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Effect of Codigestion of Rice Straw, Fish Meal, and Cow Manure on Biogas Production and Quality of Solid Bioslurry Fertilizer

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ABSTRACT

The solid phase bioslurry (sludge) had the potential to be used as organic fertilizer. However, the NPK content in it did not meet SNI standards. This research aimed to study the effect of adding rice straw and fish meal to cow dung substrate for anaerobic processing, on the NPK content of the sludge produced and biogas production. Two digesters were used, which functioned as a control and a codigestion digester. Initially, in both digesters, starter breeding was carried out in batches. After the starter had grew well, then the substrate along with water was fed continuously at 88 mL/day in each digester, and an output of 88 mL/day was also produced. Analysis of COD, sCOD, VFA concentrations, and measurements of the pH values of feed and output were carried out every 3 days. Biogas volume measurements were carried out every day. The process was stopped when conditions were steady. At the end of the process, an analysis of the NPK content in the sludge and the methane content in the biogas were carried out. The results showed that biogas from codigestion content almost no methane. However, the sludge contained NPK within the range of SNI standard.

1. INTRODUCTION

The increase in population causes greater energy needs, energy needs in 2026 will reach 4.5 x 10^{11} kWh in 2026 (Rianawati *et al*., 2021). The use of energy that only relies on fossil fuels can cause a decrease in fossil reserves so that other energy alternatives such as biogas are needed. Biogas is produced by the digestion process of organic compounds under anaerobic conditions, which generally consists of four stages, namely hydrolysis, acidogenesis, acetogenesis and methanogenesis (Kumar *et al*., 2023; Kapoor *et al*., 2020). Biogas consists of 50 – 75% methane (CH_4), 25 – 50% CO_2, and other gases such as N_2, H_2, H_2S, and O_2 up to 100% (Sarker *et al*., 2020). With the main composition of methane, biogas can be used as fuel with the lowest calorific value of around 20 MJ/Nm^3 (Skorek-Osikowska *et al*., 2020).

One of the potential materials for biogas production in Indonesia is cow dung. This is in line with the increase in the cattle population in Indonesia, which has reached around 17.25 million head by the end of 2022 (BPS, 2022). Currently, most small-scale biogas production in Indonesia uses cow dung. Until 2015, around 16 thousand biogas digesters had been built spread across rural Indonesia (Roubík & Mazancová, 2020). One of the villages that has many biogas digesters in Lampung is Kediri Village, which is in Gadingrejo District, Pringsewu Regency. In this village, around 20 fixed dome type digesters have been built with a capacity of 4 m^3, 10 m^3, and 12 m^3 (Damayanti *et al*., 2020).

Apart from biogas, the by-product produced by the digester is bioslurry fertilizer. Utilizing this fertilizer will certainly really help farmers. Bioslurry fertilizer has been widely researched as a raw material for making organic fertilizer (Sogn *et al*., 2018; Yafizham & Sutarno, 2018; Abebe, 2017). The quality of this fertilizer is very good,

considering that the macro and micro nutrient content is suitable for plant needs. Apart from that, bioslurry also contains B vitamins, organic acids, growth hormones and humic acid (Tim Biru, 2014). Moreover, bioslurry has been fermented for a long time (around 2 months), so it is safer to apply directly to land. However, the form of bioslurry, which is a mixture of sludge and quite a lot of water, makes it difficult to apply (Bonten *et al*., 2014; Tim Biru, 2014).

Bioslurry can be separated into solid and liquid phases (Damayanti *et al*., 2022). Solid phase bioslurry contains Nitrogen (N) of 0.24%, Phosphorus (P) of 0.25%, Potassium (K) of 0.95%, Iron (Fe) of 381.51 ppm, Manganese (Mn) of 631 .41 ppm, Copper (Cu) of 9.92 ppm, and Zinc (Zn) of 53.92 ppm. The liquid phase bioslurry contains Nitrogen (N) of 0.03%, Phosphorus (P) of 0.31%, Potassium (K) of 2.46%, Iron (Fe) of 46.65 ppm, Manganese (Mn) of 11.39 ppm, Copper (Cu) at 4.96 ppm, and Zinc (Zn) at 0.99 ppm (Hakim, 2022). From the solid phase bioslurry composition above, it can be seen that the total NPK is 1.44%. This value does not meet the standards for solid organic fertilizer according to Minister of Agriculture Regulation Number 70/Permentan/SR.140/10/2011, where the minimum NPK content in solid organic fertilizer is 2%. Meanwhile, the NPK content in the liquid phase bioslurry is 2.79% and has met the POC standard according to Minister of Agriculture Regulation No: 26/KPTS/SR.310/M/4/2019, namely 2 - 6%. Therefore, it is necessary to carry out research to increase the NPK levels of solid phase bioslurry. Increasing NPK levels can be done by codigestion of cow dung with other organic materials.

One of the materials that is abundant and cheap in Indonesia as a source of nitrogen and potassium is rice straw. Indonesia has the potential to produce 7 – 10 tonnes/ha of rice straw waste (Mandal *et al*., 2004). Rice straw contains nutrients, such as N, P_2O_5, and K_2O (Alhanif *et al*., 2023). Rice straw has an organic C content of around 44.71%, total N of around 1.08%, P reaching 0.17% and K elements reaching 2.7% (Kementerian Pertanian, 2023). To increase nitrogen and phosphorus content, fish meal has the potential to be used. Indonesia is one of the largest fish producing countries in the world with production reaching 24.85 million tons in 2022 (Kementerian Kelautan dan Perikanan, 2022). According to Syukron (2018), fish meal has a nutrient content of 9.63% Nitrogen, 3.26% Phosphate and 0.3% Potassium. The fish chosen are caught fish that have been damaged and are not suitable for consumption (trash fish) so the price is cheap. This research aims to study the effect of codigestion of rice straw, fish meal, and cow dung on biogas production and the quality of the solid phase bioslurry produced.

