

Biogas from a Mixture of Banana Stalks and Chicken Manure

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ABSTRACT

The laying hen farming business produces manure that can pollute the environment if not handled properly. Processing laying chicken manure needs to be done to reduce negative impacts on the environment. Biogas technology uses raw materials derived from livestock manure to create a renewable alternative fuel source. The research's goal is to assess the biogas potential of a combination of laying chicken manure and banana stems. This research used a completely randomised design (CRD) with 3 treatments, namely the control (K₁₀₀B₀: 100% chicken manure), treatment 1 (K₇₀B₃₀: 70% chicken manure and 30% banana stems), and treatment 2 (K₅₀B₅₀: 50% chicken manure and banana stems) which are stored in a 30 litre digester for 35 days. The parameters observed in this research were pH, total solids (TS), volatile solids (VS), flame test, and gas volume. The initial and final TS and VS in treatments 1 and 3 indicated that biogas production was higher than the control. Treatments 1 and 2 produced a longer, blue flame with a higher methane content than the control, with T1 of 177.5 and P2 of 665.0 mL. The results of this research indicate the high potential for using laying chicken manure and banana stems as materials for making biogas.

Keywords: Biogas, Chicken manure, Flame, Temperature, Total solids



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1. Introduction

Indonesia's laying hen farming business has grown every year. The population of laying hens in Indonesia is 281,108,407 [1]. Chicken manure contains carbohydrates, protein, fat, and other organic compounds. Protein in chicken manure is a source of nitrogen, which will undergo a decomposition process by microorganisms to form ammonia, nitrate, nitrite, and sulphide gas. This gas causes a pungent odour [2]. The composition of chicken manure varies greatly depending on the type of chicken, age, condition of the individual chicken, and type of food. Indonesian chicken farms have not properly managed their solid and liquid waste, leading to environmental pollution. This is not in accordance with the government's goal of turning livestock into an environmentally sound and efficient business. Improper management of chicken manure can lead to odours, disease, and even death in chickens, while also releasing greenhouse gases like methane [3]. Therefore, optimal processing of chicken manure has the potential to make it a basic ingredient for biogas.

A laying hen has a potential waste of 0.06 kg per day and has a dry matter content of 26%. Chicken manure has a C/N ratio of 13.71 [4]. When used as biogas, the low C/N content in chicken manure exerts an effect. Previous research has shown low biogas production. Therefore, to get high biogas production, organic materials containing carbon (C) are added, such as banana stem waste, which can be used to produce biogas by increasing the C/N ratio content in chicken manure.

West Java province produces 12,040,830 kg of bananas, whereas Bogor district produces 456,136 kg [1]. The Directorate General of Horticulture [5] noted that bananas are one of Indonesia's leading fruit commodities, with a production potential of 34.65% of Indonesia's total fruit production and a harvest area of 100,600 HA. Every year, farmers cut down as many as 100.6 million banana trees. In addition to these benefits, utilizing all parts of the banana stem will undoubtedly enhance its value. Banana stems are an organic material that has the potential to be used as a raw material for making biogas. The composition of banana stems, which contained 46% cellulose, 38.54% hemicellulose, and 9% lignin. Banana stems are agricultural waste that can be used as a raw material for making biogas because they contain potential compounds [6]. The chemical composition of banana stems includes 4.77% protein, 30.85% dry matter, 76.76% organic matter, 46.53% dry matter digestibility, 43.91% organic matter digestibility, liquid pH 6.74%, odour 1.40%, colour 1.50%, mould 1.00%, texture 1.0%, and banana stem ash content of 25.12% [7].

Anaerobic fermentation breaks down organic materials to produce biogas, which burns as methane gas (CH₄). Biogas can be developed for household and industrial needs. Remote areas that do not yet receive electrical energy supplies from PLN are expected to be able to develop electrical energy sources independently by using biogas as an energy source [8]. This research aims to analyse biogas production from a mixture of banana stems and laying hen manure.

2. Materials and Methods

2.1 Materials

The tools used during the research were a digester (30-litre jerry can), scales, thermometer, alcohol, pH metre, analytical scales, measuring cups, furnace, and oven. The materials used during the research were fresh laying hen droppings, banana stems, and water.

