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Comparison of Syngas Gasification Results of Teak Sawdust and Mahogany Sawdust

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ABSTRACT

Indonesia has many sources of biomass. Biomass is an alternative energy source that is environmentally friendly, economical, and renewable. The gasification process can be the process of converting biomass into energy. Gasification is a technology for converting solid materials into syngas (CO, H_2, and CH_4) for fuel. Wood sawdust from furniture processing is biomass that can be used as raw material for gasification in this study. This study aimed to determine the syngas concentration from the gasification of teak sawdust and to compare it with the syngas from the gasification of mahogany sawdust. The stages of the research method start from drying raw materials in the sun, weighing raw materials with varied masses, gasifying raw materials with variations in the mass of raw materials, taking samples of gas products, analyzing gas products to determine levels of syngas (CO, CH_4, and H_2). The results showed that teak sawdust can be converted into gas fuel or syngas through gasification. Syngas from teak sawdust has more CO content by 16.75% than mahogany sawdust by 8.135%. Syngas from mahogany sawdust has more H_2 content by 17.47% than syngas from teak sawdust by 6.615%.

1. Introduction

Gasification is a leading technology for converting biomass into energy and serves as an attractive alternative for the thermal treatment of solid waste [1]. This process produces a combustible gas [2], which can be utilized for energy generation. Alongside gasification, biodiesel also represents a viable renewable energy source [3][4]. The Lurgi fixed-bed gasifier, developed in 1936 in Böhlen, Germany, was the first commercial high-pressure, oxygen-blown gasifier [5]. In Indonesia, research and production of biomass gasification stoves have been actively pursued to expand renewable energy applications [6][7][8]. Biomass gasification has been widely studied for its potential to generate sustainable energy, with research highlighting the influence of feedstock properties and operating conditions on syngas quality [9].

Biomass refers to organic materials derived from the photosynthetic process, encompassing both primary products and waste. Typically, biomass used as fuel has low economic value or consists of by-products after primary material extraction. In the wood industry, logs and slivers are repurposed for blockboard and particleboard production, while sawdust remains underutilized. Although some sawdust waste is used as fuel for stoves or is simply burned—leading to environmental pollution [10]—its potential as an energy source remains largely untapped, especially in small-scale sawmills. Larger industries have commercialized sawdust waste into charcoal briquettes and activated charcoal, but widespread utilization is still lacking in smaller, rural sawmills [11].

Various biomass sources are commonly used for gasification, including plantation by-products such as palm shells and empty fruit bunches [12], tamarind fruit shells [13], and agricultural residues like bagasse [14]. Additionally, waste from the furniture industry, including coconut sawdust [15], sengon sawdust [16], and mahogany sawdust [17], has been explored as potential feedstock. Studies have demonstrated the feasibility of teak and mahogany sawdust for biomass gasification, achieving promising syngas compositions and cold gas efficiency values [18].

Repurposing furniture waste for gasification offers several advantages. First, it enhances overall energy efficiency by harnessing the significant energy content of waste materials that would otherwise be discarded. Second, it reduces disposal costs, as waste management can be more expensive than repurposing. Third, it mitigates landfill demand, an increasingly pressing issue in urban areas. A comprehensive review of biomass gasification technologies emphasizes the importance of feedstock selection and process optimization for sustainable energy production [19]. Furthermore, recent studies have investigated the modeling and optimization of syngas production, highlighting key parameters that influence efficiency [20].

Given the need for efficient wood utilization, sawdust can be transformed into alternative fuels rather than being discarded. Experimental studies have demonstrated that when used in small-scale downdraft gasifiers, teak sawdust can achieve a higher heating value of 2.84 MJ/Nm³ and a cold gas efficiency of 66.36% [21]. Additionally, integrated biomass pyrolysis and gasification processes from teak wood waste have shown promising results in syngas production [22]. Therefore, this study aims to compare syngas' gasification characteristics derived from two furniture waste types: teak sawdust and mahogany sawdust.