2. MATERIALS AND METHODS

2.1. Research Location

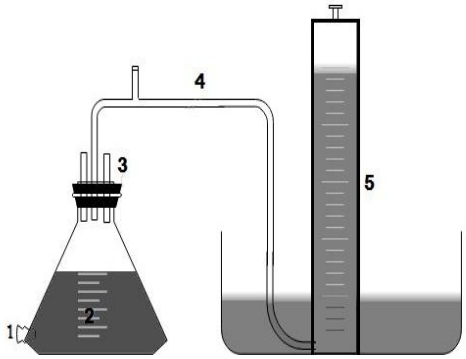
This research was conducted at the Reaction and Separation Engineering Laboratory, Department of Chemical Engineering, Faculty of Engineering, University of Lampung.

2.2. Materials

The materials used were cow dung, rice straw, fish meal, and chemicals for analysis of test parameters. The cow dung used was fresh cow dung, obtained from Kediri Village, Gadingrejo District, Pringsewu Regency, Lampung. The rice straw used was dry straw which was chopped using a chopping machine to a size of 2 - 3 mm, obtained from Kediri Village, Gadingrejo District, Pringsewu Regency, Lampung. Fish meal was made from trash fish that was dried and ground using a disk mill to a size of around 40 mesh, which was obtained from the Fish Auction House (TPI) located in Sukajaya Lempasing, East Betung Bay, Bandar Lampung City, Lampung. Chemicals for analysis included Aquades, Sodium Hydroxide (NaOH) p.a. (Merck), Sulfuric Acid (H_2SO_4) p.a. (Merck), Silver (II) Sulfate (Ag_2SO_4) p.a. (Merck), Acetic Acid (CH_3COOH) p.a. (Merck), $MgSO_4.7H_2O$ p.a. (Merck), Potassium Dichromate ($K_2Cr_2O_7$) p.a. (Merck), Hidrargium Sulfate (Hg_2SO_4) p.a. (Merck), Methyl Orange, Borax, Phenophthalein.

2.3. Equipments

The research equipment was a 5 liter Erlenmeyer flask which had been modified by adding a glass jug at the bottom as an outlet for the product. The top of the Erlenmeyer was closed using a rubber stopper fitted with a glass pipe as an inlet and a gas outlet for the gasometer (biogas production measuring instrument). A schematic of the research equipment was shown in Figure 1.



1. Sludge outlet
2. Digesters
3. Feed entry point (inlet)
4. Hose connecting digester and gasometer
5. Gasometer

Figure 1. The research equipment scheme.

2.4. Methods

2.4.1. Raw Materials Calculation

Determining the amount of raw materials for cow dung, rice straw and fish meal was carried out through calculations based on data on the NPK composition of cow dung, rice straw and fish meal in the reference. A mixture of three ingredients was said to had met the criteria if the NPK content in the mixture of three ingredients had reached 2% or more. The mass ratio of cow dung to rice straw to fish meal was determined as 3:1:1. The mixture of the three materials used in the research was shown in Table 1. The NPK content in material mixture was calculated by summing up NPK amount (kg) and dividing it by total amount of mixture which was 5 kg. This resulted NPK content of 3.34%.

Table 1. The mixture of research materials

Materials	Amount of materials (kg)	% NPK in materials			Amount of NPK in materials (kg)		
		N	P	K	N	P	K
Cow dung	3	0.24	0.25	0.95	0.0072	0.0075	0.00285
Rice straw	1	0.50	0.07	1.20	0.0050	0.0007	0.01200
Fish meal	1	9.63	3.26	0.30	0.0963	0.0326	0.00300
Material mixture	5				0.1085	0.0408	0.01785

2.4.2. Equipment Testing

A leak test was carried out to detect gaps that result in leaks in the biogas digester system during the running process. Leak tests were carried out on the 2 digesters that would be used, namely digester A and digester B. After all the equipment was assembled and the gasometer had been connected to the salt solution, then all open parts were closed. After that, the salt liquid was sucked up to a certain height in the gasometer. This condition was left for 3 days and it was observed whether the salt liquid in the gasometer decreased or not.

2.4.3. Starter Preparation

A starter was made in the biogas digester (Erlenmeyer) A and B. This process was carried out by mixing 1.6 kg of cow dung, 0.8 kg of bioslurry and 1.6 kg water. This process was carried out until the microorganisms were able to reproduce and adapt well in the digester, marked by a decrease in the concentration of Chemical Oxygen Demand (COD), the concentration of soluble Chemical Oxygen Demand (sCOD), the concentration of Volatile Fatty Acid (VFA), and the formation of biogas that entered the gasometer. The start up process was carried out in batches.

