World Chemical Engineering Journal Vol.8, No.2, (2024), pp. 34-40

WORLD CHEMICAL ENGINEERING JOURNAL

Journal homepage: http://jurnal.untirta.ac.id/index.php/WCEJ

Review: Biogas Production from Rice Husks

Windi Astria, Ratih Ramadhani Putri, Hanif Al Fattah, Endang Suhendi, Iqbal Syaichurrozi*

Chemical Engineering Department, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon-42435, Indonesia

*Corresponding Author Email: *iqbal_syaichurrozi@untirta.ac.id*

ARTICLE HISTORY

Received 25 November 2024
Received in revised form 14 December 2024
Accepted 14 December 2024
Available online 14 December 2024

ABSTRACT

For Indonesians, rice is a basic diet. Rice husks, a waste product of the milling process used to turn paddy into rice, have a great potential for conversion into raw materials for biogas. Several factors that affect the rate of biogas production are the initial treatment (pre-treatment), temperature, acidity (pH), total solid content (TS), and C/N ratio, this is done to help the degradation process of lignin and cellulose can run quickly which has an impact on increasing biogas production. The development of biogas from rice husk waste has significant promise for Indonesia since it can help reduce the country's rice husk waste stockpile and could eventually become one of the country's primary alternative energy sources.
Keywords: *Biogas, Lignin, Rice Husk*

1. RICE HUSK AND ITS CONTENT

Because it's so readily available, rice husk is one of the biomass that works well as a raw material for biogas. According to bps.go.id in 2021 rice production in Indonesia is 55.27 million tons of GKG (dry milled rice) while the rice produced is 31.69 million tons (Badan Pusat Statistik, 2021), where the milling process typically yields milled rice between 50 and 63.5% of the initial grain weight, bran between 8 and 12%, and husk between 20 and 30% (Kencanawardhani et al., 2016). If we calculate 20% of the initial weight of rice, it means that the rice husk produced from milling reaches 11.054 million tons.

In the handling process, rice husk, which can be seen in Fig. 1, is a biomass that is difficult to be degraded by microorganisms. This is due to the hard and dry physical characteristics of rice husks where the lignin content in rice husks can inhibit microorganisms from decomposing. The rice husks will not decompose if they are left in a specific location. This is one of the factors that need to be taken into account in order for the biogas generation process to function properly, necessitating first treatment prior to entering the digester (Matin et al., 2020).

Fig 1. Rice Husk (source: https://en.wikipedia.org/wiki/Rice_hull)

Rice husk is made up of lignocellulose, which is made up of three different kinds of polymers: cellulose, hemicellulose, and lignin (Zhu et al., 2010). Houston (1972) reported that the bulk density of rice husk is 0.100 g/ml, its calorific value is 3300-3600 kcal/kg of husk, and its thermal conductivity is 0.271 BTU. The chemical composition of rice husks is composed of 15-20% silica, 25-30% lignin, and 50% cellulose. Some of the constituents of rice husks are listed in Table 1.

Table 1. Rice Husk Content (Manurung and Ismunadji, 1988)

Composition	% Weight
Moisture content	32.40 – 11.35
Crude protein	1.70 – 7.26
Fat	0.38 – 2.98
Free nitrogen extracts	24.70 – 38.79
Fiber	31.37 – 49.92
Ash	13.16 – 29.04
Pentose	16.94 – 21.95
Cellulose	34.34 – 43.80
Lignin	21.40 – 46.97

2. BIOGAS

2.1. Definition

In anaerobic settings, biogas is a gas that is created when organic matter, such as home trash, animal and human waste, or biodegradable organic waste, ferments. According to Fadli et al. (2013), methane and carbon dioxide are essential components of biogas. These anaerobic processes determine the composition of biogas. If the formation comes from the landfill gas process, it has a methane concentration of about 50%, if using an advanced waste treatment system, it can produce biogas with a composition of 55-75%. The components of biogas are shown in Table 2.

Table 1. Biogas Composition (Burke, 2001)

Component	%
Methana (CH_4)	55 – 75
Carbon dioxide (CO_2)	25 – 45
Nitrogen (N_2)	0 – 0.3
Hydrogen (H_2)	1 – 5
Hydrogen Sulfide (H_2S)	0 – 3
Oxygen (O_2)	0.1 – 0.5

2.2. Stages of Biogas Production

The formation of biogas biologically includes four stages, namely the hydrolysis stage (dissolution stage), the acidification stage (acidification stage), the acetogenesis stage and the methanogenesis stage (methane gas formation stage).