2. Research Methodology

2.1. Materials

The material used in this study was teak sawdust. Teak sawdust was obtained from a furniture craftsman who produces doors, windows, and other products in Kalasan, Sleman Regency, Yogyakarta, Indonesia.

The research tools consist of a gasification unit (gasification reactor, blower, and thermocouple), as shown in Fig. 1, and a density measuring device and gas sampling tool.

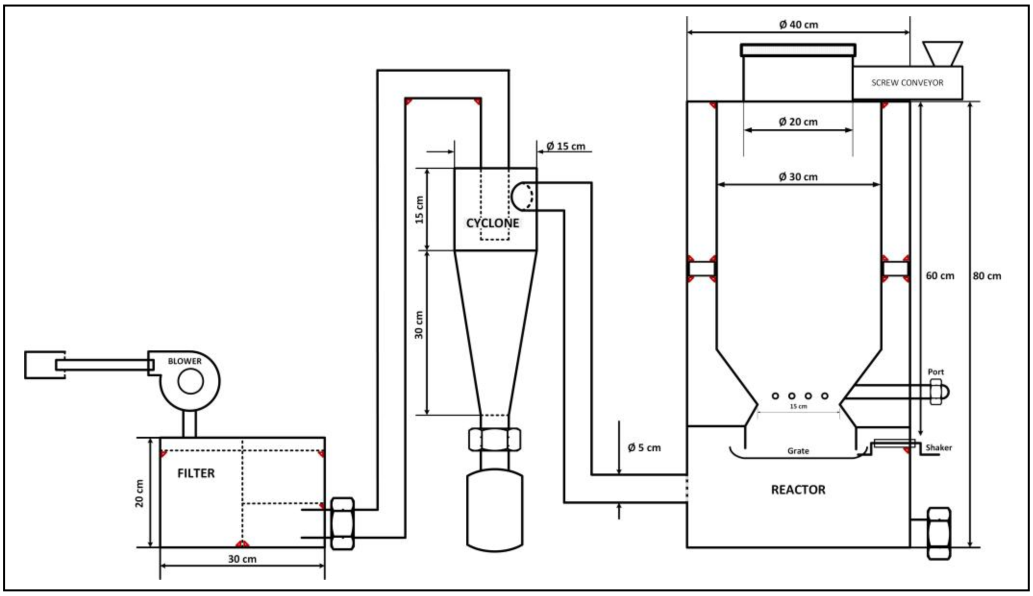

Fig. 1. Gasification unit

2.2. Procedures

In this study, the independent variable was teak sawdust weight. At the same time, the dependent variables that will be obtained are syngas output, gasification temperature, and the time needed to produce syngas. The research stages are described in Fig. 2.

