Volume 12. No 1, January 2025
e-ISSN 2527-9572 / p-ISSN 2354-8924

Efficiency of Sawdust as an Alternative Fuel to Replace Coal in Steam Power Plants

***Muhammad Facheruddin BJ**
Mechanical Engineering
Faculty of Engineering and Informatics
Patria Artha University
Jl. Tun Abdul Razak, Paccingang
kec. Somba Opu, Kabupaten Gowa
Sulawesi Selatan 90241
*muhammadfacheruddin@gmail.com

A. Besse Riyani Indah
Industrial Engineering
Faculty of Engineering
Hasanuddin University
Jl. Malino No.Km.6, Romang Lompoa, Kec. Bontomarannu
Kabupaten Gowa, Sulawesi Selatan 92171
a.besseriyani@gmail.com

Gerard Antonini Duma
Mechanical Engineering
Faculty of Engineering
Hasanuddin University
Jl. Malino No.Km.6, Romang Lompoa, Kec. Bontomarannu
Kabupaten Gowa, Sulawesi Selatan 92171
gantoniniduma@gmail.com

Article history: Received Nov 11, 2024 | Revised Jan 14, 2025 | Accepted Jan 15, 2024

***Abstract* – This study aims to test the effectiveness of sawdust as an alternative fuel to replace coal in a 50 MW power plant in an effort to reduce dependence on fossil fuels and have a negative impact on the environment. The use of coal in power plants produces high carbon emissions that contribute to climate change. Sawdust, as a by-product of the wood industry, is considered an environmentally friendly fuel because of its abundant availability and its calorific value close to coal. This study was conducted by measuring the calorific value, fuel consumption, and electrical energy output produced during power generation using sawdust compared to coal. The measurement results show that the calorific value of sawdust is 3900 kcal/kg, slightly higher than coal, which has 3878 kcal/kg. Although the fuel consumption of sawdust is almost equivalent to coal, the energy output produced by sawdust (47,090 kWh) is lower than coal (50,900 kWh). The thermal efficiency of sawdust is recorded at around 25.72%, slightly lower than coal, which has an efficiency of 27.76%. Despite its lower efficiency, these results suggest that sawdust can still be a viable alternative fuel, especially if emission reduction and desirability are priorities. This study shows that sawdust has the potential to be a more environmentally friendly energy source and support efforts to transition energy towards a more sustainable system.**

***Keywords:* *Sawdust, Coal, Alternative fuels, Power generation, Thermal efficiency*.**

I. INTRODUCTION

In recent decades, the increasing demand for energy worldwide has placed the energy sector at the forefront of global environmental issues. Most of the world's power plants still rely on fossil fuels, especially coal, to meet the ever-increasing demand for electricity. Coal is one of the most widely used energy sources due to its abundant availability and relatively low cost compared to other energy sources. However, the process of burning coal produces large amounts of carbon dioxide (CO_2), as well as particles and other chemical compounds that have negative impacts on air quality and human health. The increase in CO2 levels in the atmosphere due to coal combustion is one of the main triggers of global warming and climate change. Therefore, finding alternative fuels that are more environmentally friendly and sustainable is a top priority in global efforts to reduce the carbon footprint of the energy sector [1], [2].

One alternative fuel that is starting to attract attention is sawdust, which is a by-product of the wood processing industry. On a global scale, wood waste such as sawdust is available in quite large quantities and is often not utilized optimally. Sawdust is usually only disposed of as waste or used as fuel on a small scale. In fact, if utilized properly, sawdust has the potential to be a more environmentally friendly and sustainable fuel. The high calorific value of sawdust makes it suitable for use in power plants as an alternative to coal [3], [4]. By utilizing sawdust, the energy industry can not only reduce dependence on coal but also help reduce the volume of wood waste, thus supporting the principle of a circular economy [5].

The main reason for using sawdust as an alternative fuel is that sawdust is an abundant, sustainable, and easily accessible wood industry waste, especially in wood-producing areas. Its use as an alternative fuel can reduce waste, reduce energy costs, and support carbon emission reductions due to its more environmentally friendly nature than coal. In addition, its continuous availability makes it an economical energy source and has the potential to support the transition to sustainable energy.