2.2.1 Hydrolysis Stage

The first phase in the process of producing biogas is the hydrolysis stage. Complex substances having soluble characteristics, including proteins, lipids, carbohydrates, and nucleic acids, undergo the breakdown of organic matter to produce glucose, glycerol, purines, and pyrimidines. Hydrolyzing microbes release hydrolase, which breaks down the polymer into smaller molecules (Megawati, 2014). This anaerobic bacterium can thrive in environments that are acidic, specifically those with a pH between 5.5 and 6.5. Around 30°C is the ideal temperature for this bacterium to thrive (Rachman, 2018).

$$Lipids \xrightarrow{lipase} Fatty\ Acids, glycerol \quad (1)$$

$$Polysaccharide \xrightarrow{cellulase,selobiase,xilanase,amilase} Monosaccharide \quad (2)$$

$$Protein \xrightarrow{protease} Amino\ Acids \quad (3)$$

2.2.2 Stages of Acidogenesis

The hydrolysis products are transformed into methanogenic substrates by acidogenic bacteria during the acidogenesis process. Simple sugars, amino acids, and fatty acids are broken down into alcohol, volatile fatty acids (VFAs), acetate, carbon dioxide, and hydrogen.

2.2.3 Stages of Acetogenesis

The acidogenesis products that methanogenic bacteria are unable to directly convert to methane will be transformed into a methanogen substrate during the acetogenesis process. Alcohol and VFA oxidize to produce carbon dioxide, hydrogen, and acetate, which are methanogenic substrates. A byproduct of the acetogenesis process, hydrogen products raise the partial pressure of hydrogen and prevent acetogenic bacteria from metabolizing (Megawati, 2014). Acetogenic bacteria (bacteria that create acetate and H_2), such *Syntrobacter wolinii* and *Syntrophomas wolfei*, convert ethanol, propionic acid, and butyric acid to acetic acid.

2.2.4 Stages of Methanogenesis

Because these bacteria develop very slowly—up to three days—this stage is the most crucial and delicate in the anaerobic breakdown of organic waste. The reduction of the produced acetic acid by methanogenic bacteria yields a very basic end product in the form of carbon dioxide gas (CO_2) and methane gas (CH_4). Methanogenic bacteria, including methanococus, methanosarcina, and methanobactherium, are the bacteria involved in this step. Two distinct groups of methanogenic bacteria are also involved in this stage. Hydrogenotropic methanogenic bacteria convert CO_2 to methane, whereas methanogenacetotropic bacteria convert acetic acid to methane and CO_2. Methanobacterium, methanobacillus, methanosacaria, and methanococcus are the types of methane bacteria. This bacteria thrives at 35°C, however it is extremely sensitive to temperature variations of 2 to 3°C. 6.5 to 7.5 is the pH range (Rachman, 2018).

Methanogenic bacteria make methane and carbon dioxide from intermediate products. Acetate provides 70% of the methane produced, with the remaining 30% coming from the conversion of hydrogen (H_2) and carbon dioxide (CO_2).

$$CH_3COOH \rightarrow CH_4 + CO_2 \quad (4)$$

$$2H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad (5)$$

Being the slowest biological event in the entire anaerobic digestion process, methanogenesis is a crucial stage. Operating circumstances have a big impact on the methanogenesis process. Temperature, pH levels, dietary comparison, and raw material composition are a few examples of factors that influence the methanogenesis process. Methane production can stop due to digester overload, temperature fluctuations, and the entry of huge volumes of oxygen (Megawati, 2014).

2.3. Factor Affecting Biogas Production

2.3.1 Preliminary Treatment

The preliminary treatment in this study was a chemical treatment carried out with the addition of NaOH to accelerate the degradation of lignocellulosic content and increase biogas yield (Chandra *et al.,* 2012). The addition of NaOH is 3% of the total volume of liquid in the digester (200 ml), which is 6 ml. With the preliminary treatment with the addition of NaOH, total biogas production with a concentration ratio of Total Solids (TS) of 7% was obtained of 56.64 ml/g TS, while without the addition of NaOH, total biogas production was obtained of 28.89 ml/g TS. With this, the treatment of adding NaOH has an effect on biogas production (Saputri *et al.,* 2017).

