting cow dung to produce biogas, considering that cow dung and corn wastewater are very abundant and have not been utilized by the community.

II. MATERIAL AND METHODS

The initial stage involves preparing the tools and materials to be used. Before mixing according to the specified composition, the pH of the corn wastewater and water is measured. After the pH measurement, cow manure is mixed with the mixture in compositions A, B, and C, with cow manure and corn wastewater in ratios of 1:1, 1:2, and 1:3, respectively. D, with the control variable being cow manure and water, is 1:1. Before being added to the digester, all the mixed substrates must be adjusted to the specified pH of 7. The digester is made from a 5-liter can and filled to 70% of the digester's capacity with substrate. The digester is stored in a room protected from direct sunlight and maintained at ambient temperature. A schematic of the digester can be seen in Figure 1 below.

Figure 1. Preparation of tools and materials for the biogas digester.

The fermentation process was carried out for 30 days and during this time period observations and measurements were made such as: the pH of the substrate before and after the digester, environmental temperature, the volume of biogas produced, and biogas quality testing. Biogas quality testing was carried out by laboratory analysis using a gas chromatograph. Measurement of the volume of biogas produced from the fermentation process can be done using the Archimedes method. Biogas is inserted into a cylinder immersed in water, when the biogas is inserted into the cylinder, the cylinder submerged in water will be lifted according to the mass or volume of the gas, so that the gas volume can be determined by calculating the volume of the lifted cylinder (Anggraeni, 2011).

Figure 2 Biogas quality testing equipment

III. RESULTS

The research process begins with the preparation of a substrate according to the variables, which is then inserted into the digester to undergo an anaerobic fermentation process. Before being inserted into the digester, the pH of the liquid was measured, the pH after mixing, and the pH was controlled to 7.0. Next, after 30 days of anaerobic fermentation, the final pH of the substrate was measured. The results of the pH measurement. The results of the pH measurement on corn liquid waste showed that the liquid was alkaline with a pH value of around 11.8 and the pH of the water was 7.2. After mixing compositions A, B, C, and D, the pH value of the mixture was obtained with a value range of 6.0 - 11.35. In each composition, the pH was adjusted to a fixed value of 7.0 ± 0.1 by adding sulfuric acid (H2SO4) or lime (CaCO3) to all compositions made. At the end of the study, it showed that the substrate of each composition experienced a decrease in pH value, indicating that the substrate conditions in the digester were acidic. The comparison between the average initial pH value of the substrate and the final pH value can be seen in Figure 3.