Studies on sawdust as an alternative fuel are still in their early stages, but several studies have shown that sawdust can produce energy that is competitive with coal in terms of calorific value and fuel consumption. In addition, sawdust as a fuel tends to produce lower emissions than coal, especially in terms of carbon dioxide emissions and other hazardous particles [6].

The use of sawdust as a fuel also supports the concept of renewable energy because wood can be renewed through replanting trees. This is in line with global efforts to adopt sustainable energy sources to reduce negative impacts on the environment [7].

However, the use of sawdust as a fuel for large-scale power plants requires further study, especially in terms of combustion efficiency and energy performance. Unlike coal, which has stable and easily controlled combustion characteristics, sawdust has different physical and chemical characteristics that can affect the combustion process in power plant boilers [8]. Therefore, to assess the feasibility of sawdust as a coal substitute, a comprehensive analysis of thermal efficiency, fuel consumption, and energy output is needed [9]. Thermal efficiency is a key indicator in this study because it shows how effectively the energy from sawdust can be converted into electrical energy. The higher the thermal efficiency, the greater the potential for sawdust to replace coal as a reliable energy source [2].

This study focuses on the comparison of the thermal efficiency of sawdust with coal in a 50 MW power plant. This study includes an analysis of key parameters such as calorific value, hourly fuel consumption, and electrical energy output produced. These data are expected to provide an overview of the feasibility and performance of sawdust as an alternative fuel. This study also considers fluctuations in energy output during the combustion process to assess the stability of sawdust in generating electricity [5]. In addition, this study will discuss the potential of sawdust in supporting sustainable energy transitions and reducing the environmental impact of the power generation sector [3], [10].

Through this research, it is expected to gain a better understanding of the potential of sawdust as a viable alternative fuel for power plants. These findings can form the basis for the development of more environmentally friendly renewable fuels and help accelerate the adoption of renewable energy in the future. By utilizing local renewable resources such as sawdust, power plants not only contribute to reducing carbon emissions but also support the local wood industry and create added value for previously underutilized by-products [11].

II. METHOD

To determine the potential of sawdust as an alternative fuel, a one-hour test was conducted on a 50 MW power plant using coal as the main fuel and continued with one hour of testing using sawdust as an alternative fuel. The parameters analysed include:

1. Calorific Value (kcal/kg):

The calorific value is a measure of the energy content in a fuel per kilogram, which indicates how much energy can be produced when the fuel is completely burned. This value is usually measured by taking a sample of fuel from the bunker before the fuel enters the combustion chamber in a power plant. The measurement process is carried out using a tool such as a bomb calorimeter to determine the heat energy released during combustion. The calorific value is an important parameter for assessing fuel quality; fuel with a high calorific value is able to produce more energy than fuel with a low calorific value, thus affecting the efficiency of the power plant operation.

2. Fuel Consumption (kg/hour):

Fuel consumption refers to the amount of fuel used by a power plant in one hour of operation. This parameter is calculated to monitor overall fuel requirements, ensure adequate fuel supply, and assess the efficiency of the power plant. Fuel consumption is affected by various factors, including the calorific value of the fuel, the capacity of the power plant, and thermal efficiency. This measurement is usually carried out by monitoring the flow of fuel from the bunker to the combustion chamber using a flowmeter. The lower the fuel consumption per hour for the energy produced, the better the efficiency of the power plant.

3. Energy Output (kWh):

Energy output is the amount of electrical energy produced by the power plant in one hour of fuel combustion. This energy is measured in kilowatt-hours (kWh) and is an important parameter for evaluating power plant performance. Energy output depends on the efficiency of the power plant system, the type of fuel used, and the design of the turbine or generator. Measuring energy output helps operators understand how effectively fuel is converted into electrical energy and ensures that the power plant is able to meet targeted power needs. This data is also useful for calculating thermal efficiency and evaluating overall power plant performance. Data on the amount of energy produced can be seen on the DCS (Distributed Control System) monitor.