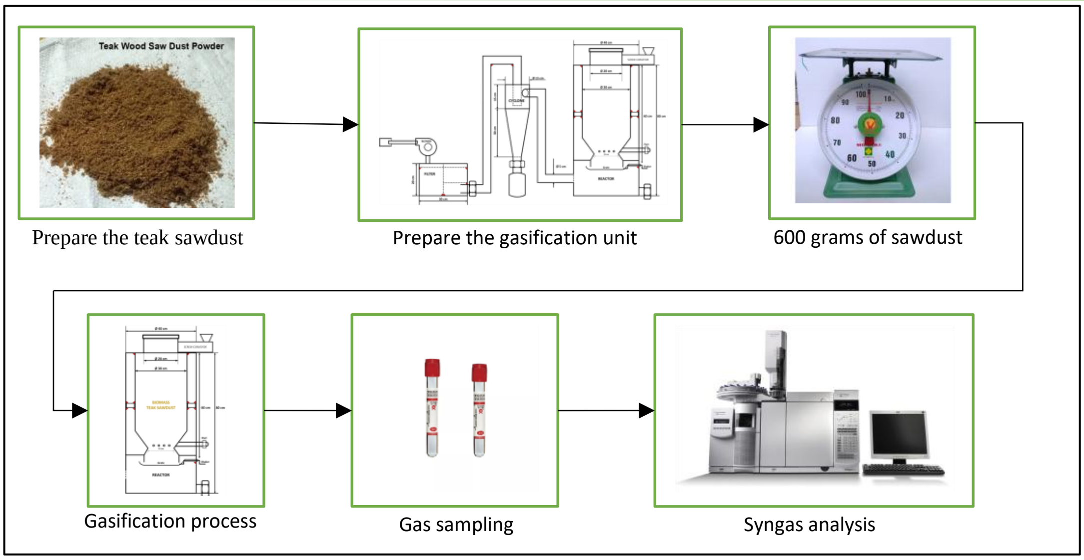

Fig. 2. Research procedure

2.3. Analysis Method

In this study, the independent variable was teak sawdust weight. At the same time, the dependent variables that will be obtained are syngas output, gasification temperature, and the time needed to produce syngas. The research stages are described in Fig. 2.

The results of gasification of biomass in the form of gas were analyzed for its gas content components using gas chromatography analysis at the UGM Chemical Engineering Instrument Analysis Laboratory.

The data obtained from this research are the time syngas are produced, and the concentration of syngas resulting from Gas Chromatography Analysis at UGM is processed in tables or graphs. Tables or graphs of syngas concentrations are compared with syngas data from the gasification of mahogany sawdust.

3. Results and Discussion

The data obtained during the research is the temperature in the reactor (top and bottom temperature) with an interval of 10 minutes. Syngas are collected using an injection and then put into a vacuum tube to be tested in the laboratory. This test aims to determine the composition of the syngas produced.

3.1. Effect of Feed Weight on Syngas

To assess the effect of feed weight on syngas production, the study considered two important variables: the weight of the remaining ash and the weight of tar. These parameters were then used to determine the syngas yield for varying amounts of teak sawdust. The results are presented in Fig. 3.

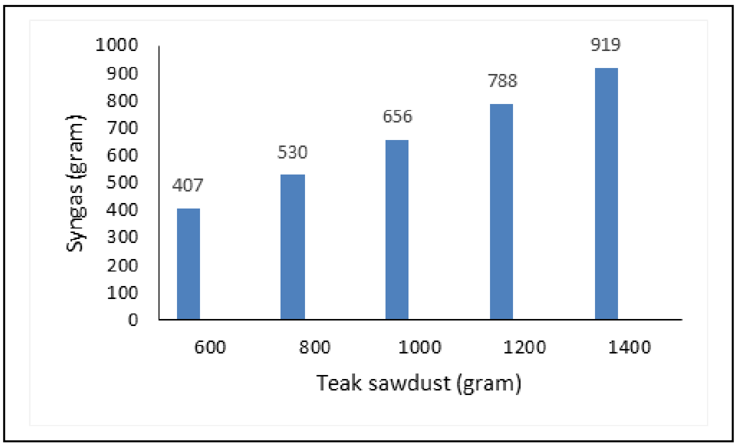

Fig. 3. Graph of Teak Sawdust Weight vs Syngas Weight

Fig. 3 shows a clear positive relationship between the amount of teak sawdust fed into the system and the weight of the syngas produced. Specifically, when 600 grams, 800 grams, 1000 grams, 1200 grams, and 1400 grams of teak sawdust were used, the corresponding syngas yields were 407 grams, 530 grams, 656 grams, 788 grams, and 919 grams, respectively. This observation indicates that higher feed weights lead to an increase in syngas production.

This finding is consistent with similar studies in the field. For instance, in [22], it was reported that an increase in biomass feedstock weight results in a proportional increase in syngas yield due to the greater availability of carbon sources for gasification. Similarly, in [23], it was demonstrated that feedstock weight plays a significant role in syngas production, with higher feed amounts leading to greater syngas generation and energy recovery. Moreover, [24] emphasized that biomass type and feedstock weight are key determinants of syngas composition, showing a direct correlation between biomass feed weight and syngas yield. However, they also noted that syngas production may plateau after a certain feed weight due to reactor capacity limitations.

This consistent pattern across multiple studies underscores the general principle that increasing feed weight improves syngas yield. However, it also suggests that optimal feed quantities should be carefully considered to avoid diminishing returns, a point that could be explored further in future studies.