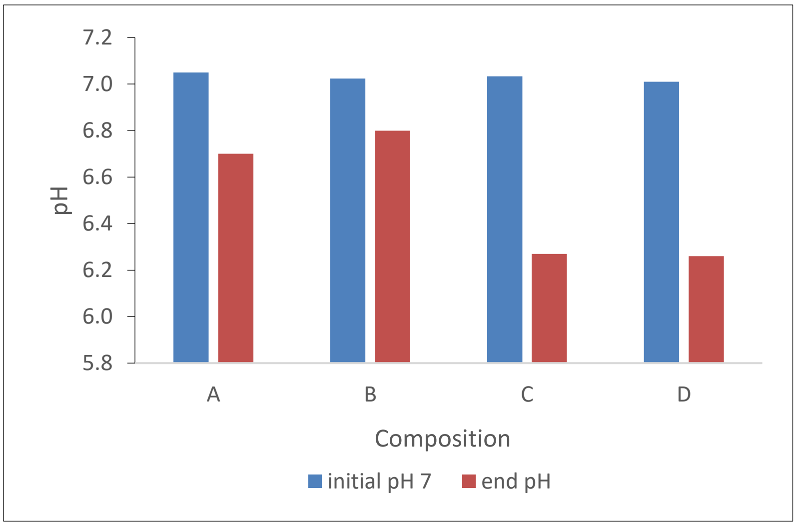

Figure 3. Comparison diagram of initial pH and end pH

In the anaerobic fermentation process, pH significantly influences biogas production. In this study, the initial pH was set at 7, with a tolerance of 0.1. According to Rittman and McCarty (2001), pH regulation in the anaerobic process is crucial, as the desired range for methanogen formation is 5.5 to 7.6. Therefore, the pH value in this study met the requirements for methanogen formation. Research by Yonathan et al. (2013) indicates that at a neutral pH, methanogen-forming bacteria (methanogens) experience optimal growth, thus impacting biogas production. At the end of the study, the pH decreased to 6.2-6.8. The tendency of the material solution to become acidic during the fermentation process is caused by the activity of anaerobic microorganisms that convert complex organic compounds into organic acids. In the initial stages of fermentation, namely hydrolysis and acidogenesis, microbes break down organic materials such as carbohydrates, proteins, and fats into simple compounds such as glucose, amino acids, and fatty acids. These compounds are then converted into various organic acids such as acetic acid, propionic acid, butyric acid, as well as alcohol and gases such as CO_2 and H_2. The accumulation of these organic acids causes a decrease in the pH of the solution, making it more acidic. This decrease in pH is an indicator that the fermentation process is actively underway, but if not controlled, a pH that is too low can inhibit the activity of methanogenic microbes that play a role in the final stage of fermentation, namely methanogenesis. Therefore, pH control is very important to maintain microbial balance and ensure efficient biogas production. This aligns with Rahmalia (2009), who stated that a decrease in pH indicates the degradation of organic compounds in the substrate into organic acids, causing the substrate to become acidic.

During the fermentation process to produce biogas, the pH of the feed solution tends to decrease and become more acidic due to the accumulation of organic acids produced in the early stages of fermentation. At this stage, complex compounds such as carbohydrates are broken down into simpler compounds, then converted into acetic, propionic, and butyric acids, as well as methane, hydrogen, and carbon dioxide gases. The production of these acids causes a decrease in pH, usually to the range of 5–6. Therefore, controlling the pH by adjusting the C/N ratio, adding buffers such as bicarbonate, and separating the fermentation stage into two reactors (acidogenesis and methanogenesis) is crucial to maintaining the efficiency and sustainability of the biogas fermentation process.

3.1 Volume of biogas

Based on the results of biogas measurements, it shows that, for all compositions made, biogas has been produced on the 5th day, where composition A produces the highest volume and reaches its peak biogas production. The highest average volume for compositions B, C, and D was obtained on the 15th day. On the 20th day, biogas production decreased and stopped producing biogas on the 30th day. This is in accordance with the growth phase of microorganisms, where in the initial stage methanogenic bacteria are still experiencing an adjustment stage to environmental conditions such as pH and temperature. In the next phase, methanogenic bacteria experience growth because they consume nutrients contained in the substrate, causing an increase in biogas production. Next, methanogenic bacteria experience a stationary phase, where the amount of biogas production tends to be constant because the number of bacteria that grow is proportional to the number of bacteria that die. In the final phase, methanogenic bacteria experience a lack of nutrition so that the bacteria die, which results in a decrease in biogas production. The growth phase of microorganisms consists of an adaptation phase, a growth phase, a stationary phase, and a death phase (Moat et al., 2002).