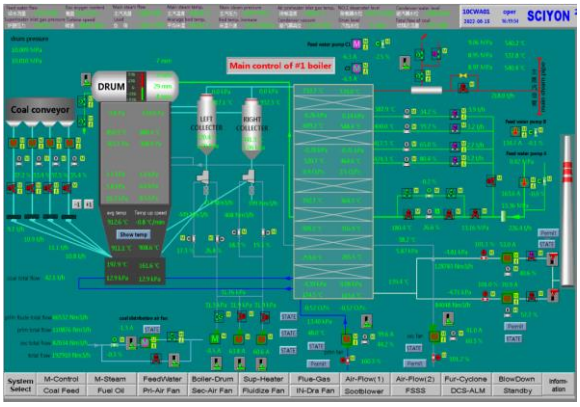

Figure 1. Distributed Control System

4. Thermal Efficiency (%):

Thermal efficiency is a measure of the effectiveness of the power plant system in converting available energy from the fuel into usable electrical energy. Thermal efficiency is calculated by comparing the electrical energy output (kWh) to the total heat energy available in the fuel, using the formula:

$$\eta_{\text{thermal}} = \frac{E_{\text{out}}}{\dot{m_{\text{fuel}}} \times L_{\text{cv}}} x\, 100\%$$

Description of the terms:

- η_{thermal} : Thermal efficiency (in percentage or decimal form)
- E_{out} : Energy output (the useful energy produced, such as mechanical energy or electricity, measured in units like joules or watt-hours)
- $\dot{m}_{\text{fuel}}$: Fuel consumption rate (the mass of fuel consumed per unit of time, measured in units like kg/s or kg/hour)
- L_{cv} : Calorific value (or heating value) of the fuel (the amount of energy contained in a unit of mass of fuel, typically measured in J/kg or kJ/kg)

Explanation:

- Energy Output (E_{out}): This refers to the useful energy generated by the system, such as mechanical work done by an engine or electricity produced by a power plant.
- Fuel Consumption Rate ($\dot{m}_{\text{fuel}}$): This represents the rate at which fuel is consumed by the system, typically measured in kilograms per second (kg/s) or kilograms per hour (kg/h).
- Calorific Value **(L_{cv})**: The calorific value of the fuel indicates how much energy is available in the fuel per unit mass. It reflects the fuel's energy potential when fully burned, and is typically measured in joules per kilogram (J/kg) or kilojoules per kilogram (kJ/kg).

The result is expressed as a percentage, with higher values indicating better energy conversion. Thermal efficiency is affected by various factors, such as boiler design, operating conditions, fuel type, and power plant technology. Maintaining high thermal efficiency is essential to reduce fuel costs and carbon emissions, thereby improving the sustainability of plant operations.

III. Results and Discussion

Based on one hour of observation, the following are the measurement results for each sawdust and coal fuel parameter:

Table 1. Parameter Operation data

Parameter	Coal (100%)	Sawdust (100%)
Calorific Value (kcal/kg)	3878	3900
Fuel Consumption (kg/jam)	40525	40521
Energy Output (kWh)	50900	47090

1. Calorific Value

The calorific value of sawdust reaches 3900 kcal/kg, slightly higher than coal, which is 3878 kcal/kg. This value shows that sawdust has an energy content comparable to coal, making it a viable candidate to replace coal in terms of energy availability [4], [5].

Figure 2. Sawdust

2. Fuel consumption

During the one-hour observation, sawdust fuel consumption was recorded at 40,521 kg, which was only slightly lower than coal consumption, which was 40,525 kg in the same time period. This result shows that sawdust fuel consumption is almost equivalent to coal, so the difference in the amount of material needed is very small. This fact shows that sawdust can be a competitive alternative as a fuel source [5].

This similar fuel consumption has an important influence in the context of placing fossil fuels such as coal with biomass fuels such as sawdust. Apart from the quantity of material needed, this factor also provides potential advantages in terms of environmental desirability. Sawdust, as a by-product of the wood industry, can be used to reduce dependence on non-renewable energy sources, which generally have a negative impact on the environment [3], [4].

From an energy efficiency perspective, the almost similar fuel consumption between sawdust and coal shows that the current combustion technology or system is able to optimize the use of biomass fuel. This is a major consideration in promoting the use of sawdust as a more environmentally friendly and sustainable renewable energy solution. In addition, the abundant availability of sawdust in several regions makes it an economical and strategic choice for local and industrial energy needs.