2.4.4. Running Process

There were 2 digesters used for running, namely digester A and digester B. Digester A, as a control digester, would be fed continuously with raw materials at a rate of 88 mL/day in the form of cow dung and water with a ratio of 1:1. Meanwhile, digester B would be continuously fed raw materials at a rate of 88 mL/day in the form of 33 g of cow

dung, 11 grams of rice straw, 11 grams of fish meal and 33 ml of water. With this continuous feeding, output would continuously come out of the digester due to overflow. During the process, every 3 days samples were checked in the form of pH, VFA concentration, COD concentration and sCOD concentration. Meanwhile, the volume of biogas produced was measured every day. pH measurement using the Hanna HI 98107 pH meter, VFA analysis using the titrimetric method according to APHA Standard 5560C, COD analysis using the colorimetric method according to APHA Standard 5220D with the HACH Colorimeter DR900, biogas volume measurement using a gasometer according to the method published by Walker *et al*. (2009). The process was stopped when steady conditions were reached, where the pH, VFA concentration, COD concentration and sCOD concentration were relatively constant. After steady conditions were reached, an analysis of the methane content in the biogas was carried out using Shimadzu Gas Chromatography (GC) and an analysis of the NPK content in the resulting solid phase bioslurry.

2.4.5. Data Processing Methods

Analysis of COD and sCOD concentrations was carried out 2 times for each sample. The data presented was the average value of the analysis results. Meanwhile, VFA concentration analysis was carried out once for each sample. pH measurements were carried out 2 times for each sample, so that the data presented was the average value of the measurement results. Daily gas production measurements were carried out once and analysis of methane levels in biogas was carried out once for each sample.

3. RESULTS AND DISCUSSION

3.1. Start Up Period

3.1.1. COD and sCOD Concentrations

The COD value showed the amount of dissolved oxygen needed to degrade all organic materials in the substrate that can be oxidized with strong oxidizing agents such as dichromate or permanganate (Yustika *et al*., 2023). Indirectly, it showed the number of organic compounds, both easily degraded and difficult to degrade, contained in the substrate. If anaerobic digestion was going well, the COD concentration would decrease significantly, which showed that the substrate had been successfully degraded by microorganisms. However, Figure 2 showed that it did not appear that COD had experienced significant decomposition. The decrease in concentration was only visible on the 14th day, because apart from organic substrates, microorganisms were also detected as COD. In fact, as the substrate was increasingly consumed by microorganisms, the microorganisms grew in greater numbers, so it appeared that COD did not decompose. This could be explained by the significant decrease in sCOD concentration as shown in Figure 3.

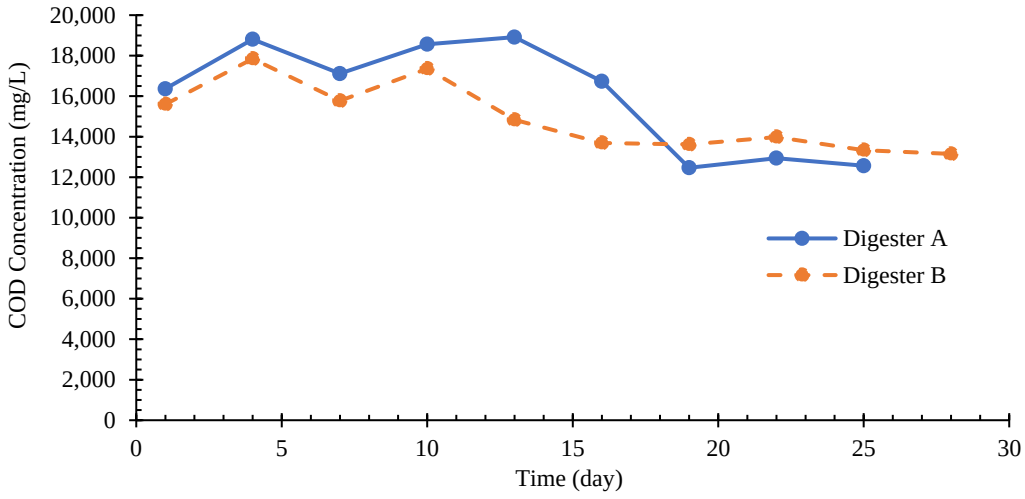


Figure 2. COD concentration during the start up period.

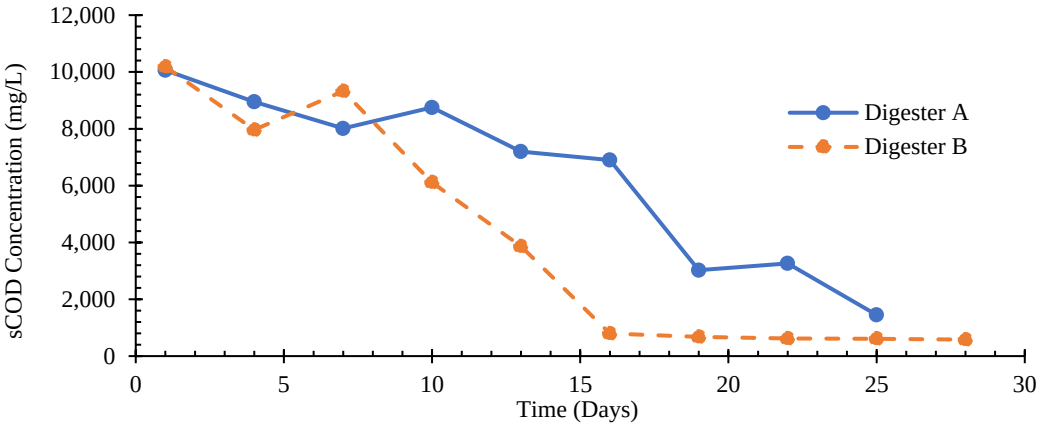


Figure 3. sCOD concentration during the start up period.

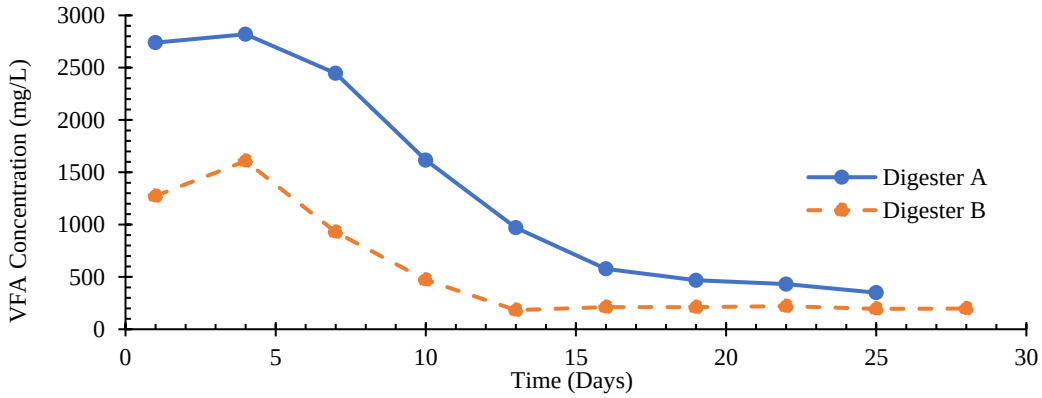


Figure 4. VFA concentration during the start up period.

The sCOD was obtained by centrifuging the sample until the solids were separated. This means that the microorganisms which were one of the constituents of the solid had been successfully separated from the substrate, so they did not contribute to the sCOD concentration value. sCOD was only contributed by organic substrates which would be decomposed by anaerobic microorganisms. In Figure 3, it appeared that sCOD had decreased significantly, which showed that hydrolytic and acidogenic bacteria were working well. The decrease in sCOD concentration in the control digester was slower than in the codigestion digester, possibly because the processed feed was not identical for the two digesters, so the number and composition of the microorganisms contained therein were also different. Preparation of raw materials was not done together, it was then divided into two, and fed to each digester. This non-identical feed could be seen from the VFA content at the beginning of the process which was quite significantly different between the control digester and the codigestion digester as shown in Figure 4. The figure shows as COD and sCOD concentrations decrease, which meant hydrolytic and acidogenic bacteria worked well to convert COD into VFA, the VFA concentrations would also increase at the beginning of time.

3.1.2. VFA Concentration

Changes in VFA concentration during the anaerobic process in the start up period could be seen in Figure 4. Figure 4 showed that the VFA concentration graphs for digesters A and B had the same trend throughout the process, where the VFA concentration increased at the beginning of the process until the fourth day and then decreased. This was in accordance with research conducted by Damayanti, Astiti, *et al*. (2019) and Damayanti, Sarto, *et al*. (2019). The increase in VFA concentration at the beginning of this time was reinforced by the pH value which also decreased as shown in Figure 5. This occured because hydrolytic and acidogenic bacteria had worked well to convert COD into

VFA as shown in Figures 2 and 3, where this VFA would later converted by methanogens into biogas (methane). However, at the beginning of time there were generally more acidogen populations than methanogens, so the acidogenesis process which converted COD into VFA took place more quickly than the methanogenesis process which converted VFA into biogas (methane), causing an increase in VFA concentration at the beginning of the process.

Acceleration of the performance of methanogenic bacteria in converting VFA into biogas began to appear after the fifth day of the process, which was indicated by a decrease in VFA concentration until the end of the process. On the 16th day, the VFA concentration did not decrease significantly due to having reached the limiting substrate that could be used by methanogens.

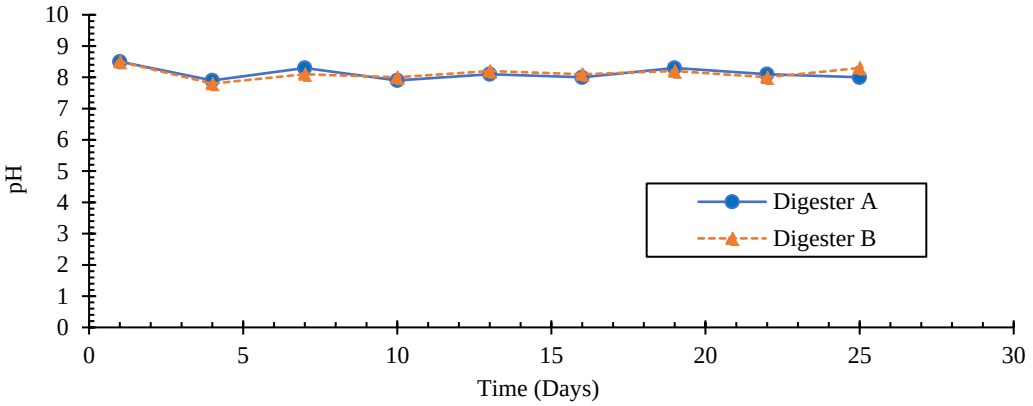


Figure 5. pH value during the start up period

3.1.3. pH Value

The initial pH value in the start up period was around 8.5 for both digesters (Figure 5). During the first four days, there was a decrease in pH, indicating that hydrolytic and acidogenic bacteria were starting to work to convert the substrate into VFA, resulting in an increase in VFA concentration which made the system more acidic. This increase in VFA concentration could be seen in Figure 4. In the following days, although the formation of VFA by acidogens was still ongoing, the acceleration of the performance of methanogens which converted VFA into methane had also occurred so that the VFA concentration would continue to fall until the end of the process. This caused the pH value to rise again.

The anaerobic digestion process to produce biogas (methane) must met a certain pH range to ensure that all the microorganisms involved could work properly. Acidogenic microorganisms were able to survive in acidic conditions, but methanogens were not. A good pH value range was in the range of 6.8 - 7.2 (Pambudi *et al*., 2018). Meanwhile, according to Iriani *et al*. (2017), the optimum pH range for biogas formation was 7 - 8. If the pH was too acidic (< 6.5) then the methanogen would not work optimally, and at a pH value < 5 the methanogen would die. Meanwhile, if the pH was too alkaline (> 8.5) it could affect the number of bacterial populations so that it could affect the rate of biogas formation (Budiyono *et al*., 2013). The pH conditions during the start up period were identical between digester A and digester B, namely ranging from 7.58 - 8.5. This showed that the anaerobic process was going well in both digesters, which was an indication that the anaerobic microorganisms were growing and developing well, so they were ready to become starters.

3.1.4. Biogas Production

The performance of microorganisms in degrading substrates anaerobically could be seen from several factors, namely their success in reducing COD, sCOD and VFA concentrations, as well as maintaining the pH value in the optimal range. Apart from that, the performance of microorganisms could also be seen from the biogas produced. Figure 6 showed that the system produced a lot of biogas, reaching almost 350 liters. This further showed that the anaerobic digestion process was successful, meaning that the process of conditioning and cultivating the starter microorganisms was successful.

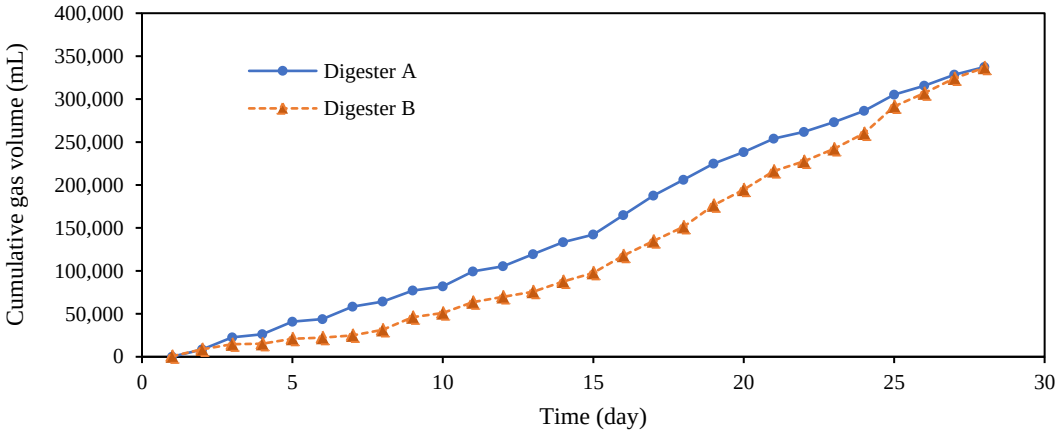


Figure 6. Biogas production during the start up period

3.2. Continuous Codigestion Process

After the starter in each digester was ready, continuous research was carried out. The condition of the substrate in each digester before continuous feeding was shown in Table 2. During the continuous process, COD and sCOD concentration analysis was carried out to see the ability of hydrolytic and acidogenic microorganisms to degrade the substrate, with the analysis results shown in Figure 7 and Figure 8.

Tabel 2. The condition of the substrate in the digester before continuous feeding

Variable	Digester A	Digester B
pH value	8.1	8
VFA Concentration (mg/L)	198.47	349.64
COD Concentration (mg/L)	13150	14705
sCOD Concentration (mg/L)	580	1450

The COD and sCOD concentrations outside the digester at the beginning of continuous feeding were not yet stable, then tended to decrease over time. In fact, the COD concentration outside the digester, which should be lower than the feed COD concentration because it had undergone anaerobic digestion, was actually higher, as can be seen in Figure 7. This was possibly due to the fact that at the beginning of continuous feeding, the output sample taken was a substrate resulting from a batch process which had a very high COD concentration compared to the COD concentration of continuous feeding. As time goes by, all the substrate resulting from the batch process would come out, so that future digester output would only be influenced by the COD concentration of the continuous feed and the anaerobic processes that occurred. In addition, process instability at the beginning of the continuous feeding time was very visible and lasts a long time for the codigestion process of cow dung, rice straw and fish meal. This was different from the process that occurred in the control digester, which only processed cow dung as a substrate. The instability of this long process was probably caused by microorganisms from cow dung which had been bred in batches as a starter, requiring adaptation time due to changes in the substrate being processed, namely co-substrates in the form of cow dung, rice straw and fish meal.

Based on Figure 8, it could be seen that the sCOD concentration leaving the digester was actually higher than the feed sCOD concentration in the codigestion process. This was possibly because COD in the codigestion process was largely contributed by complex compounds originating from rice straw and fish meal, such as cellulose and protein. During the process, these complex compounds would also break down into simpler compounds which were detected as soluble COD (sCOD), thereby increasing the sCOD concentration outside the digester. This was different from the control digester which processed cow dung. COD in cow manure was mostly contributed by simpler soluble compounds (sCOD), which were readily decomposed into VFA.