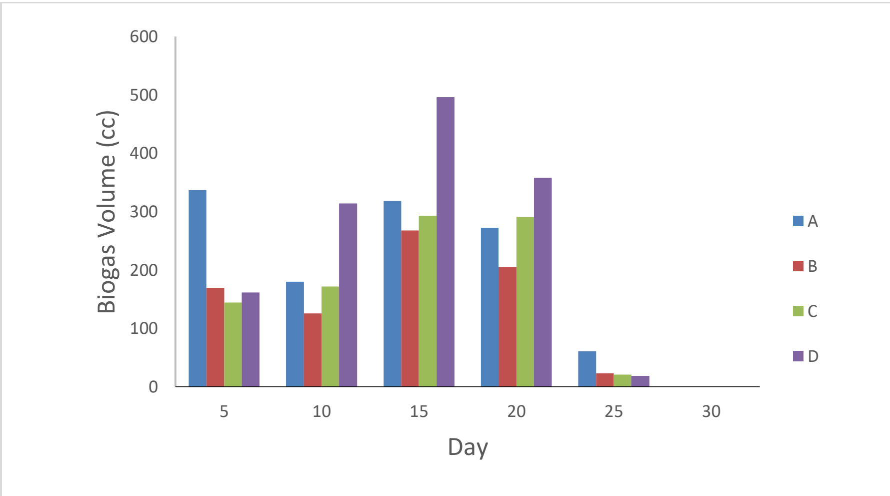

Figure 4. Average biogas volume.

The largest average total biogas production was obtained in composition D, followed by composition A, composition C, and composition B, with values of 1348.05 cm3, 1168.08 cm3, 921.07 cm3, and 791.21 cm3, respectively. Biogas production increased starting from the 5th day and continued until the 20th day. The increase in biogas production in the digester from day 5 to day 20 reflects the active phase of anaerobic fermentation, where microorganisms begin to develop and adapt to the substrate environment. Initially, hydrolysis and acidogenesis occur, where complex organic compounds such as carbohydrates, proteins, and fats are broken down into simple compounds and organic acids. Once the methanogenic microbes become active, methanogenesis occurs, converting acetic acid, hydrogen, and carbon dioxide into methane and carbon dioxide, the main components of biogas. This phase is characterized by an increase in microbial population, pH stability, and sufficient substrate availability, resulting in a significant increase in biogas production. This phenomenon indicates that the fermentation system is in optimal condition, with balanced and efficient microbial interactions in converting organic matter into gaseous energy.

The decline in biogas production after approximately 20 days of fermentation is caused by a reduction in the availability of readily degradable organic substrates, leading to a decline in the activity of anaerobic microorganisms, particularly methanogens. In the initial phase of fermentation, microbes actively break down complex organic matter into organic acids and gases, producing high volumes of biogas. However, over time, primary substrates such as carbohydrates and proteins are consumed, while toxic compounds such as ammonia and organic acids can accumulate and inhibit microbial growth. Furthermore, a decrease in pH, enzyme degradation, and an imbalance in the microbial population contribute to a decrease in fermentation efficiency. This condition indicates that the system has entered the final phase of fermentation, and to maintain biogas production, new substrates or a reset of fermentation conditions are necessary to maintain microbial activity and ensure optimal methanogenesis.

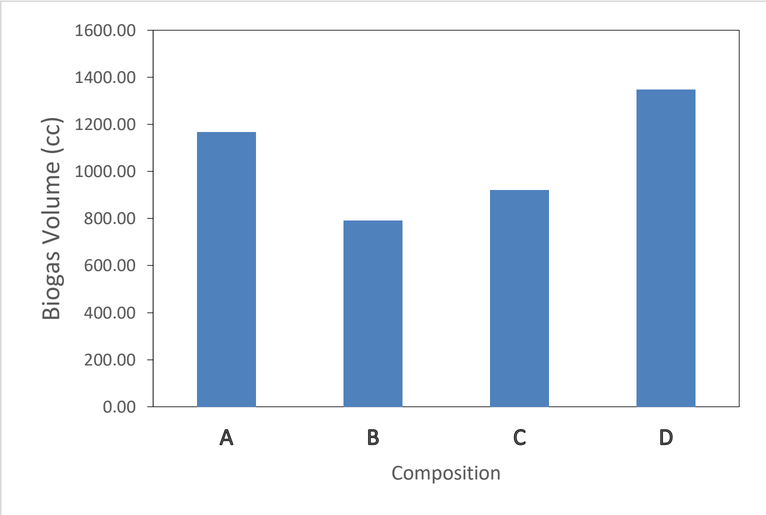

Figure 5. Total average volume of biogas

The average total volume production data shows that there are varying amounts for each composition. This occurs due to differences in fluid addition and the physical properties of the substrates used. This aligns with Mara and Alit's (2011) statement that variations in composition can affect the amount of biogas produced by each substrate. Increasing the amount of corn wastewater in the cow manure mixture can actually reduce biogas production because the chemical composition and fermentability characteristics of corn waste do not support methanogenic microbial activity. Corn wastewater generally has a high lignocellulose content, an unbalanced C/N ratio, and the potential to produce antinutritional compounds or inhibitors such as phenols and organic acids in excess. This imbalance can inhibit the hydrolysis and acidogenesis processes, and cause the accumulation of volatile acids that drastically lower the solution's pH. As a result, methane-producing microorganisms cannot grow optimally, disrupting the methanogenesis process and reducing biogas production. Furthermore, the high-water content and low content of easily degradable organic matter in corn waste reduce the efficiency of converting the substrate into gas. Therefore, the mixing of corn wastewater needs to be proportionally controlled to avoid disrupting the microbiological and chemical balance in the anaerobic digester.

3.2 Quality of biogas

Biogas quality parameters are determined based on methane gas content (%). Based on laboratory testing results using a gas chromatograph, the average methane gas content of cow dung biogas with the addition of corn liquid waste. Laboratory test data show that the percentage of methane gas in compositions A, C, and D has a value that is not much different. Meanwhile, in composition B, the percentage of methane gas has the lowest value. A comparison of the methane content of cow dung biogas and corn liquid waste (A, B, and C) with that of cow dung biogas and water (D), which served as a control, showed that composition D had a higher methane content. This could be due to several factors, one of which is the viscosity of the substrate. According to research by Saleh et al. (2016), if the substrate mixture ratio is too dilute, it can result in a decrease in methane concentration. Furthermore, the addition of nutrients contained in the substrate also affects methane production.

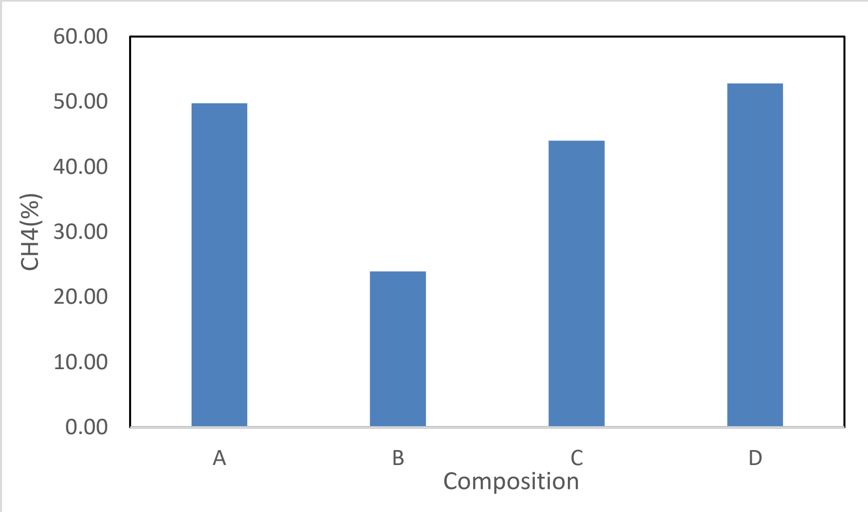

Figure 6. Percentage of biogas (CH_4)

Biogas quality is largely determined by the methane (CH_4) content, which is the primary component and energy source in biogas. The higher the methane content, the better the calorific value and efficiency of the biogas. In the fermentation process, methane content is influenced by several important factors, including the type and composition of the substrate, the carbon-to-nitrogen (C/N) ratio, the ambient temperature and pH, and the presence of active methanogenic microorganisms. Substrates rich in readily degradable organic matter, such as carbohydrates and proteins, tend to produce higher levels of methane. An ideal C/N ratio (around 20–30) supports balanced microbial growth, while a mesophilic temperature (30–40°C) and neutral pH (6.8–7.2) create optimal conditions for methanogenic microbes. Furthermore, sufficient retention time and a stable fermentation system without toxic compounds or inhibitors also play a crucial role in increasing methane production and maintaining overall biogas quality.

The sulfate (SO42-) content in corn liquid waste also influences methane production. According to MeCartney and Oleszkiewicz (1993), sulfate-reducing bacteria will form in a substrate containing sulfate. These bacteria can compete with methanogenic microorganisms involved in the fermentation process, which also utilize hydrogen and acetate in the anaerobic process. Furthermore, during the anaerobic process, sulfate is reduced to sulfide (S2-) by sulfate-reducing bacteria. Sulfide is destructive to various groups of bacteria, thereby inhibiting the activity of these bacteria (Chen et al., 2007).

The decrease in methane gas percentage in biogas fermentation using corn wastewater compared to regular water is caused by the chemical characteristics of corn wastewater that do not support the activity of methanogenic microbes. Corn wastewater generally contains lignocellulosic compounds that are difficult to degrade, an unbalanced carbon-to-nitrogen (C/N) ratio, and the potential to produce inhibitory compounds such as phenols, excess organic acids, and other antinutrients. These conditions can hinder the hydrolysis and acidogenesis processes, and cause the accumulation of volatile acids that drastically lower the pH of the solution, so that methane-producing microorganisms cannot grow optimally. Furthermore, the content of easily fermented organic matter in corn wastewater is relatively lower than in regular water, making the conversion of substrate to methane less efficient. As a result, although the volume of biogas may still be produced, the methane content is lower, reducing the energy quality of the produced biogas.

Based on the analysis process of the effect of adding liquid to the volume (quantity) of biogas obtained, it is known that Fcount (17.99)> Ftable (2.80) on the composition of the filling material, then H0 is rejected and H1 is accepted which there is a real effect of adding liquid on the composition of filling materials A, B, C, and D. In the biogas production results obtained Fcount (128.83)> Ftable (2.41) then H0 is rejected and H1 is accepted which there is a real effect of adding liquid on production results from day 5 to day 30. The hypothesis H0 is rejected and H1 is accepted also occurs in the interaction between the composition of the filling material and biogas production where the value of Fcount (6.75)> Ftable (1.88) which means there is a real effect on the addition of liquid. To find out more about which compositions have a real effect, further tests are carried out using the Duncan test. Based on the data from the results of further test calculations using the Duncan test, it is known that composition A is significantly different from compositions B, C, and D. Composition B is significantly different from compositions A and D, but not significantly different from composition C. Composition C is significantly different from compositions A and D, but not significantly different from composition B. Composition D is significantly different from compositions A, B, and C.

Based on the analysis process of the effect of adding liquid on the CH4 content (quality) of the biogas obtained, it is known that Fcount (43.9042)> Ftable (4.0700) in the composition of the filling material, then H0 is rejected and H1 is accepted where there is a significant difference between the composition of the filling material A, B, C, and D on the quality of biogas from the addition of liquid. Based on the results of the ANOVA calculation which shows a significant difference, to determine which compositions have differences, a further test in the form of a Duncan test was carried out. Based on the further test using the Duncan test, it was found that composition B was significantly different from compositions A, C, and D. Composition C was significantly different from compositions B and D but not significantly different from composition A. Composition A was significantly different from composition B but not significantly different from compositions C and D. Composition D was significantly different from compositions B and C but not significantly different from composition A.

IV. DISCUSSION AND CONCLUSION

Based on the results of the research that has been carried out, several conclusions can be drawn as, the addition of corn liquid waste can affect the quality and quantity of biogas. In the addition of corn liquid waste, the highest volume was obtained by composition A where the volume value obtained was 1168.08 cm3 and the lowest volume was obtained in composition B with a value of 791.21 cm^3. Biogas production on average starts on the 5th day to the 25th day and stops producing biogas on the 30th day, with the highest biogas production on average obtained on the 15th day. Corn liquid waste is not good as an additional material for biogas mixtures because it contains sulfate which can suppress methane gas production. Based on the Anova analysis for the quality and quantity of biogas, it can be concluded that the addition of corn liquid waste has an effect on biogas production from cow dung.

Conflict of interest

There is no conflict to disclose.

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