2.2 Method

The research began with the preparation of tools and materials, such as making a digester from a 30-litre jerry can. Preparation of ingredients, namely laying hen droppings, banana stems, and water. Chicken manure was taken from the Global Buana laying hen farm in Ciherang, Bogor. Barangan banana stems (*Musa acuminata Linn*) were taken from the Field Laboratory of the Faculty of Animal Husbandry, IPB. Banana stems weighing 12 kg are finely chopped into 2 cm pieces to make it easier to put the ingredients into the digester and to be broken down more quickly by bacteria. Fresh laying hen manure weighing 33 kg is mixed with water and put into the digester along with chopped banana stems. According to the treatment, then the chicken manure, banana stems, and water are stirred in the digester. Figure 1 presents the design of the biogas system.

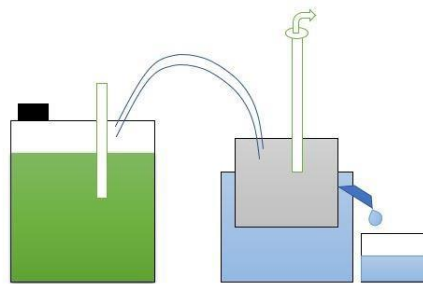


Figure 1. Design digester biogas

2.2.1 Treatment

The research used 3 treatments, control (K₁₀₀B₀) the ingredients are not mixed with banana stems 0% only using 100% laying hen manure, treatment 1 (K₇₀B₃₀) 30% banana stem and 70% chicken manure, and treatment 2 (K₅₀B₅₀) 50% banana stem and 50% chicken manure, and each treatment add water twice the amount of chicken manure and banana stems [9]. Each treatment had 3 repetitions with the composition of chicken manure, banana stems and water as shown in Table 1. 33 kg of chicken manure, 12 kg of banana stems and 90 liters of water.

Table 1. Composition of Filling Ingredients

Treatment	Composition of Filling Ingredients		
	Banana Stem (%)	Chicken Manure (%)	Water (Liter)
K ₁₀₀ B ₀	-	100	30
K ₇₀ B ₃₀	30	70	30
K ₅₀ B ₅₀	50	50	30

The total amount of chicken manure, banana stems, and water needed to make biogas in the research was 33 kg of laying hen manure, 12 kg of banana stems, and 90 liters water. After placing the chopped banana stems in the digester according to each treatment, the chicken manure and water are added and stirred to mix evenly.

2.2.2 Temperature

To determine the temperature in the digester, temperature measurements are required. We take temperature measurements three times a day: in the morning (06.45–07.45 am), during the day (12.00–1.00 pm), and in the afternoon (04.15–05.00 pm). Temperature measurement uses a thermometer. The way it works is that the thermometer is inserted into the pipe hole at the top of the digester, and the unit used is Celsius (°C).

2.2.3 Degree of Acidity (pH)

Measurement of the degree of acidity (pH) is carried out using potentiometers (pH meters). Measurements are carried out every day only in the morning, namely 06.45–07.45 am.

2.2.4 Organic Compound Total Solids (TS) and Volatile Solids (VS)

Total solids (TS) is the amount of organic material in the materials used in making biogas. First, we measure the fresh weight of each ingredient, specifically banana stems and chicken droppings, and then place them in the oven for 24 hours at a temperature of 104°C. Volatile solids (VS) are the amount of organic material in the slurry that is burned or lost at a temperature of 550°C using a furnace for 2 hours after heating in an oven at a temperature of 103–105°C. The Integrated Laboratory of the Department of Animal Production Science and Technology, Faculty of Animal Husbandry, Bogor Agricultural Institute, carried out the determination of total solids and volatile solids. We then measure and calculate the weight of the material that has turned into ash. The following is the calculation of water content, total solids, ash content, and volatile solids.

2.2.5 Volume Biogas

Biogas volume measurements are carried out every morning from the day the ingredients are filled until the 35th day. Daily gas production is measured by measuring the volume of water in a container that has been prepared. The digester connects a smaller, upside-down jar or bucket to a small hose in the digester as a gas bridge, pressurizing the water in the jar as it enters the holding container.

2.2.6 Flame test

The flame test from the digester is carried out by releasing gas through a pipe that has been designed and lit with a match. The digester initiates the flame test once it begins to produce gas. This flame test was carried out to determine whether the biogas produced contains methane or not, so that this research can replace kerosene or LPG gas.

2.3 Data Analysis

A completely randomised design (CRD) will process the data obtained after the study. The data will be analysed using three distinct treatments: Add neither banana stems nor 100% chicken manure (K₁₀₀B₀). Incorporate 30% banana stems and 70% chicken manure (K₇₀B₃₀). Combine 50% stems and 50% chicken manure (K₅₀B₅₀). Each level gets three replications [10]. The data obtained were analysed using analysis of variance (ANOVA) at a confidence level of 95% to determine the effect of the treatment. If six treatments have a significant or very significant effect, the Tukey test is carried out [10].

3. Results and Discussion

3.1 Material Characteristics

Agricultural waste is generally rich in C components but deficient in N, whereas livestock waste is rich in N but deficient in C. So a combination of livestock and agricultural waste is needed. Chicken manure as livestock waste is needed as a source of N in the formation of methane gas; chicken manure has a C/N ratio of 13.71 [4]. The chicken manure used is laying hen manure. Per laying hen has the potential to waste 0.06 kg per day. So far, banana stem waste has been left alone, so if it is not used, it will become a problem, such as polluting the environment and so on. Banana stems contain 27.86% cellulose, 12.08% lignin, 35.95% hemicellulose, and 0.03% glucose. Their high chemical content makes them an excellent combination for chicken manure as a biogas producer, with a C/N ratio of 35.28. Table 2 presents the C/N ratio of chicken manure and banana stems.

Table 2. Ratio C/N

Treatment	Chicken Manure	Banana Stem (%)	Ratio C/N
K ₁₀₀ B ₀	100	0	13,71
K ₇₀ B ₃₀	70	30	20,17
K ₅₀ B ₅₀	50	50	24,49

The C/N ratio is the ratio between carbon and nitrogen in an organic material. Microorganisms use nitrogen and carbon, the two main elements that form organic material substrates, as an energy source during the breakdown process. Anaerobic bacteria will quickly consume a C/N ratio value that is too high to meet their protein needs, preventing them from reacting again when the carbon content remains. A ratio value that is too low will result in the formation of high organic acids. The optimum C/N ratio, according to Dioha, is 20-30. Based on their data, the C/N ratio for each treatment was 13,71; 20,17; and 24,49. The value for each treatment of adding banana stems meets the optimum ratio [11]. A low substrate C/N ratio, if processed anaerobically, can cause ammonification and poison the bacteria in the digester [12]. If the C/N ratio is very low, it causes nitrogen to be free and accumulate in the form of ammonia (NH₄).

3.2 Temperature During Biogas Formation Process

Temperatures are parameters that significantly influence the gas formation process within the system. The anaerobic fermentation process is very sensitive to changes in the digester. Biogas production will decrease rapidly due to sudden temperature changes in the digester. Methanogenic bacteria grow slowly and are sensitive to sudden changes in physical and chemical conditions. Anaerobic bacteria work at mesophilic temperatures (25–40°C, with an optimum temperature of 35°C) or thermophilic temperatures (50–65°C, with an optimum temperature of <55°C). The optimal temperature for producing large amounts of biogas is 51.49-54.44°C [13].

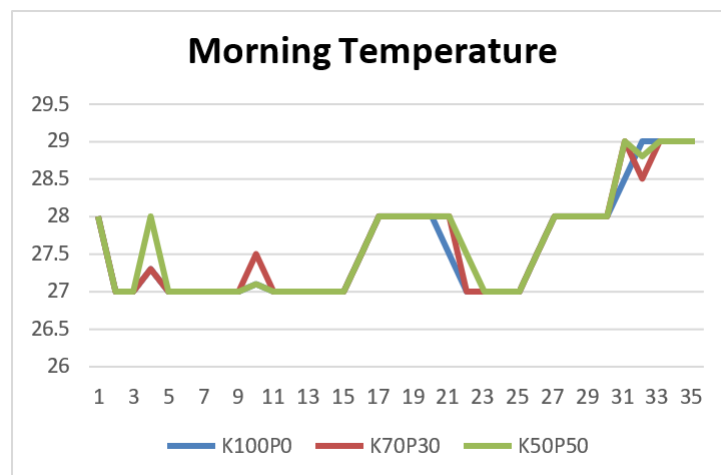


Figure 2. Morning temperature on biogas

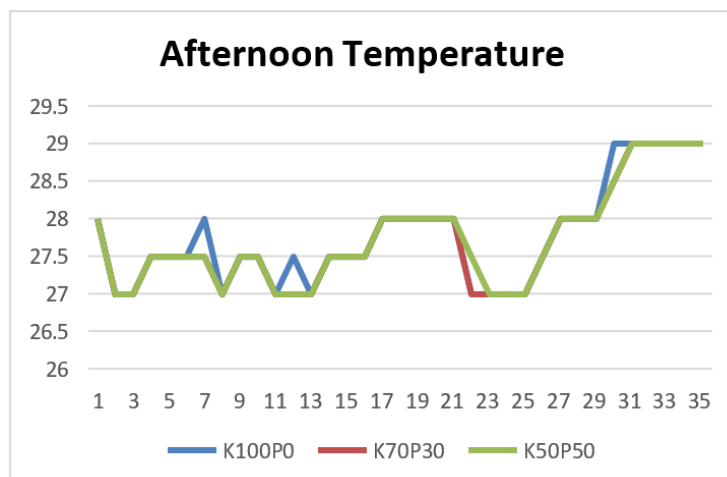


Figure 3. Afternoon temperature on biogas

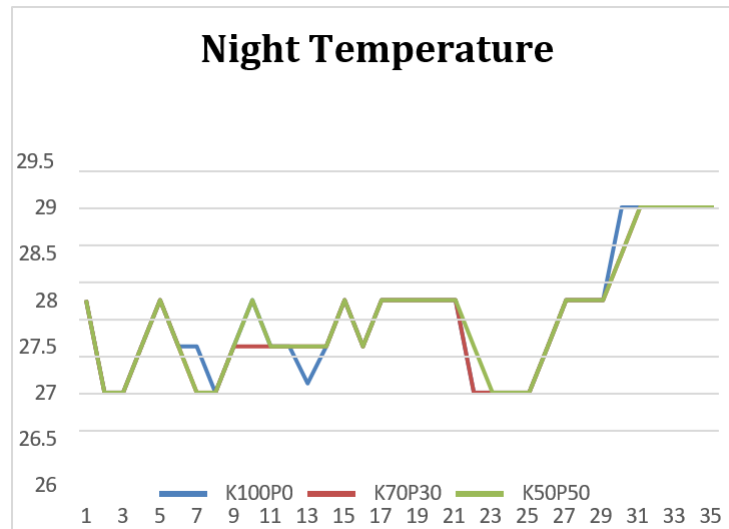


Figure 4. Night temperature on biogas

While the afternoon and evening temperatures are relatively unstable due to the influence of the hot weather outside, the morning temperatures are relatively more stable. The temperature in Figures 2, 3, and 4 began to rise on day 7. The high temperature in the digester was due to bacterial activity. On days 23–35, there is an increase in temperature, but it is still at a mesophilic temperature between 25°C and 30°C. A mesophilic state is a good temperature for biogas. At mesophilic temperatures, the bacteria work well, and the fermentation process runs well, resulting in gas pressure and a neutral pH. During the research, the temperature in the digester remained at a mesophilic level, which was suitable for bacteria growth and the production of stable methane gas. Optimal temperature is one of the influencing factors in biogas production [14].

3.2 Degree of Acidity (pH)

Microorganism activity requires a pH of 6–8. Anaerobic fermentation can work well to produce gas optimally at pH 5-8 [9]. At pH below 6, the activity of methanogenic microorganisms decreases, while acetogenic bacteria that produce acetic acid continue to increase, resulting in decreased gas production. Similarly, a high pH will result in the production of CO₂. Meanwhile, the optimum pH condition is 7.2–8 [15]. The fermentation process creates favorable conditions for bacterial growth at a neutral pH. Only some bacteria live in extreme conditions. The pH value at the beginning of the first treatment shows the process of acidification and breakdown of organic material. This shows that fermentation is still in the acidification stage, where acetogenic bacteria dominate the material decomposition process.

The formation of acetic acid by bacteria is important for the continued production of methane gas in the next process. The initial pH values in the treatments (K₁₀₀B₀), (K₇₀B₃₀), and (K₅₀B₅₀) ranged between 6.1 and 6.5, which occurred because of the process of acidification and breakdown of organic materials. On the 16th day onward, the pH begins to increase, ranging between 6.5 and 7.5. This occurs because the acidification process and biogas production are already underway from day 16 to day 35. The pH value is still stable, and biogas is also producing well.

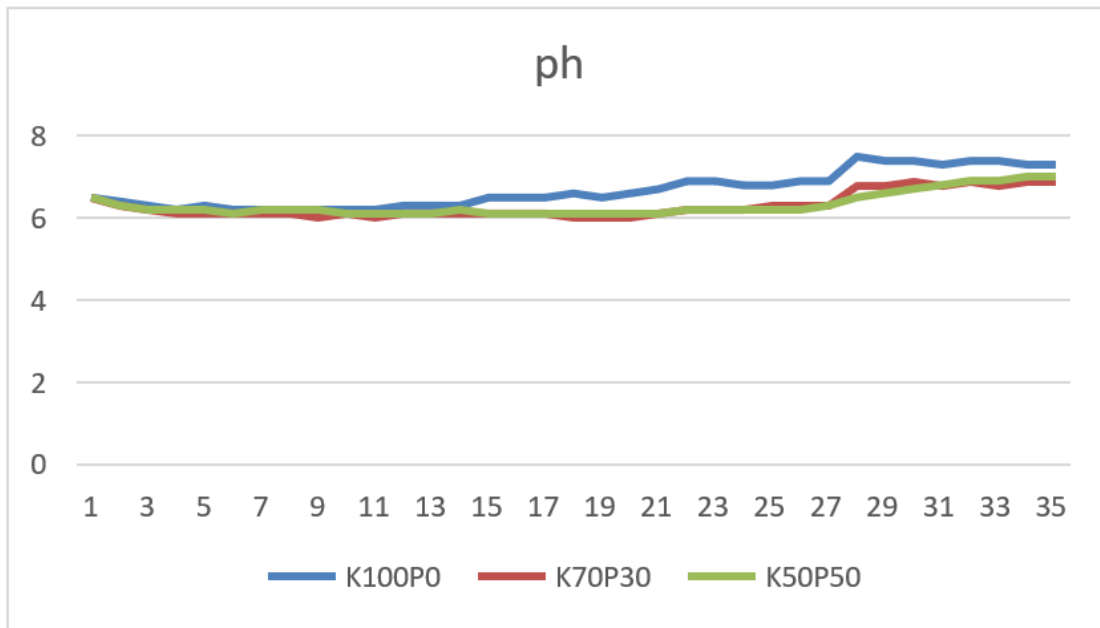


Figure 5. Daily Degree of Acidity

The best pH value in the biogas fermentation process is one where the value decreases. This is because the decrease in pH indicates that the microorganisms working in the initial stage are microorganisms in the acidogenesis process that have very fast growth, thus increasing the acidity level [16]. Each microorganism has a different optimal pH. If the digester contains high levels of volatile acids, methane gas formation will be inhibited by methanogenic bacteria, which cannot thrive at pH levels below 5 [17].

3.3 Total Solid (TS) dan Volatile Solid (VS)

The total solids (TS) factor indicates the presence of a solids degradation process. The amount of TS is presented as a percentage of the raw material. VS is the solid part of TS that changes to the gas phase during the acidification and methanogenesis stages, such as in the waste fermentation process. Volatile solids are an initial indication of the formation of methane gas [17]. Table 3 displays the TS and VS content in this study.

Table 3. Content of Total Solid (TS) and Volatile Solid (VS)

Treatment	Start		End	
	TS(%)	VS(%)	TS(%)	VS(%)
K ₁₀₀ B ₀	9,4±0,003 ^A	6,4±0,008 ^B	3,2±0,093 ^B	1,9±0,133 ^A
K ₇₀ B ₃₀	7,2±0,011 ^B	5,8±0,004 ^C	4,5±0,086 ^B	3,3±0,351 ^A
K ₅₀ B ₅₀	9,4±0,003 ^A	7,3±0,005 ^A	6,6±0,023 ^A	4,2±0,845 ^A

Superscripts with different letters indicate significant differences (P<0.05)

In each treatment, the initial total solids and initial solid volatiles had a high percentage content. After completing the research for 35 days, the final total solids and final solid volatiles showed a decrease in value. This indicates that decomposing bacteria break down organic material. An increase in methane gas production caused a decrease in TS and VS levels. VS is a food source for bacteria that work in the early stages of biogas production. The decrease in VS in the digester is due to bacteria's degradation of organic compounds. Bacteria such as bactericides, clostridia, and facultative anaerobes like streptococcus assist in the degradation process of organic compounds. The optimum total solids for microbes in fermentation to produce optimal methane content is 5% [18]. The increased growth of microorganisms from degraded organic compounds influences TS and VS values [19]. After 35 days of research, the TS and VS values decreased in each treatment (Table 3).

As biogas production increases, the bacteria in the digester gradually achieve balanced growth between non-methanogenic and methanogenic microorganisms [20]. The type of organic material chosen as the raw material for making biogas also influences the length of the decomposition process. Table 4 shows a decrease in both the initial and final TS following the production of biogas. After the biogas digester broke down the organic material, the initial and final VS also decreased [16].

3.4 Biogas Production from a Mixture of Banana Stems and Chicken Manure

One of the factors that influences biogas production is the presence of certain compounds that act as inhibitors. Therefore, it is necessary to add something to the raw material to reduce the factors that influence the inhibitors. The ideal C/N ratio for the anaerobic decomposition process to produce methane is 25–30, whereas in this study, the C/N ratio in K₁₀₀B₀ was 13.71, in K₇₀B₃₀ it was 20.17, and in K₅₀B₅₀ it was 24.49. The study's C/N ratio was far from ideal in anaerobic decomposition. Table 4 displays the biogas production from a mixture of banana stems and chicken manure.

Table 4. Biogas production

Treatment	Volume (ml)
K ₁₀₀ B ₀	177,5 ± 245,7 ^B
K ₇₀ B ₃₀	665,0 ± 63,4 ^A
K ₅₀ B ₅₀	80,7 ± 114,5 ^C

Superscripts with different letters indicate significant differences (P<0.05)

As shown in Table 4, there is a difference (P > 0.05) in the potential for biogas production from chicken manure without banana stems (K₁₀₀B₀), which produces less biogas. Biogas production from chicken manure and banana stems (K₇₀B₃₀) produces more biogas than (K₁₀₀B₀), but biogas production from chicken manure and banana stems (K₅₀B₅₀) is not very high.

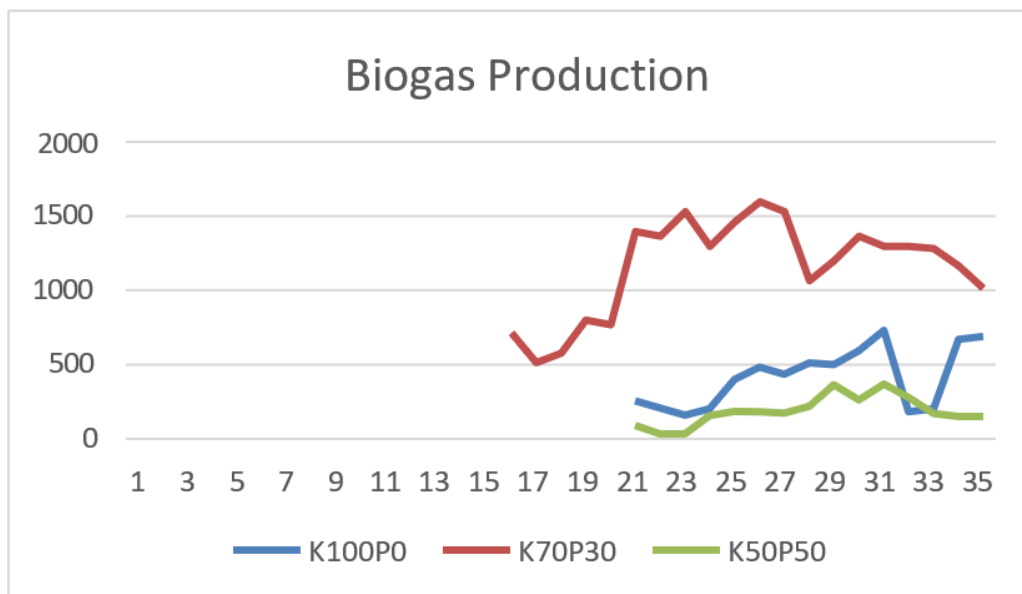


Figure 6. Daily biogas production for each treatment

Day 16 saw the start of biogas production in treatment (K₇₀B₃₀), while day 21 saw the production of biogas in treatments (K₁₀₀B₀) and (K₅₀B₅₀). On day 21, (K₁₀₀B₀) produced the least amount of biogas, (K₇₀B₃₀) produced the most, and (K₅₀B₅₀) produced less biogas than (K₁₀₀B₀) and (K₇₀B₃₀). The growth of methanogenic bacteria in the digester influences biogas production by converting volatile acids into methane, CO₂, and other compounds, ensuring that the rate of methane formation aligns with the growth rate of these bacteria. K₇₀B₃₀ produced the highest biogas production with a C/N ratio of 20.17%, making it an optimal mixture for gas production [21].

3.5 Flame

Use a match to light the biogas flame test. The flame test is carried out after the gas starts to produce. This aims to determine whether the biogas produced during fermentation contains methane gas or not. The results obtained contain methane gas (CH₄) because, when it burns, the flame color is blue. In treatment (K₁₀₀B₀), the fire burned for about 1 minute; in treatment (K₇₀B₃₀), the fire burned for 1-3 minutes; and in treatment (K₅₀B₅₀), the fire burned for 1-2 minutes. The fire burned longer in the treatment (K₇₀B₃₀) due to the different composition of the substrate, which was 70% chicken manure and 30% banana stems. Differences in

material variations and specified concentration variations determine the duration of a fire's burn. Methane gas typically burns blue and produces a lot of heat energy. Research also confirms that methane gas exhibits a blue color and emits flames [22]. Methane gas (CH₄) plays a crucial role due to its relatively high heat content, and anaerobes produce gas that burns and contains 45% methane gas [22]. The anaerobic fermentation stage consists of hydrolysis, acidification, and methanogenesis processes. The flames (CO₂) are blue and yellow in color. There is still burning biogas (CH₄).

This research produces little methane gas. Table 3 displays the biogas volume. Temperature, the amount of CO gas (CH₄), and digester conditions influence the production of low methane gas. The results of the analysis of the influence of the C/N ratio (%) in this study were not very significant, with the C/N content being less than the optimum C/N content. The high C/N ratio (%) affects flame and biogas production. Because there are so many raw materials for making biogas from agricultural and livestock waste, it could be a good alternative energy source that doesn't pollute the environment too much. However, it's important to keep an eye on the water content balance, temperature, C/N ratio, and other environmental factors that affect biogas formation [23].

4. Conclusion and Recommendation/Policy Implication

The production using a combination of chicken manure and banana stems influences the production of the biogas and the flame. Banana stems have the potential to be used as a substrate mixture for making biogas. The addition of up to 30% banana stem composition can be used as a mixture in making biogas.

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