3. Energy Output and Thermal Efficiency

Energy output and thermal efficiency were calculated based on data obtained in a one-hour test for each fuel, as follows:

- Thermal Efficiency of Coal

$$\eta_{\text{thermal}} = \frac{E_{\text{out}}}{\dot{m_{\text{fuel}}} \times L_{\text{cv}}} x\, 100\%$$

$$\eta_{\text{thermal}} = \frac{50900 \text{ x } 860}{40525 \text{ x } 3878}\, x\, 100\%$$

$$\eta_{\text{thermal}} = 27.76\%$$

- Thermal Efficiency of Sawdust

$$\eta_{\text{thermal}} = \frac{E_{\text{out}}}{\dot{m_{\text{fuel}}} \times L_{\text{cv}}} x\ 100\%$$

$$\eta_{\text{thermal}} = \frac{47090 \text{ x } 860}{40521 \text{ x } 3900}\ x\ 100\%$$

$$\eta_{\text{thermal}} = 25.72\%$$

4. Hourly fuel usage graph analysis

From the graphs shown for each fuel during the 1-hour test period, there is an energy output pattern that shows differences in performance. Figure 2: The energy output graph for coal tends to be more stable with higher output, reflecting that coal provides optimal and consistent performance. Meanwhile, Figure 3: sawdust graph shows slight fluctuations in energy output, with slightly lower output values. However, this fluctuation is not too significant, and sawdust fuel consumption is still comparable to coal, indicating that sawdust can still produce energy close to coal in short-term use [5].

Figure 2. 100% coal graph for 1 hour

Figure 3. 100% sawdust graph for 1 hour

5. Interpretation of 1-Hour Observation Results

The comparison between energy output and thermal efficiency shows that sawdust has several advantages as well as limitations compared to coal as a fuel. Based on the analyzed graph, sawdust has a slightly higher calorific value compared to coal. This indicates that sawdust is theoretically capable of producing a large amount of energy when burned. In addition, the fuel consumption of sawdust, which is almost the same as coal during the combustion process, indicates that the amount of material required to produce energy is relatively balanced between the two [4], [5].

However, although sawdust has a higher calorific value, the actual energy output produced is slightly lower compared to coal. This can be attributed to the chemical composition of sawdust, which is different from coal. Sawdust as a biomass consists of cellulose, hemicellulose, and lignin, which have different combustion characteristics compared to the main components of coal, such as pure carbon and solid organic compounds [6]. The sawdust combustion process may produce more residue or ash, which can reduce the efficiency of energy transfer from the fuel to the power generation system [4].

In addition, the moisture content of sawdust is often higher than coal, even though it has been dried before hand. High humidity can absorb some of the heat during combustion, reducing the amount of energy actually available to generate electricity. Other factors, such as differences in combustion temperature, chemical reaction rates, and the efficiency of the combustion technology used, can also influence the difference in energy output [6], [7].

However, this slightly lower energy output difference is considered insignificant from an environmental and sustainability perspective. Sawdust is a more environmentally friendly fuel than coal because its combustion produces lower carbon emissions [4]. In addition, sawdust is a renewable resource, derived from the abundant waste of the wood industry, so its use can help reduce the accumulation of organic waste and improve resource efficiency [3], [7].

Additional benefits of using sawdust as a fuel include reduced greenhouse gas emissions, particularly carbon dioxide, sulfur dioxide, and nitrogen oxides, which are often higher when coal is burned. Thus, despite its slightly lower energy output, sawdust remains a competitive and sustainable alternative fuel, especially in the context of global efforts to reduce reliance on fossil fuels and increase the use of renewable energy.

IV. Conclusion

Based on the results of the research and analysis conducted, it can be concluded that sawdust has the potential as an alternative fuel to replace coal in a power plant with a capacity of 50 MW. In this test, sawdust was able to produce competitive energy output and thermal efficiency, although slightly lower than coal. The results of the analysis showed that sawdust has a calorific value of 3900 kcal/kg, slightly higher than coal, which is worth 3878 kcal/kg. This indicates that sawdust has an energy content equivalent to coal, which means that in terms of available raw energy, sawdust is able to compete with coal. In terms of fuel consumption, the use of sawdust in a one-hour test requires 40.521 kg of fuel, while coal requires 40.525 kg to produce energy output of 47.090 kWh and 50.900 kWh, respectively. This almost the same fuel consumption indicates that sawdust can function as an effective substitute in terms of the quantity needed per unit time [5]. However, the energy output of sawdust is lower than coal, which is also reflected in its thermal efficiency. The calculation of thermal efficiency shows that sawdust has an

efficiency of 25.72%, slightly lower than the efficiency of coal, which reaches 27.76%. This thermal efficiency shows that the power plant is able to utilize sawdust energy quite well, although not as optimally as coal. The analysis of the fuel usage graph for one hour also shows that sawdust produces a stable but slightly lower energy output than coal. The graph for coal shows a higher and more consistent output level, indicating a very efficient combustion performance. In contrast, the sawdust graph has some slight fluctuations in energy output, although overall, the results remain close to the output of coal. These fluctuations can be influenced by differences in the chemical composition of sawdust, which affect the combustion process but do not have a significant impact on its overall performance [5], [6].

Considering all these results, sawdust has several advantages as a fuel for power plants. In addition to its competitive fuel consumption, sawdust is more environmentally friendly because it is a renewable material and a by-product of the wood industry that is usually not optimally utilized. Its use can help reduce wood industry waste while reducing carbon emissions resulting from coal combustion. In the long term, the use of sawdust as an alternative fuel not only has the potential to reduce dependence on coal but also provides a sustainable solution for the energy sector [4], [7]. Thus, sawdust is worth considering as an alternative fuel for power generation, especially in scenarios where sustainability and emission reduction are priorities [4], [6]. However, to improve its performance, further research is needed on sawdust combustion techniques or its blending with coal to achieve higher energy efficiency. Additional studies on the impact of sawdust emissions can also help understand the potential for deeper pollution reduction, making sawdust a more optimal alternative in the future [7].

REFERENCES

[1] M. A. Destek, S. A. Sarkodie, and E. F. Asamoah, ‘Does biomass energy drive environmental sustainability? An SDG perspective for top five biomass consuming countries’, *Biomass and Bioenergy*, vol. 149, p. 106076, 2021, doi: https://doi.org/10.1016/j.biombioe.2021.106076.

[2] M. A. Brown, A. Favero, V. M. Thomas, and A. Banboukian, ‘The economic and environmental performance of biomass as an “intermediate” resource for power production’, *Util. Policy*, vol. 58, pp. 52–62, 2019, doi: https://doi.org/10.1016/j.jup.2019.04.002.

[3] T. P. da Costa, P. Quinteiro, L. A. da C. Tarelho, L. Arroja, and A. C. Dias, ‘Environmental impacts of forest biomass-to-energy conversion technologies: Grate furnace vs. fluidised bed furnace’, *J. Clean. Prod.*, vol. 171, pp. 153–162, 2018, doi: https://doi.org/10.1016/j.jclepro.2017.09.287.

[4] S. Tokarski, K. Głód, M. Ściążko, and J. Zuwała, ‘Comparative assessment of the energy effects of biomass combustion and co-firing in selected technologies’, *Energy*, vol. 92, pp. 24–32, 2015, doi: https://doi.org/10.1016/j.energy.2015.06.044.

[5] A. Demirbas, ‘Combustion characteristics of different biomass fuels’, *Prog. Energy Combust. Sci.*, vol. 30, no. 2, pp. 219–230, 2004, doi: https://doi.org/10.1016/j.pecs.2003.10.004.

[6] J. O. Awulu, P. A. Omale, and J. A. Ameh, ‘Comparative analysis of calorific values of selected agricultural wastes’, *Niger. J. Technol.*, vol. 37, no. 4, p. 1141, 2018, doi: 10.4314/njt.v37i4.38.

[7] X. Zhang, K. Li, C. Zhang, and A. Wang, ‘Performance analysis of biomass gasification coupled with a coal-fired boiler system at various loads’, *Waste Manag.*, vol. 105, pp. 84–91, 2020, doi: https://doi.org/10.1016/j.wasman.2020.01.039.

[8] A. Paletto, S. Bernardi, E. Pieratti, F. Teston, and M. Romagnoli, ‘Assessment of environmental impact of biomass power plants to increase the social acceptance of renewable energy technologies’, *Heliyon*, vol. 5, no. 7, p. e02070, 2019, doi: https://doi.org/10.1016/j.heliyon.2019.e02070.

[9] S. Zou *et al.*, ‘Experimental research on an innovative sawdust biomass-based insulation material for buildings’, *J. Clean. Prod.*, vol. 260, p. 121029, 2020, doi: https://doi.org/10.1016/j.jclepro.2020.121029.

[10] A. A. Abdulhameed *et al.*, ‘Experimental and environmental investigations of the impacts of wood sawdust on the performance of reinforced concrete composite beams’, *Case Stud. Constr. