

## A Study Of Bio-Oil Derived From Rice Husk Using Pyrolysis As A Potential Gasoline Additive

Mochammad Ilham Alafi Habibi<sup>1</sup>, Muhammad Reno Aldiansyah<sup>1</sup>, Nanda Ahmad Wijaya<sup>1</sup>, Maulana Erik Cantona<sup>1</sup>, Naili Zulfatul Jannah<sup>2</sup>, Akhmad Faruq Alhikami<sup>1\*</sup>  
<sup>1</sup>Department of Mechanical Engineering, Universitas Islam Malang, 65144 Malang, Indonesia

<sup>2</sup>Department of Agrotechnology, Universitas Islam Malang, 65144 Malang, Indonesia  
\*Corresponding author: alhikami@unisma.ac.id

### ABSTRACT

*Biomass energy is an alternative solution for reducing emissions compared to traditional energy sources because biomass is a carbon-neutral resource. In this study, rice husk biomass was processed using pyrolysis technology at temperatures of 250°C, 300°C, and 350°C, with retention times of 60 and 90 minutes. The crude pyrolytic oil was then refined through a distillation process to improve its quality, followed by chemical and physical composition tests. The results showed that the highest yield of crude pyrolytic oil was obtained at a temperature of 300°C with a retention time of 90 minutes. A longer pyrolysis duration indicates that thermal decomposition was more optimal for obtaining the liquid product. The distillation process produced oil with more than 90% of its carbon chains in the gasoline range (C7-C11). Additionally, around 80% of phenolic compounds were detected in the bio-oil, making it a viable option as a fuel additive. The bio-oil derived from rice husk waste had a calorific value of 1777.24 cal/gram, indicating its potential as a gasoline blend alternative fuel.*

*Keywords: bio-oil, distillation, pyrolysis, phenolic, rice husk*

## INTRODUCTION

Energy is a fundamental need that continues to grow in demand alongside the increasing population and economic development of a country. One of the most critical energy sources is fuel oil (BBM) (Yaşar, 2020). BBM is essential not only for transportation but also as a driver of economic growth and national income. However, BBM derived from fossil fuels contributes to harmful exhaust emissions, which pose risks to human health, degrade the environment, and exacerbate climate change. In contrast, biomass-derived fuels have been shown to reduce exhaust emissions and utilize environmentally friendly raw materials significantly (Alhikami et al., 2022; Hsu et al., 2024). An effective approach to supporting sustainable transportation is to use biofuels derived from biomass, such as biodiesel, bio-aviation fuel (bioavtur), and biogasoline (Duarte Souza Alvarenga Santos et al., 2021).

Biofuels can be produced from various raw materials, including vegetable oil, animal fat, used cooking oil, and agricultural waste. Production techniques include hydrolysis, pyrolysis, hydrocracking, and transesterification. For instance, Huang et al. (2020) successfully produced bioethanol and bioethanol from sugarcane bagasse waste using hydrolysis technology. Wang and Hsieh (2020) synthesized bio-oil from rice husk waste using pyrolysis followed by hydrocracking to produce aviation fuel. Additionally, Özçimen et al. (2020) produced bioethanol from *Nannochloropsis* sp. microalgae through hydrolysis.

Rice husk, a byproduct of rice milling, is a significant agricultural waste in wetland farming. One way to enhance the value of rice husk waste is through pyrolysis, which converts it into bio-oil (Chen et al., 2021; Das & Goud, 2021; Ma et al., 2018). In Indonesia, a large portion of rice husk is either discarded or burned in open spaces, contributing to environmental pollution. Rice milling typically yields 20-30% rice husk, with the remainder being rice bran (Nasywa and Sa'diyah, 2023). The abundant availability of rice husk presents a great potential for fuel production via pyrolysis. This process involves burning rice husk in a pyrolysis reactor and utilizing the resulting pyrolysis gas as an energy source (Chen et al., 2021).

Previous research on converting agricultural waste like rice husk using pyrolysis technology primarily focuses on producing bio-oil. However, bio-oil typically has high density, viscosity, acid content, oxygen content, and complex carbon chains, making it unsuitable for direct use in combustion engines. Therefore, our research proposes an additional step: distilling the bio-oil at specific temperatures and durations to enhance its quality, as suggested by Panwar and Paul (2021). The distillation process breaks down long carbon chains, producing shorter-chain compounds closer to the gasoline range. The resulting biogasoline will then undergo a series of chemical and physical tests to assess its suitability as an alternative fuel.

## METHOD

### 2.1 Experimental materials

The tools and materials used in this research included rice husk waste obtained from local agricultural fields. The tools consisted of scales for measuring the rice husks to be processed, ovens for drying the sterilized rice husks, pyrolysis equipment for producing bio-oil by heating the rice husks to a specified

temperature, and nitrogen cylinders for pushing steam from the pyrolysis process into the condenser. Distillation equipment was used to separate the chemical compounds in the bio-oil. Additionally, various laboratory tools such as analytical scales, Erlenmeyer flasks, beakers, funnels, filter paper, bottles, and pipettes were employed.

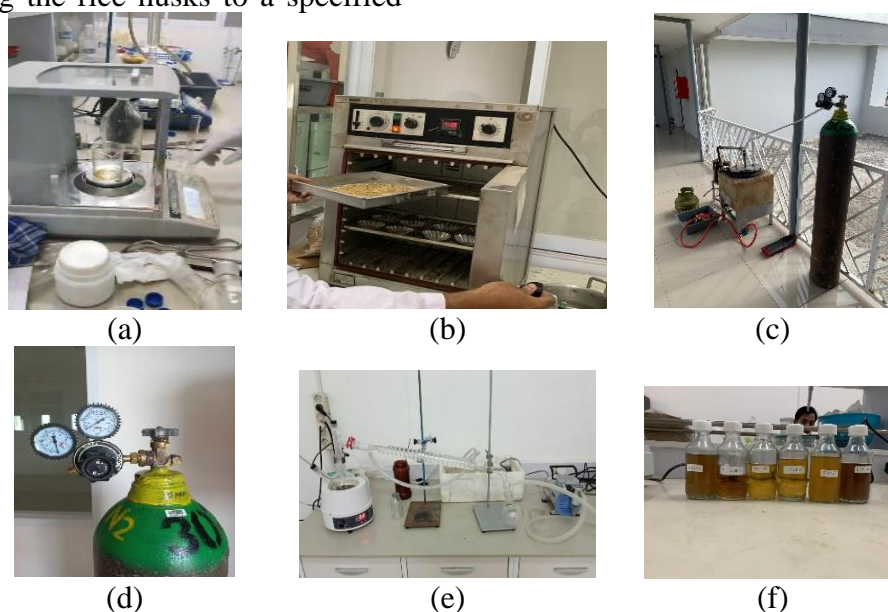


Figure 1. a). Scales, b). oven, c). pyrolysis apparatus, d). nitrogen, e). distillation apparatus, and f ). bottle.

### 2.2 Experimental procedure

In general, this research procedure is divided into seven activities: (1) collecting rice husk waste from local agricultural fields, (2) weighing 500 grams of rice husk for each production process, (3) cleaning the rice husk waste using distilled water, (4) drying the rice husk waste in an oven at 110°C for 24 hours, (5) performing pyrolysis to obtain bio-oil

from the rice husk waste at temperature variations of 250°C, 300°C, and 350°C for durations of 60 and 90 minutes, (6) distilling the obtained bio-oil at a temperature range of 30-180°C to produce bio-gasoline with high selectivity, and (7) testing the distillation products chemically and physically to determine the characteristics of the bio-oil. The design of the research procedure is illustrated in Figure 3 and Figure 4.

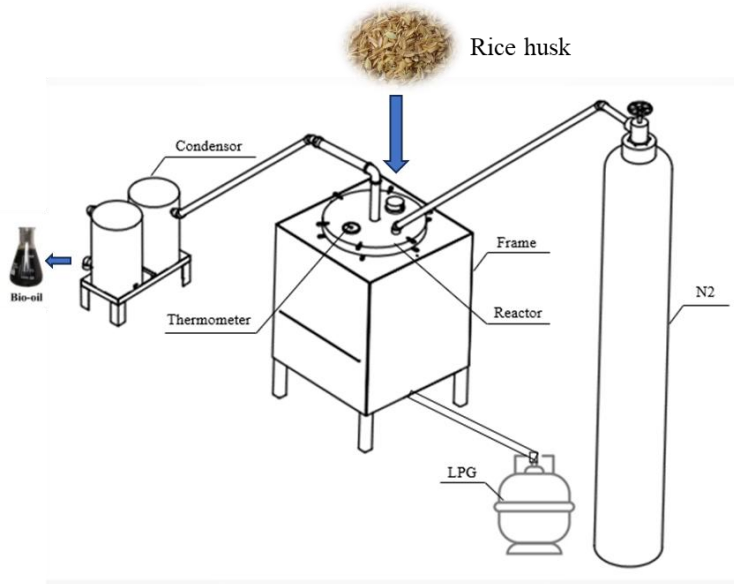


Figure 3. Illustration of pyrolysis setup

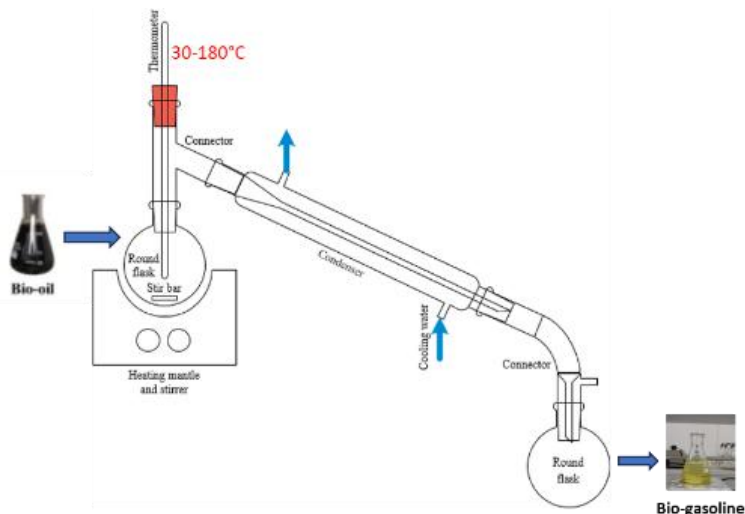


Figure 4. Illustration of distillation setup

The pyrolysis process was conducted at temperature range 250, 300, and 350 C, and the retention time of 60 and 90 minutes as optimized by Marlina and Raharjo (2023). A constant nitrogen pressure of 0.5 bar was used as an inert gas to remove oxygen during the pyrolysis process. This results in a total of six sample variations. From these experiments, the variation that produces the highest liquid yield will be identified. The

distillation process will then be conducted at a temperature range of 30-180°C, which corresponds to the gasoline range. The quality of the bio-oil will be evaluated by identifying its chemical and physical properties. The yield calculations are performed using the following equation:

$$Liquid\ yield\% = \frac{m_{liquid}}{m_{feed}} \times 100 \quad (1)$$

$$\text{Char yield\%} = \frac{m_{\text{char}}}{m_{\text{feed}}} \times 100 \quad (2)$$

$$\text{Gas yield\%} = 100 - (\% \text{Liquid} + \% \text{Char}) \quad (3)$$

### 2.3 Data analysis

The pyrolytic product was divided into liquid, gas, and char. This study focused on the liquid product, which underwent further testing to identify its physical and chemical properties. The chemical composition of the bio-oil was analyzed using gas chromatography-mass spectrometry (GC-MS) (GCMS-QP2010 SE, Shimadzu, Kyoto, Japan). The physical properties, including density, viscosity, and heating value, were also measured to characterize the bio-oil.

## RESULTS AND DISCUSSION

### 3.1 Pyrolytic product

Figure 6 shows the results of bio-oil production using rice husk waste as a raw material, which underwent pyrolysis processes. The data were collected using temperature variations of 250°C, 300°C, and 350°C, with durations of 60 minutes and 90 minutes, as depicted in Figures 5 and 6. The highest yield of liquid bio-oil, 37.52%, was obtained at 300°C for 90 minutes. The highest charcoal yield, 77.09%, was recorded at 250°C for 60 minutes, while the highest gas yield, 45.46%, occurred at 350°C for 90

minutes. As shown in Figures 5 and 6, increasing the pyrolysis time from 60 to 90 minutes resulted in a liquid yield increase of up to 37.8%, while the char yield decreased by up to 55.8%. A longer pyrolysis duration indicates that thermal decomposition was more optimal for obtaining the liquid product. Moreover, pyrolysis temperature significantly affected bio-oil production. As shown in Figure 5, increasing the operating temperature from 250°C to 350°C led to a bio-oil yield increase of up to 21.7% when the retention time was extended to 90 minutes, as shown in Figure 6, raising the pyrolysis temperature from 250°C to 300°C further increased bio-oil yield by up to 40.5%.

This trend aligns with previous studies (Açıklın et al., 2012; Das & Goud, 2021). Das and Goud (2021) reported that increasing the pyrolysis temperature of acid-treated rice husk from 300°C to 430°C improved bio-oil yield by up to 28%. Additionally, extending the retention time to 40 minutes further enhanced bio-oil yield by up to 35.2% at 430°C. Similarly, Açıklın et al. (2012) observed that varying the reaction temperature from 350°C to 650°C resulted in a maximum bio-oil yield of 52.73% at 500°C. The bio-oil with the highest yield will be analyzed using GC-MS to determine its quality, as well as to quantify and identify the compounds present.

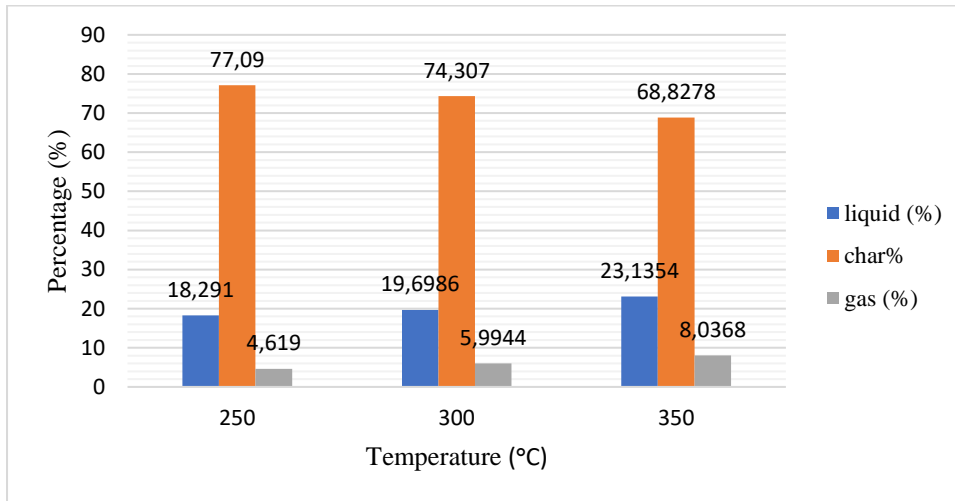


Figure 5. Results of pyrolytic products at a temperature of 250, 300, and 350°C at 60 minutes.

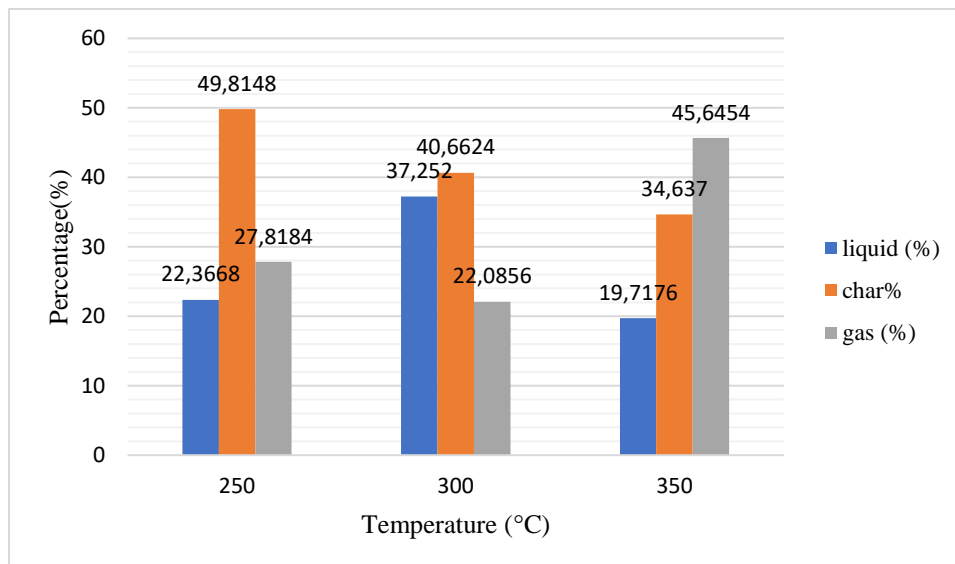


Figure 6. Results of pyrolytic product at a temperature of 250, 300, and 350°C at 90 minutes.

### 3.2 Chemical properties of pyrolytic oil

Figure 8 shows the carbon range of bio-oil after the distillation process, and Figure 9 illustrates the chemical composition of the bio-oil. According to Nugroho et al. (2023), gasoline typically contains carbon chains in the C7-C10 range, while diesel contains C11-C22. The tested bio-oil sample contained over 90% C7-C10, less

than 10% C11-C22, and a minimal amount of >C22 compounds. Additionally, the bio-oil had a phenolic content of 76.69% and aromatic hydrocarbons at 20.31%. These results indicate that the bio-oil's chemical composition closely matches the gasoline range.

Notably, the majority of the bio-oil composition is phenolic. According to previous studies (Badia

et al., 2021; Zhang et al., 2023), phenolic compounds are attractive gasoline additives that can increase the research octane number (RON) and reduce CO<sub>2</sub> emissions when blended with petroleum-based gasoline. Therefore, this research

demonstrates that simple pyrolysis can produce high-quality phenolic compounds. Furthermore, the significant aromatic hydrocarbon content in the bio-oil can enhance engine performance (Yuan et al., 2018)

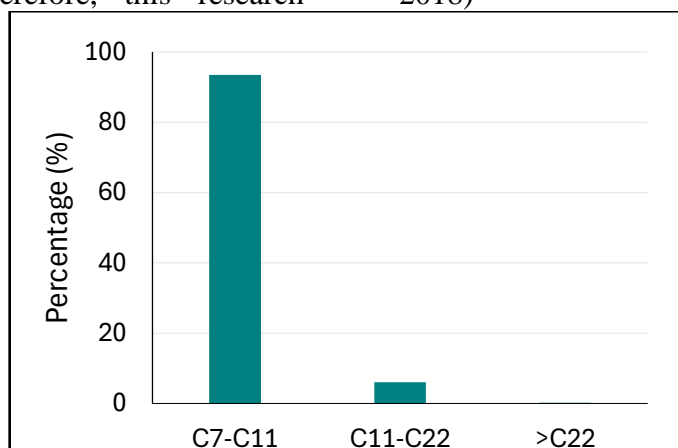


Figure 7. Carbon range content of the results GC-MS test.

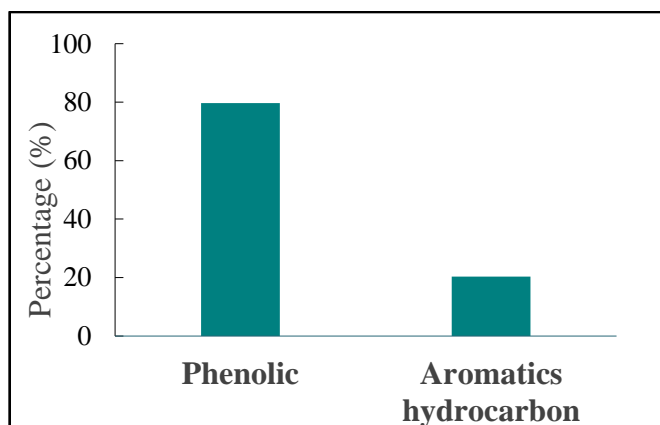


Figure 8. Bio-oil content of rice husk waste biomass.

### 3.3 Physical properties of bio-oil

The liquid bio-oil samples were tested for density, viscosity, and calorific value of the highest liquid yield. Results showed that the density, viscosity, and heating value of bio-oil is 0.861 g/ml, 6.48 cSt, and 1777.24 cal/gram.

### CONCLUSION

This paper investigated the pyrolysis of rice husk at temperatures of 250°C,

300°C, and 350°C, with retention times of 60 and 90 minutes. The crude pyrolytic oil produced from the pyrolysis process was subsequently distilled at temperatures ranging from 30°C to 180°C. The chemical composition of the bio-oil consisted of over 90% gasoline-range compounds, with phenolic compounds being the predominant product. The physical properties of the bio-oil showed a high calorific

value of 1777.24 cal/gram, indicating its potential as a fuel additive. This paper aims to provide insights into producing phenolic compounds from waste biomass as a potential fuel additive.

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