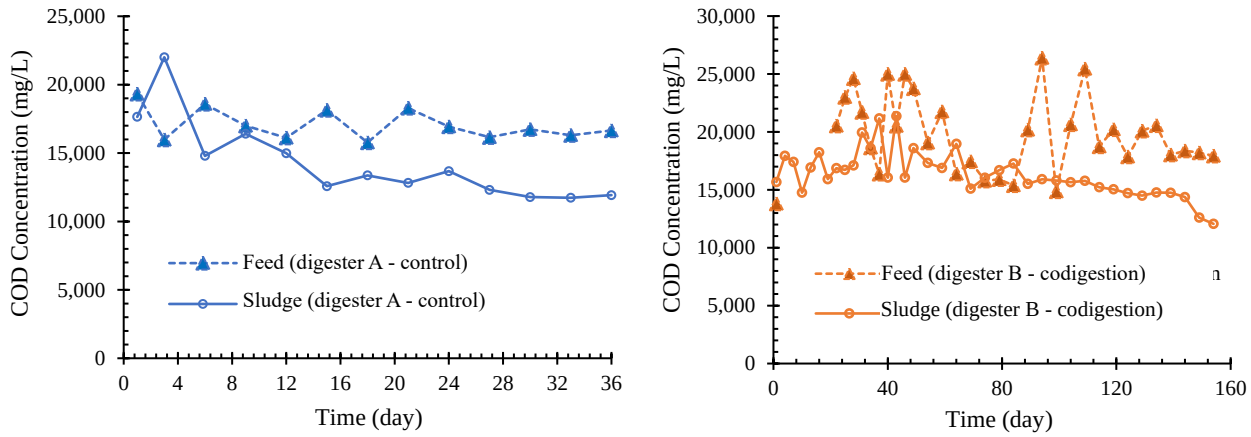


Figure 7. COD concentration during the continuous period: control (left), and codigestion (right)

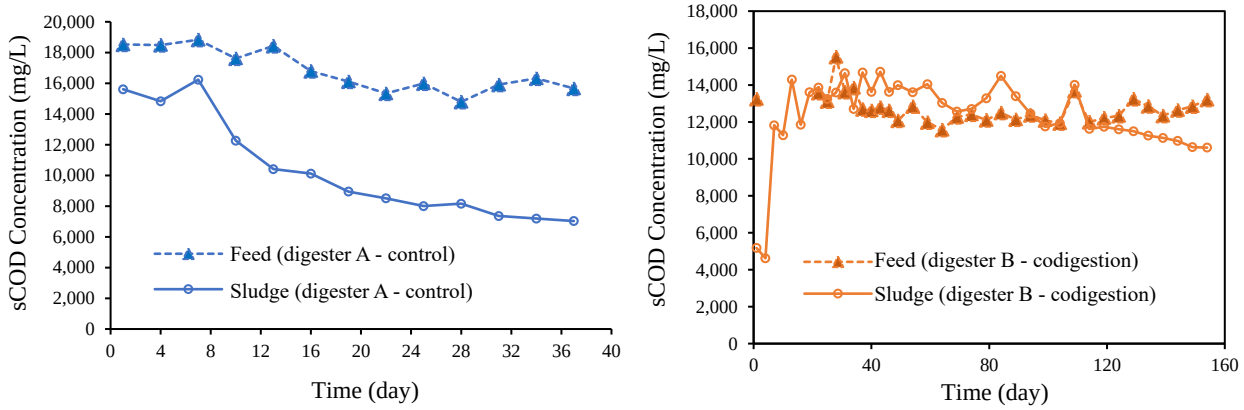


Figure 8. sCOD concentration during the continuous period: control (left), and codigestion (right)

Based on Figure 7, the average COD removal in the control process reached 21.43%, while the average COD removal in the codigestion process reached 25.79%. COD removal for the two processes was not significantly different. However, to achieve the COD removal value, the codigestion process required a longer time. Based on Figure 8, the average sCOD removal in the control process reached 39.35%, while the average sCOD removal in the codigestion process reached 10.92%. The sCOD removal values for the two processes differ very significantly. This probably occurred because sCOD was a soluble compound that was more easily decomposed by starter microorganisms than COD, and starter microorganisms were more easily adapted to cow dung substrates than co-substrates.

3.2.1. VFA Concentration

VFA was an intermediate compound resulting from the acidogenesis process which would become a substrate for the methanogenesis process to become methane (biogas). Apart from that, VFA would also affect the pH of the system, where methanogens were microorganisms that were susceptible to changes in pH. Therefore, VFA played an important role (Eryildiz *et al*., 2020). Changes in VFA concentration during the process were shown in Figure 9. From Figure 9 it could be seen that the output VFA concentration of the two digesters was not stable at the beginning of the continuous feeding process. Even the codigestion process only stabilized after 30 days of processing. This phenomenon was also in accordance with the phenomenon of COD and sCOD concentrations, which strengthens the assumptions that had been presented in the discussion of COD and sCOD concentrations above.

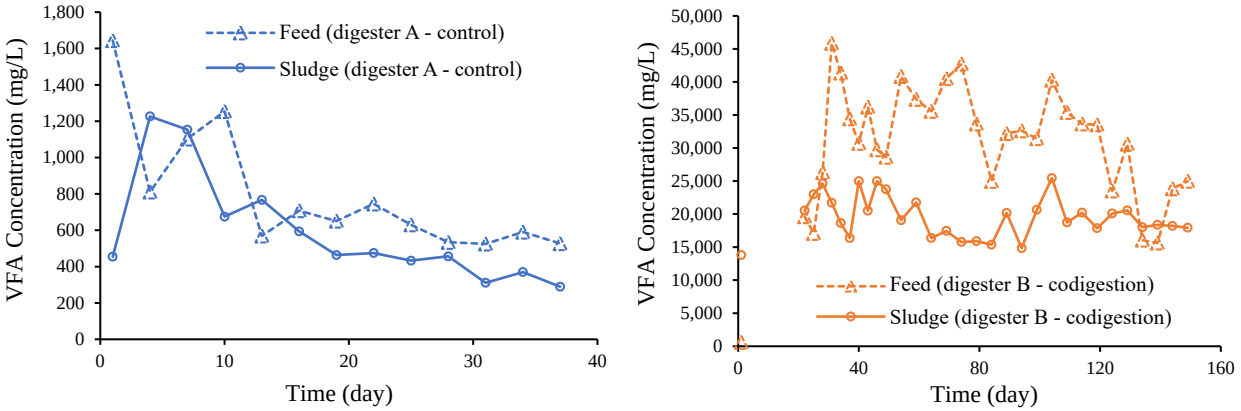


Figure 9. sCOD concentration during the continuous period: control (left), and codigestion (right)

