Potential as biogas energy and organic fertilizer: a mixture of rice husks and cow dung on full scale anaerobic digestion

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ABSTRACT

Rice husk is a biomass that can potentially be converted into biogas energy. In this research, a study was carried out regarding the effect of alkaline pretreatment and then a study related to the potential for developing biogas from rice husks in Indonesia and a study related to the potential utilization of biogas by-products in the form of slurry as solid organic fertilizer. So, the main objective is to determine the effect of alkaline pretreatment of rice husks on the potential development of rice husks as raw material for biogas production on a full-scale anaerobic digestion (AD). Research related to the effect of alkaline pretreatment using 3% NaOH by immersion in the substrate for 24 hours was carried out on a lab scale. The variable TS is set at 27%, C/N ratio is 35, uses a 2-liter digester, and measurements are carried out every other day for 60 days. Furthermore, the up-scale was carried out with an AD fixed dome model with a volume of 6 m^3. In this study, it was found that pre-treatment with 3% NaOH increased biogas productivity by 1.6 times higher. The potential for rice husk to be converted into biogas energy can reach 3.5 million liters of biogas by 2022. The by-product of biogas in the form of slurry also has the potential to be used as solid organic fertilizer directly. Parameter tests that have been carried out show that the slurry in biogas from rice husks that have gone through a 60-day AD fermentation process complies with the Indonesian National Standard (SNI) 7763:2018 concerning solid organic fertilizers.

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1. INTRODUCTION

One of the most agricultural countries in the world is Indonesia where most of the people work in the agricultural sector. Based on data compiled from the Central Bureau of Statistics (BPS), document with the title Official Statistical News No. 74/10/Th. XXV published on October 17, 2022, the harvested area of rice plants reached 10.6 million hectares with production in the form of dry milled grain (*Gabah Kering Giling* (GKG)) of 55.6 million tonnes. If converted into rice, rice production is estimated to reach 32.07 million tonnes [1]. Of course, it is good news that Indonesia has a staple food in the form of rice. So, it can be fulfilled properly. However, it needs to be understood that GKG does not completely turn into ready-to-cook rice. Rice obtained from GKG is 64.02%. The rest is waste in the form of rice husks. If calculated, in 2022, there will be an estimated generation of rice husk waste of 20 million tons. Based on [2], [3], the utilization of rice husks is still relatively low, usually used as a planting medium where some are made into charcoal first, and some are left intact in their original form. Other uses are as fuel for making bricks, cooking fuel, and made into briquettes, but the amount is very small. The research was carried out on a laboratory scale and needs to be scaled up and further developed [4]. Most of the handling of rice husk waste is by burning it [5]. Usually carried out directly by farmers after the main harvest period. Farmers note that burning rice husks can make paddy fields fertile and ready for replanting [6]. However, this is not in accordance with the research conducted by [7], stating that burning rice husks can reduce nutrients in the area used to burn the rice husks. Besides having a poor impact on the soil, burning rice husks also causes air pollution [8]. According to [9], [10], the combustion process will release various pollutants such as SO_2, NO_2, CO, O_3, Pb, PM_{10}, and $PM_{2.5}$, which can be detrimental to environmental health. Air pollution affects humans, animals, including plants [11]. Rice husk waste is included in the class of organic waste from agricultural activities [12]. Currently, biogas technology development uses agricultural waste (biomass) as raw material, whereas initially biogas technology only uses livestock waste [13]-[15]. Of course, this trend is beneficial for agrarian countries like Indonesia, where the generation of organic waste from agricultural activities is very high. Biogas is a technology that utilizes microorganisms anaerobically and converts organic waste into methane gas and other gaseous elements [16]-[18]. Biogas is also renewable energy because the production process uses simple raw materials and does not require a long time [19], [20]. This research conducts a study on the potential of rice husk to be converted into renewable energy in the form of biogas on a full scale in Indonesia. This is also a novelty and the latest contribution to scientific knowledge in the field of biogas energy. Furthermore, a study was also carried out on the potential of biogas slurry to be used as a solid organic fertilizer.

2. METHOD

This research was carried out on a full scale and directly applied to rural areas where rice husk waste is abundant. Anaerobic digestion (AD) for biogas was built in Kalisidi Village, West Ungaran District, Semarang Regency, as can be seen in Figure 1. This AD is made with a volume of 6 m^3, with a fixed dome model made of concrete. The biogas produced is channeled to residents' homes using polyvinyl chloride (PVC) pipes buried in the ground for a two-burner gas stove. Previously, alkaline pretreatment of rice husks was carried out using 3% NaOH. Soaking rice husks with 3% NaOH was carried out for 24 hours. Next, the rice husk is cleaned with clean water until the pH is neutral. This condition refers to previous research on a laboratory scale conducted by the authors.

Figure 1. Full-scale AD for biogas from a mixture of rice husks and cow dung in Kalisidi village

Scanning electron microscopy (SEM) analysis was carried out to see the rice husk surface microscopically. SEM analysis was conducted at the Integrated Laboratory of Diponegoro University with a magnification of 500× and 1500× on rice husks before and after 3% NaOH pretreatment and on rice husks that had undergone AD fermentation for 60 days in a biogas digester. Preliminary studies on a laboratory scale were carried out to obtain the optimum conditions used for full-scale AD operations. The variable TS is set at 27% and the C/N ratio is 35. Laboratory-scale biogas digesters are used in batches and consist of strong, airtight plastic bottles with a volume of 2 liters. The digester is sealed with a rubber cover that has a valve for measuring biogas. The design of the biogas digester and the method for measuring biogas production using the water displacement method [2], [19], [21] can be seen in Figure 2. Biogas measurements were conducted every two days over a period of 60 days. The fermentation process on a laboratory scale and a full scale is carried out under anaerobic conditions without oxygen to form the main gas in the form of CH_4 [21]. In addition to conducting studies on rice husks and the biogas energy produced, this research also studied the potential of biogas from rice husks in Indonesia. Furthermore, an analysis is carried out regarding the quality of biogas slurry, which can be used as organic fertilizer. Analysis of the quality of biogas slurry refers to the Indonesian National Standard (SNI) 7763:2018 concerning solid organic fertilizers. The slurry analysis was carried out at the Soil Laboratory, Department of Environmental Engineering, Diponegoro University.

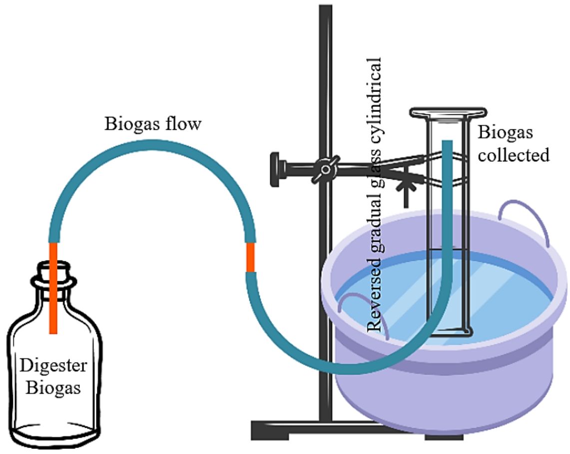

Figure 2. Series of research tools in the laboratory

3. RESULTS AND DISCUSSION

In this section, a study is carried out on the effect of alkaline pre-treatment using 3% NaOH and immersion in the substrate for 24 hours. Furthermore, a comparison of the productivity of biogas from rice husk was carried out between the variables with and without 3% NaOH pre-treatment. Based on the data presented in Figure 3, under conditions of TS 27% and C/N ratio 35, it was found that the variable with 3% NaOH pre-treatment had 1.6 times higher biogas productivity. The variable with pre-treatment was recorded at 2268.5 mL and the variable without pre-treatment was only 1433.5 mL. There is a difference in biogas volume of 835 mL. If seen per TS unit, the variable with pre-treatment reached 174.5 mL g^{-1} TS, and the variable without pre-treatment only reached 110.3 mL g^{-1} TS.

Biogas productivity on the variable with 3% NaOH pre-treatment was observed to be higher as a result of the process of destroying the lignin contained in the rice husk by the NaOH. This process is known as the delignification process [22], [23]. These conditions make it easy for anaerobic bacteria to ferment and convert into biogas [19]. The structure of rice husks seen using SEM with 500× and 1500× magnification is presented in Figure 4 and the structure of rice husks after pre-treatment with 3% NaOH is presented in Figure 5. From these two figures, it can be seen the difference in rice husks with and without 3% NaOH pre-treatment. The structure of the rice husk with 3% NaOH pre-treatment looks damaged and destroyed [19], where these conditions facilitate the fermentation process by anaerobic bacteria, which has an impact on increasing the productivity of biogas [19], [22]. The condition of being crushed into smaller sizes also makes it easier for the hydrolysis process to produce higher biogas [19].

The potential of rice husk waste as renewable energy in the form of biogas is very large, especially in an agricultural country like Indonesia [19], [24]. In Indonesia, in 2022, it will produce 55.6 million tons of dry-milled grain (GKG) [1]. From the GKG data, 64.02% goes into the rice, and the rest is rice husk waste.

So, the calculation is 35.98% become rice husks and its emergence in Indonesia in 2022 will reach 20 million tons. It is a big problem if not managed properly. If all of this waste is burned, what will happen is a massive degradation of health and environmental quality. However, if it is converted into renewable energy as biogas, the potential obtained is 3.5 million liters of biogas. If all generated rice husk waste and cow dung can be managed properly, it can support energy security for Indonesia. On the other hand, sources of air pollution from agricultural activities, especially burning rice husks, can be significantly reduced.

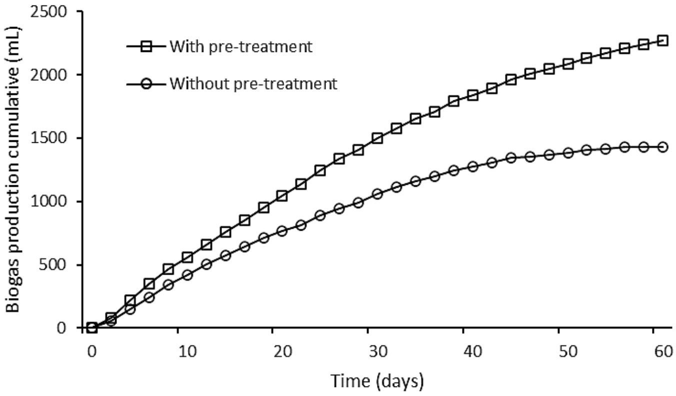

Figure 3. Comparison of biogas production with and without 3% NaOH pre-treatment

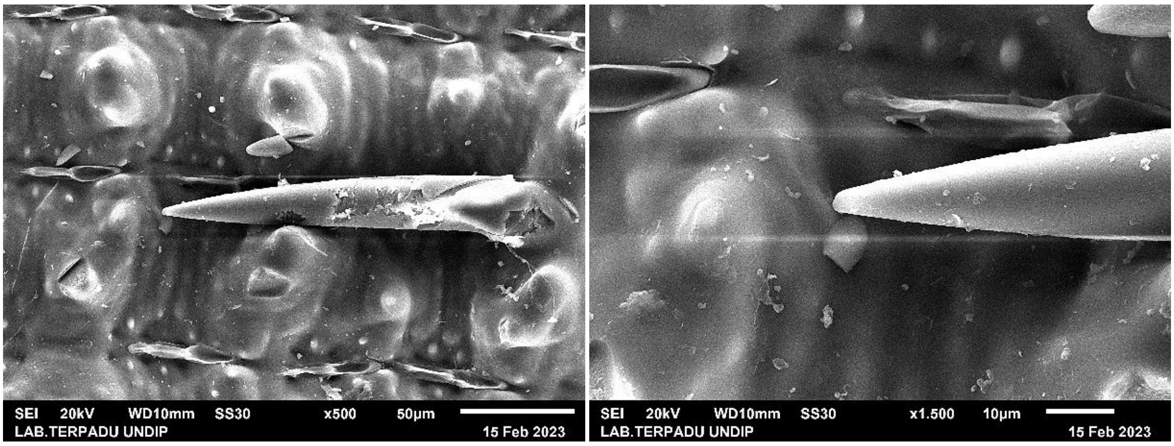

Figure 4. SEM of rice husk before the addition of 3% NaOH, 500x and 1500x magnification

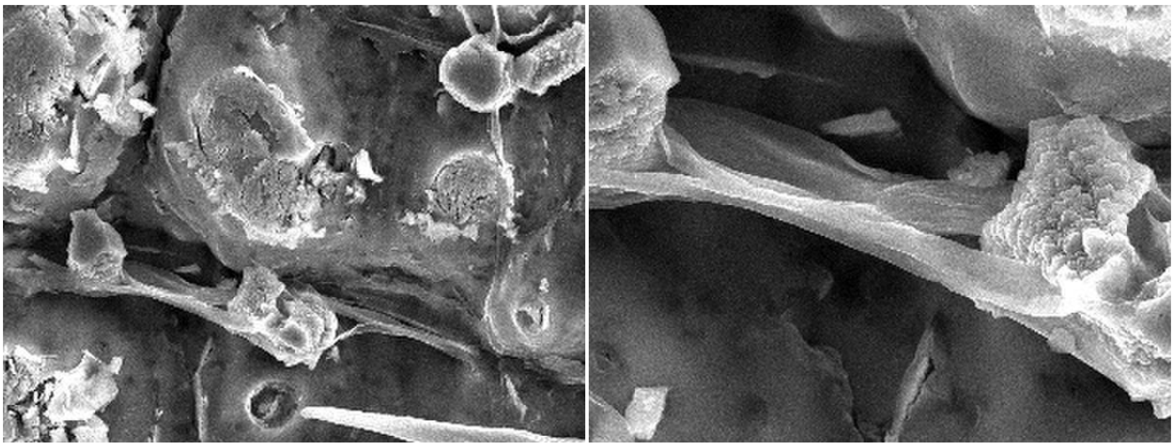

Figure 5. SEM of rice husk after addition of 3% NaOH, 500x and 1500x magnification

In assessing the quality potential of organic fertilizers, some parameters are used as standardization in determining the appropriate quality of solid organic fertilizer products where these parameters refer to SNI 7763:2018. If there are parameters that exceed the value of the quality standard or even less than the standard set, an effort or treatment is needed to improve the product according to the standard. Based on the results of laboratory tests conducted, all parameters have met the established quality standards. It's just that in several parameters such as water content it is at the upper limit of 24.57%, the pH is at the lower limit of pH 4.8, and for macronutrients, it is at the lower limit of 2.344%.

The other parameters are in a good range for solid organic fertilizers. In detail, data on the quality of the solid organic fertilizers are presented in Table 1 and in Figure 6, a photo of the solid organic fertilizer produced from the AD fermentation process from rice husks is presented. The condition of rice husk after 60 days of the AD fermentation process became brittle and destroyed due to material degradation by anaerobic bacteria which was converted into biogas energy [2], [25], [26]. This proves that it is ready to be used as a solid organic fertilizer as well as a soil enhancer. Visualization using SEM on rice husk after the 60-day AD fermentation process is presented in Figure 7.

Table 1. Biogas slurry sample quality test against SNI 7763:2018 concerning solid organic fertilizer

Parameters	Unit	Test value	SNI 7763:2018
Water content	%	24.57	8-25
pH	-	4.8	4-9
C-Organic	%	21.44	Min 15
Macronutrients ($N+P_2O_5+K_2O$)	%	2.344	Min. 2
Micro nutrients			
- Fe	mg/Kg	3.04	Max. 15
- Zn	mg/Kg	<0.05	Max. 5000
Pb	mg/Kg	<0.01	Max. 50
Cd	mg/Kg	<0.01	Max. 2
Cr	mg/Kg	<0.01	Max. 180

Figure 6. Biogas slurry after 60 days AD fermentation as solid organic fertilizer

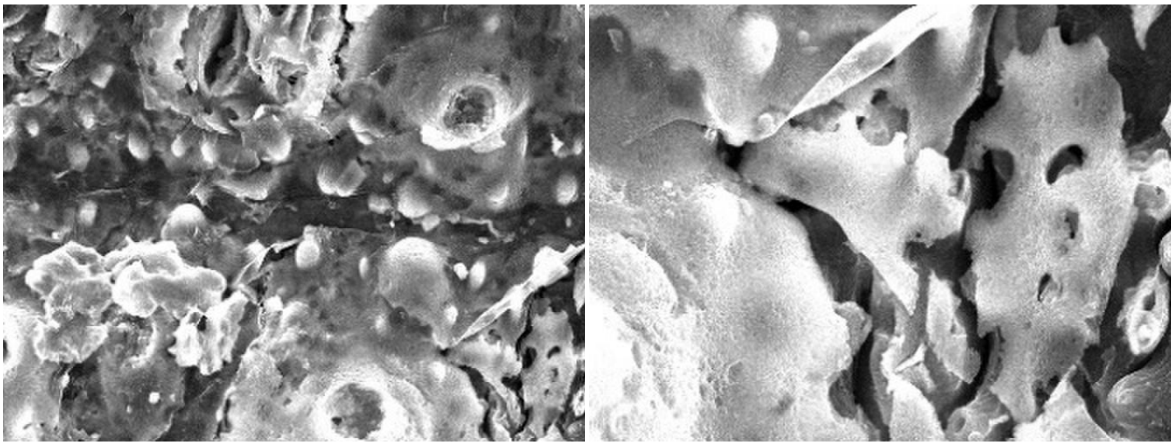

Figure 7. SEM of rice husk after addition of 3% NaOH and 60 days AD fermentation

4. CONCLUSION

Rice husk is proven to be converted into biogas energy through AD fermentation on a full scale. Pre-treatment of 3% NaOH on rice husks for 24 hours can increase biogas productivity by 1.6 times higher. This is supported by the results of SEM images which show that the structure of the rice husk with 3% NaOH pre-treatment was damaged and destroyed, making it easier for the AD fermentation process. The potential for rice husk to be converted into biogas energy in Indonesia in 2022 can reach 3.5 million liters of biogas. The by-product of biogas in the form of slurry is proven to be used as a solid organic fertilizer. This is in accordance with the results of the study that the parameter test for organic fertilizer is in accordance with the standards issued by the Indonesian National Standard (SNI) 7763:2018.

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AUTHOR CONTRIBUTIONS STATEMENT

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Syafrudin	✓	✓				✓	✓			✓		✓		
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Budiyono	✓		✓		✓		✓		✓				✓	✓
Iqbal Syaichurrozi					✓	✓				✓	✓			

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author, [HHAM], on request.

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