2.3.2 Total Solids Concentration

According to the study by Syafrudin et al. (2020), the TS variation was 5, 7, 9, 19, 21, and 23%. 57 ml/g TS, 56.64 ml/g TS, 45.36 ml/g TS, 24.62 ml/g TS, 15.15 ml/g TS, and 12.4 ml/g TS were the cumulative yields of rice husk biogas per unit of TS. Brown et al. (2012) claim that increased TS results in less biogas being produced. Between a 5% and 23% TS level, the high TS content inhibits the hydrolysis step because of a restricted mass transfer between the microorganisms and the raw materials, specifically rice husk waste. Due to limited mass transfer, only a small number of acidogenic bacteria can access the hydrolysis product, resulting in a decrease in the amount of product produced during the acidogenesis stage (Sheets et al., 2015).

2.3.3 Temperature

One of the key elements influencing the anaerobic digestion process is temperature. In comparison to mesophilic settings, anaerobic digestion under thermophilic conditions offers a number of benefits, including a high metabolic rate, a high specific growth rate of bacteria, and a high bacterial death rate (Van Lier, 1995). Anaerobic digestion of cattle manure at 60°C was found to be more stable than mesophilic conditions (40°C) by Mackie and Bryant (1995).

Ghatak and Mahanata (2018) compared the cumulative generation rate of rice straw and rice husk biogas when mixed with cow dung at 45°C, 50°C, and 55°C, respectively. The findings showed that the rate of biogas production rose as the temperature rose by one degree. In the case of rice straw and cow dung, for instance, the biogas production was 18.24 ml/g VS, 30.73 ml/g VS, and 32.93 ml/g VS. In contrast, the biogas production in the rice husk and cow manure mixture was 13.41 ml/g VS, 19.41 ml/g VS, and 22.74 ml/g VS. This indicates that the rate of biogas production is lower for the rice husk and cow dung mixture than for the rice straw and cow manure mixture. The high lignin (25%) and silicon content of rice husks are the causes of this.

2.3.4 pH

The research of Onaji *et al.* (2019) stated that to determine the effect of pH on biogas production from cow manure waste, rice husks, and a mixture of both, which was carried out with pH variations of 5, 7, and 9 and observed for 30 days. From the results obtained, the total volume of biogas (cm^3) in the biomass of consecutive cow manure was 126 cm^3; 775 cm^3; and 510 cm^3, then in rice husk biomass 2.0 cm^3 consecutively; 47 cm^3; and 9.0 cm^3, then in a mixture of cow dung and rice husks 182 cm^3 respectively; 938 cm^3; and 683 cm^3. Based on the aforementioned findings, the optimal biogas production occurs at pH 7, as opposed to pH 5 and pH 9. Methanogenic bacteria are significantly inhibited when the pH falls below 7, and methane generation is minimal at pH 5, which is poisonous to bacteria. The ideal pH range for digester is between 6.5 and 8, which is suitable for acetogen and methanogen bacteria, according to Antonopoulou et al. (2008). Additionally, Sahota and Singh (1996) demonstrated that a drop in the digester system's methanogenic activity at pH 5 had a substantial impact on gas output.

2.3.5 C/N Ratio

Research conducted by Matin *et al* (2016) stated that the study was carried out anaerobically with a TS of 21%, and it was found that at the C/N ratio of 20 obtained biogas results of 10.25 ml / gTS. Then in C/N 25, the biogas yield was obtained from 12.0 ml / gTS. At C/N 30, the biogas yield was obtained from 13.54 ml / gTS. From this result, it was found that the higher the C/N value, the higher the biogas yield obtained.

Matin and Hadiyanto (2018) reported that a cumulative volume of rice husk biogas with a C/N ratio of 35, or 11.6 ml/g TS, was produced with a TS concentration of 21%. The total amount of biogas at C/N 40 is 10.2 ml/gTS. It is 9.86 ml/gTS for C/N 45 and 9.4 ml/gTS for C/N 50. According to the information gathered, the ideal range for anaerobic bacterial development for a C/N ratio is between 20:1 and 35:1, with slightly moist ambient conditions. C/N 35 is the maximum biogas yield.