Figure 9 also reveals that the co-substrate reaching an average of 32,237.19 mg/L, so that the process output also had a VFA concentration which was higher than the output of the control process. Even though the VFA concentration was very high, this did not cause the codigestion system to be acidic. The codigestion process was able to maintain a stable system pH condition at an average pH value of 8.8 as shown in Figure 10. This was likely due to the high protein content in fish meal, which was degraded into ammonia (Deng *et al*., 2023). Ammonia in the form of ammonium acetate formed a buffer in systems rich in VFA (acetic acid), which stabilized the pH value. Based on Figure 10, the average VFA removal in the control process reached 30.94%, while the average VFA removal in the codigestion process reached 43.88%. The higher removal of VFA for the codigestion process did not necessarily indicate that the acetogenesis and methanogenesis processes which caused the reduction in VFA took place better in the codigestion process. This was because VFA was an intermediate compound, whose existence not only depends on the processes of acetogenesis and methanogenesis, but also depends on the processes of hydrolysis and acidogenesis which change COD and sCOD. Since the sCOD removal in the codigestion process was very much smaller than the sCOD removal in the control process, it was natural that the VFA removal appeared to be greater. VFA concentration data in the first 20 days was not taken because there was human error.

3.2.2. pH Value

pH greatly influenced the anaerobic degradation process. In the anaerobic process to produce methane, a good pH value range was 6.8 - 7.2 (Pambudi *et al*., 2018). According to Iriani *et al*. (2017), the optimum pH range for biogas formation was 7 - 8. If the pH was too acidic (< 6.5) then the methanogenic microorganisms would not work optimally, and at a pH < 5 the methanogens would die. Meanwhile, if the pH was too alkaline (> 8.5) it could affect the number of bacterial populations. Figure 10 showed the change in pH of the system during the continuous process.

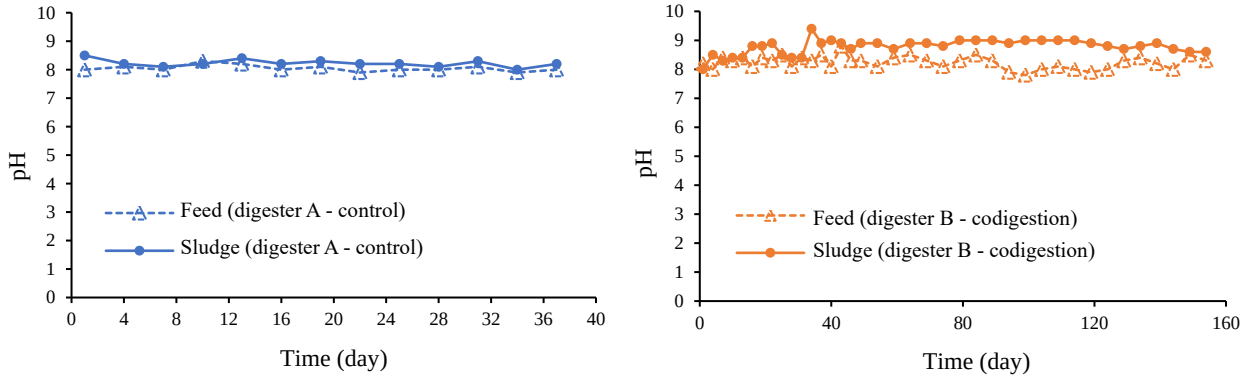


Figure 10. pH system during the continuous period: control (left), and codigestion (right)

Figure 10 shows that the codigestion system worked at pH 8 - 9.4. This was different from the control process which only processed cow dung, which worked in the pH range of 7.8 - 8.5, which means it was in the pH range suitable for the anaerobic process to form biogas. The more alkaline pH of the codigestion system was probably due to the influence of ammonia which was formed from the degradation of proteins in fish meal (Deng *et al*., 2023). This might also cause almost no methane to form during the codigestion process. An increase in total nitrogen-ammonia concentration could result in inhibition of methanogenesis (Jiang *et al*., 2019).

3.2.3. Biogas Production and Methane Content in Biogas

Biogas production during the continuous process was shown in Figure 11. Biogas production produced by the control process was more stable than that produced by the codigestion process. This showed that co-substrates such as straw and fish meal, which were complex compounds, became obstacles for anaerobic microorganisms originating from cow dung. Apart from being more stable, the average daily biogas production of the control digester was also higher, reaching 14,294.77 mL, compared to the codigestion process which only reached 4,367.60 mL. Lower biogas production in the codigestion process was very likely due to the presence of obstacles to microorganisms and because sCOD removal was much smaller. The low removal was also indicated due to the presence of obstacles to microorganisms as previously explained.

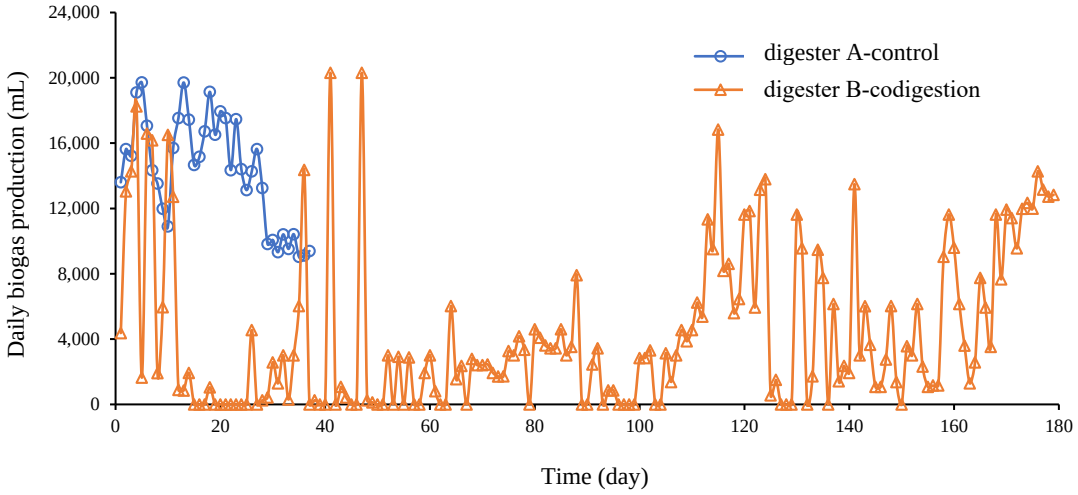


Figure 11. Daily biogas production during the continuous period for control and codigestion process

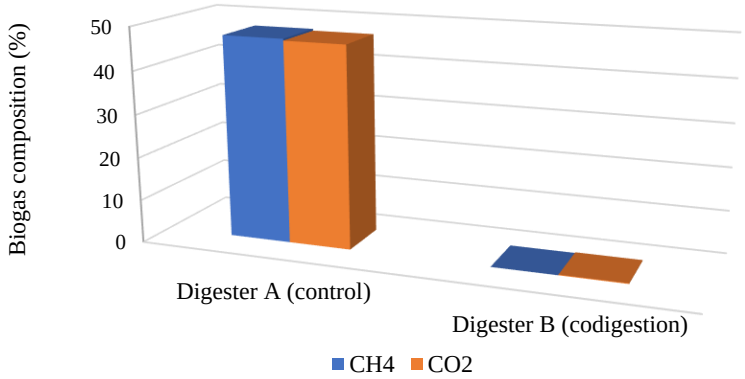


Figure 12. Methane (CH_4) and carbondioxide (CO_2) content in biogas.

The methane content in the biogas produced by the control process reached 47.33%, while the codigestion process did not produce methane. The methane levels in the biogas produced by the control digester were in accordance with published research (Kabeyi & Olanrewaju, 2022; Hamzah *et al*., 2023). With almost no CH_4 and CO_2 produced, it was likely that the gas produced in the codigestion process was ammonia. This ammonia was produced from the anaerobic breakdown of fish meal which contained a lot of protein. Jiang *et al*. (2019) stated that anaerobic protein breakdown would produced ammonia. In the solution phase, this ammonia was in the form of ammonium ions, while in the gas phase it was in the form of free ammonia. The absence of methane from the codigestion process further strengthened the opinion that the codigestion process with cow dung, rice straw and fish meal as a co-substrate greatly interfered with the performance of anaerobic microorganisms in decomposing the substrate. The high concentration of VFA in the codigestion system and the possibility of the formation of ammonia originating from the degradation of proteins in fish meal could caused poor methanogen performance, and the methanogen might even die (Deng *et al*., 2023; Jiang *et al*., 2019). With the disruption of methanogens, it was natural that the codigestion process did not produce methane at all. Fishmeal was likely to be a more dominant factor in disrupting the performance of microorganisms than rice straw. Several studies had shown the success of anaerobic digestion with rice straw as a substrate, although rice straw was a substrate that was difficult to decompose so it taken a long time (Haruta *et al*., 2002; Ngan *et al*., 2019).

3.2.4. Quality of Solid Phase Bioslurry Fertilizer

The solid phase bioslurry output from both digesters was analyzed to determine the total %NPK. The analysis results were presented in Table 3. Based on Table 3, the total NPK content in the solid phase bioslurry exiting the control digester was 1.44%, while the total NPK content in the solid phase bioslurry exiting the codigestion digester reached 3.86%. This showed that codigestion of cow dung, rice straw and fish meal succeeded in increasing the total NPK level in solid phase bioslurry fertilizer, up to 168% of the original level.

Table 3. Solid phase bioslurry content outside the digester

Compound	Digester A - control	Digester B – codigestion
Total-N (%)	0.24	1.47
Total-P (%)	0.25	1.66
Total-K (%)	0.95	0.73
Fe (ppm)	381.51	985.24
Mn (ppm)	631.41	510.60
Cu (ppm)	9.92	8.49
Zn (ppm)	53.92	64.95

4. CONCLUSION

Codigestion of cow dung, rice straw and fish meal did not show positive performance on anaerobic decomposition to produce biogas. This could be seen from the length of time required for the process to run stably, which indicated that anaerobic microorganisms required quite heavy adaptation. The high level of VFA in the co-substrate was thought to be one of the causes of disruption of microorganisms. The possibility of the emergence of ammonia due to protein degradation in fish meal was also thought to hamper the performance of microorganisms. This codigestion did not produce methane gas at all, even though the solid phase bioslurry fertilizer produced met SNI standards for its NPK content, namely 3.86%.

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