3.2. Effect of Feed Weight on Syngas Expenditure Time

In this study, the combustion gases were triggered by fire to assess the release time of syngas, along with the corresponding weight of the remaining ash and tar. The time data collected allows for an evaluation of how teak sawdust's feed weight influences syngas' release, offering insights into its presence and combustion characteristics. The relationship between the weight of teak sawdust and syngas production time is illustrated in Fig. 4.

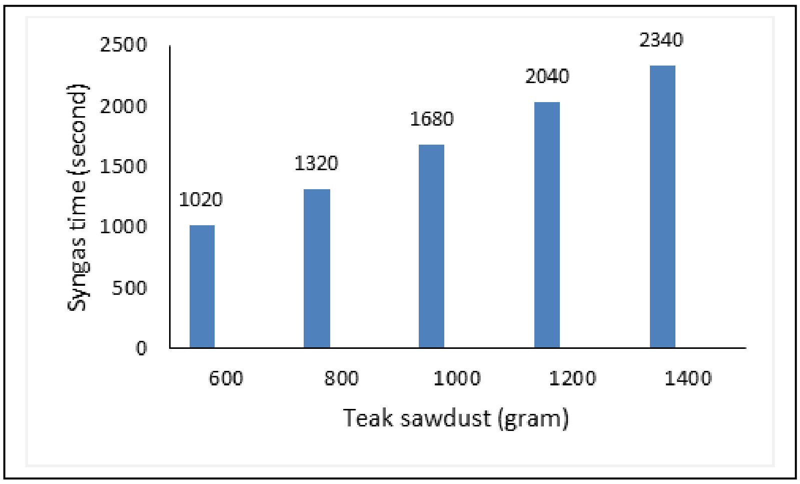

Fig. 4. Graph of Teak Sawdust Weight vs. Syngas Production Time

As seen in Fig. 4, increasing the weight of teak sawdust directly impacts both the weight of syngas produced and the time it takes for the syngas to be released. When varying the weight of teak sawdust (600 g, 800 g, 1000 g, 1200 g, and 1400 g), the corresponding syngas weights produced were 407 g, 530 g, 656 g, 788 g, and 919 g, respectively. This data highlights a positive correlation between the amount of teak sawdust fed and the volume of syngas generated, suggesting that larger feed quantities enhance syngas production. These findings are consistent with previous researchers [25], who reported that increasing feedstock weight in biomass gasification systems results in higher syngas yields.

Furthermore, the release time of syngas also increased with the feed weight. For the respective feed weights, the syngas release times were observed to be 1020 s, 1320 s, 1680 s, 2040 s, and 2340 s. This trend indicates that heavier feed weights lead to a longer syngas combustion duration, likely due to the greater quantity of material requiring time to combust fully. Previous researchers have observed similar results [26], who found that higher feedstock quantities extended syngas release times due to more extensive combustion processes.

The results from this study demonstrate a clear relationship between the weight of the teak sawdust feed and both the quantity and duration of syngas production. As the feed weight increased, the weight of syngas generated and the time required for its combustion showed a consistent rise. This suggests that the fuel mass directly influences the syngas release and burning time, which may be attributed to the higher amount of material undergoing pyrolysis and combustion in the system. These findings align with similar studies [27] and [28], which observed that an increase in feedstock mass corresponds to longer syngas production times and higher syngas yields in biomass combustion systems.

In line with the previous findings [29], who examined biomass feedstock in gasification, it is evident that optimizing the feed weight is crucial for maximizing syngas production efficiency. The observed increase in syngas yield with higher feed weight has significant implications for scaling up biomass-to-energy technologies. Furthermore, the longer combustion times observed in our study suggest that adjusting the feed rate could provide more controlled and sustained syngas generation, a consideration critical for energy systems seeking to balance efficiency and output.

These results have practical implications in energy production, where controlling the feedstock weight can help optimize combustion processes and syngas output for various applications, such as in bioenergy plants and gasification systems.

3.3. Syngas Composition

The gasification process produces syngas, a mixture of various gases, including carbon monoxide (CO), methane (CH_4), and hydrogen (H_2). These components are crucial for evaluating the syngas' quality and potential energy content produced from different feedstocks. In this study, syngas were produced from teak sawdust and mahogany sawdust, and the concentrations of CO, CH_4, and H_2 were analyzed and compared, as shown in Table 1.

Table 1. Syngas concentration comparison

Syngas Component	Concentration (%)	
	Teak Sawdust	***Mahogany Sawdust***
CO	16.725	8.135
CH_4	2.648	1.183
H_2	6.615	17.047

From the data, it is evident that the syngas produced from teak sawdust have higher concentrations of carbon monoxide (CO) and methane (CH_4). In contrast, the syngas from mahogany sawdust exhibit a significantly higher hydrogen (H_2) concentration.

Carbon Monoxide (CO): The syngas produced from teak sawdust contains 16.725% CO, which is considerably higher than the 8.135% CO found in syngas from mahogany sawdust. This difference can be attributed to the chemical composition and pyrolytic behavior of the two types of biomass. Teak sawdust may have a higher content of cellulose and hemicellulose, which, during gasification, tend to produce higher amounts of CO. CO is an important component of syngas because it is a potential fuel for combustion and can be used in the synthesis of chemicals and fuels. Similar findings were reported [30], which found that biomass rich in cellulose, like hardwoods, typically produces higher CO concentrations during gasification due to the decomposition of these polysaccharides.

Methane (CH_4): The concentration of methane in the syngas produced from teak sawdust (2.648%) is higher than that from mahogany sawdust (1.183%). Methane is a valuable component in syngas as it is a clean-burning fuel. The higher methane concentration from teak sawdust suggests a more favorable decomposition of organic material, leading to methane formation, which may improve the overall energy content of the syngas. Previous researchers [31] also observed that biomass types rich in lignin and cellulose produced higher methane concentrations due to the pyrolytic breakdown of these components. In contrast, [32] noted that lignocellulosic biomass materials with a higher lignin-to-cellulose ratio produced lower methane and higher CO during gasification.

Hydrogen (H_2): The syngas from mahogany sawdust has a notably higher concentration of hydrogen (17.047%) compared to teak sawdust (6.615%). Hydrogen is a key component in syngas as it is a clean fuel with high energy content. The higher hydrogen concentration in syngas from mahogany sawdust could be due to the different chemical compositions of the two types of biomass, as mahogany sawdust may have a higher proportion of lignin or other compounds that promote hydrogen production during gasification. Previous researchers [33] found that biomass with a higher lignin content produced higher hydrogen yields, especially during high-temperature pyrolysis. This is consistent with the higher hydrogen concentration observed in syngas from mahogany sawdust, which suggests it may be more suitable for applications requiring hydrogen as a feedstock, such as hydrogen fuel production or fuel cell technology.

These differences in syngas composition reflect the variability in the chemical properties of different biomass materials. Previous studies have also reported significant variations in syngas composition depending on the feedstock used for gasification. For instance, previous researchers [34] found that biomass type influences the relative concentrations of CO, CH_4, and H_2, with cellulose-rich materials typically producing higher CO and CH_4 concentrations. In contrast, lignin-rich materials tend to produce higher hydrogen content during gasification. Furthermore, previous researchers [35] highlighted that the gasification conditions, such as temperature and residence time, could also influence syngas composition, particularly the hydrogen yield.

In conclusion, the syngas composition from teak sawdust and mahogany sawdust shows significant differences, with teak sawdust producing more CO and CH_4, while mahogany sawdust yields higher hydrogen concentrations. These findings suggest that the choice of feedstock is an important factor in determining the suitability of syngas for specific applications, such as power generation, chemical synthesis, or hydrogen fuel production.

4. Conclusion

Teak sawdust can be converted into gas or syngas fuel through gasification. Syngas from teak sawdust has more CO content than syngas from mahogany sawdust. Syngas from mahogany sawdust has more H_2 content than syngas from teak sawdust.

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