The activity of the microbes engaged in fermentation is determined by the C/N ratio. According to Li et al. (2011), a C/N ratio of 20 to 30 is optimal for anaerobic digestion. Methane generation will be reduced in organic materials with a high C/N ratio. This is due to the low nitrogen concentration of materials with a high C/N ratio. As a result, methanogenic bacteria quickly use nitrogen, which lowers methane production because there is less nitrogen available for bacterial development (Taherzadeh and Karimi, 2008). Therefore, adding organic matter with a high nitrogen content, like cattle manure, can raise the nitrogen content of these materials.

3. STRATEGIES FOR INCREASING BIOGAS PRODUCTION FROM RICE HUSK

3.1. Codigestion

Codigestion is the anaerobic digestion of many organic wastes at the same time in a single digester. The process of codigestion is used to increase the production of methane from components, such as raw materials, that are difficult to digest or have low yields. Care should be made while choosing appropriate input materials for codigestion that can boost methane production (avoid elements that can hinder methane synthesis). Furthermore, the substantial increases in methane output that are typical of codigestion must be supported by the anaerobic systems that are now in place. Table 3 displays a few instances of rice husk co-digestion.

Table 2. Several Types of Co-Digestion Biogas from Rice Husks

Co-digestion	Operating Conditions	Result	Reference
Rice Husk Waste and Cow Manure	The composition of 25% Rice Husk is 13 g, 75% Cow Dung is 150 g, Aquades is 160 mL and nutrient/media variations (with the composition of $CaCl_2$ 5 g, $K_2HPO_4.H_2O$ 200 g, and NH_4Cl 100 g) of 0, 5, and 10 ml were put into the Anaerobic Digester	It was discovered that the Anaerobic Digester with a 10 mL nutrient/media variation generated the most gas, followed by a 5 mL nutrient/media variation and a 0 mL gas volume. The greatest gas production in 10 mL media happens between days two and three; this also happens in 5 mL media. On 0 mL media, on the other hand, no gas is created until the experiment is finished. This occurs because the high lignin and cellulose content of rice husks prevents enzymatic breakdown and influences the production of biogas as a whole. Because they enable microorganisms to break down cellulose and lignin and produce more gas, nutrients, and media have a significant impact on rice husks and cow dung.	Mulyawan, et al. 2018
Rice Husk and Kitchen Waste	The composition used between rice husks and kitchen waste is 3:1 (digester A), 1:1 (digester B), and 1:1 (digester C), where before being varied, rice husks and kitchen waste are mixed with water in the same ratio, namely 100 g of rice husks or vegetable waste mixed with 200 g of water, then a variation composition is used between rice husks and kitchen waste, for example, 75 g of rice husks with 25 g of kitchen waste.	The maximum biogas yield was obtained by mixing rice husks with kitchen waste 1:3, namely 25 g of rice husks and 75 g of kitchen waste, where the total biogas production produced for 14 days was 28.42 ml, then followed by a variation in a 1:1 ratio of 24.94 ml, and a 3:1 ratio of 19.30 ml. This can be associated with the nitrogen and nutrient content contained in kitchen waste which can increase the production of biogas, besides that rice husks and kitchen waste can also be used to overcome the problem of lack of raw materials in producing biogas	Orhevba and Onojitayoma, 2015
Rice-melon husk co-digested with cow dung as inoculant	The variation used is the NaOH variation from 8-10% and the total solids vary between 8-10%. The ratio of rice husk and melon husk used was 100:0, 75:25, 50:50, 25:75, 0:100. The temperature used is between 23.3 °C - 28.9 °C and 34.59 °C - 40.1 °C.	The highest biogas yield was found at RH:MH (100:0) of 606.943 mL/kg with a NaOH concentration of 8.25% and a total solid of 9.5%.	Mohammed et al., 2020
Cow dung and rice husks	The variations used are the addition of rice husks with concentrations of 15%, 18%, 21% and 24%	The highest biogas produced is 0.059698 kg which has a mixed composition of 79% cow dung and 21% rice husk and has a carbon/nitrogen (C/N) ratio of: 27.835:1.	Wiratmana et al., 2012

3.2. Pre-treatment

Prior to the creation of biogas, a hydrolysis procedure called pre-treatment is employed. The procedure of pre-treatment prepares biomass for microbial attack. Mechanical pre-treatment, ultrasonic pre-treatment, enzyme-based biological hydrolysis, alkaline therapy, ozone-based oxidative treatment, microwave irradiation, thermal treatment, thermochemical, and other pre-treatment methods are frequently employed.

The delignification treatment with NaOH solution is one of the chemical pre-treatment procedures. Because NaOH can attack and degrade lignin's structure, its christlain and amorphous sections, separate lignin and hemicellulose, and cause swelling of the cellulose structure, delignification is done using a NaOH solution (Marsden and Gray, 1986; Gunam and Antara 1999). The lignocellulose structure will be opened during the delignification procedure, making cellulose more accessible. To make it easier to extract lignin from fiber, the delignification procedure will dissolve the material's lignin component (Permatasari et al., 2013). Delignification can result in the release of carbohydrate molecules (cellulose) and disruption to the structure of lignin. In addition to chemical pre-treatment, the following are the types of pre-treatment of rice husks shown in Table 4.

Table 3. Miscellaneous *Pre-treatment* Biogas from Rice Husks

Substrate	Pre-treatment	Types of Pre-treatment	Operating Conditions	Result	Reference
Rice Husk	NaOH and microbial consortium additions	Combine Pretreatment	In this study, the variations in NaOH concentrations used as chemical pre-treatment were 3%, 6%, and 9% and the variations in microbial consortium concentrations used as biological pre-treatment were 5%, 8%, and 11%. Utilizing rice husk waste as a substrate, 21% of the total solids were employed, and the C/N ratio was 25. For 60 days, the amount of biogas generated is measured every two days.	The highest biogas production was obtained in pre-treatment using 6% NaOH which was 497 ml and pre-treatment treatment with microbial consortium using microbial consortium 11% which was 667.5 ml.	Agnesia et al., 2017
Rice Husk	Addition of NaOH	Chemical Pretreatment	The study was conducted at room temperature using a batch setup. At 25°C, the C/N ratio is fixed. There is a range of 5%, 7%, 9%, 19%, 21%, and 23% in the total amount of solids (TS). In order to do chemical pre-treatment, 3% NaOH (g/g solution) is added, and it is then left for 24 hours.	At a TS ratio of 19%, or 935.5, the maximum productivity volume for rice husks was achieved. In TS of 5, 7, 9, 19, 21, and 23%, the specific biogas output is 57, 56.64, 45.36, 24.62, 15.15, and 12.45 ml/g TS, respectively. Compared to SS-AD settings, the TS content in L-AD is greater.	Saputri et al., 2017
Rice Husk	Enzymatic pre-treatment using lignase enzymes	Biological Pretreatment	The total solids (TS) in the batch system used for the investigation were fixed at 21% at room temperature. The C/N ratio, or carbon to nitrogen ratio, ranges from 20 to 35.	According to the study's findings, enzymatic pre-treatment could boost biogas output by anywhere between 30 and 55 percent. The C/N ratio of 35 yielded the most amount of biogas. For C/N ratios of 20, 25, 30, and 35, the specific biogas output is 12.0, 12.6, 13.5, and 18.2 ml/gTS, respectively.	Matin et al., 2016
Rice husk	Pre-treatment using acid (H2SO4), alkaline (NaOH) and thermal methods	Combine Pretreatment	Alkaline solution of NaOH 1 and 2% in autoclave at 121°C and 15 psi, as well as thermal technique (at various times in autoclave at 121°C and 15 psi), were used to pre-treat rice husk with H2SO4 for one hour at 121°C and 15 psi. The solution undergoes filtering following each pre-treatment. Rice husks are placed in the bioreactor both before and after pre-treatment (RPM 200, temperature 37°C, pH 6.5, HRT 36 hours).	Numerous deignification techniques have been employed, and they have shown promise in producing biogas. The acid deignification process removes the most lignin, yielding 76% methane. 71% methane may be produced via alkaline depigmentation and digestion, but 73% methane can be produced by heat treatment.	Sharma et al., 2014
Rice Husk	Pre-treatment with acetic acid and nitric acid and using a fixed variable microbial consortium 5%	Combine Pretreatment	acid variations with levels of 3% and 5% and soaked for 24 hours. The study was conducted using the Solid State Anaerobic digestion (SS-AD) method with 21% TS.	CH_3COOH 5% and 3% early treatments resulted in biogas yields of 43.28 ml/g.TS and 45.86 ml/g.TS, respectively. In the meantime, 29.51 ml/g.TS was the yield of biogas without pre-treatment. Using HNO_3 5% and 3% for preparatory treatment resulted in biogas yields of 12.14 ml/g/TS and 21.85 ml/g.TS, respectively. Compared to biogas treated with nitric acid, biogas treated with acetic acid yields a higher yield.	Keumala et al., 2017
Rice Husk	Pre-treatment	Chemical Pretreatment	The variations of pre-treatment bases with NaOH were 3%, 6%,	The yield of biogas produced with NaOH pretreament for 24 hours	Permana et al., 2017

Substrate	Pre-treatment	Types of Pre-treatment	Operating Conditions	Result	Reference
	with NaOH and the variations used were 3%, 6%, 9%, and 11%, then the variation in the duration of soaking for 24 and 48 hours for each variation.		9%, and 11% with soaking times of 24 hours and 48 hours. Using the Solid State Anaerobic digestion (SS-AD) method with 21% TS	with levels of 3%, 6%, 9%, and 11% was 44.27 ml/g.TS, 43.11 ml/g.TS, 44.78 ml/g.TS, and 37.96 ml/g.TS. Meanwhile, in 48-hour NaOH pre-treatment with levels of 3%, 6%, 9%, and 11%, it was 41.69 ml/g.TS, 28.18 ml/g.TS, 19.81 ml/g.TS, and 35.77 ml/g.TS. So the yield of biogas with 24-hour NaOH pre-treatment is better than 48-hour NaOH pre-treatment.	
Rice Husk	Pre-treatment with Alkaline Peroxide (0%, 2.5%, 5%, 7.5%, and 10% concentration variations) in the manufacture of Ethanol and by determining the influence of stirring speed and temperature.	Chemical Pretreatment	The pre-treatment operating conditions were stirring speeds of 0, 100, 150, 200, and 300 rpm, then H2O2 concentrations of 0%; 2.5%; 5%; 7.5%; and 10% and with temperatures of 25°C, 35°C, and 45°C. Then the enzymatic hydrolysis stage with Novozyme Cellusoft-L cellulase of 0.12 mL/g husk at a temperature of 50°C and pH ± 4.8 for 72 hours. Then followed by fermentation using Fermipan at a temperature of 33°C and pH 5.	The results showed that 7.5% H2O2 with a temperature of 45°C produced at least 4%-5%-w/w ethanol. Stirring did not have a big effect on the cellulose and lignin levels of rice husks. Increasing operating temperatures from 25°C, 35°C, and 45°C tends to slightly increase glucose and cellulose levels.	Inggid et al., 2011
Rice husk	Pre-treatment with NaOH 3% g/g TS by letting it sit for 24 hours, and addition of microbial consortium	Combine Pretreatment	This study was carried out in a mesophilic state with a temperature (25-35°C) and a batch system. In chemical pre-treatment, rice husks are soaked with NaOH as much as 3% g/g TS and then let sit for 24 hours. Then in the biological pre-treatment, the pH is adjusted by adding HCl after the neutral pH is added microbial consortium 5% g/v. Then the substrate from the pre-treatment is mixed with bovine rumen and urea until the volume becomes 300 ml. TS varied from 5%, 7%, 9%, 11% (L-AD) and 17%, 19%, 21%, 23% (SS-AD).	Using the L-AD technique, rice husks produce the highest biogas when NaOH and a microbial consortia are added, yielding a total output of 46.44 ml/gTS.	Budiyono et al., 2019

4. CONCLUSION

Waste from rice husks is one of the biomass that is suitable for use as a raw material for producing biogas. There are several factors that affect biogas production, namely pre-treatment, temperature, acidity (pH), total solid content (TS), C/N ratio, and mixing materials with other raw materials or co-digestion. Biogas produced without going through the initial stage or pre-treatment stage is still quite small, so it is necessary to do a pre-treatment stage to help lignin compounds degrade quickly which will increase the production of biogas. This technology can be developed in Indonesia because it can reduce the accumulation of rice husk waste and has the potential to become one of the main alternative energy for people in Indonesia in the future.

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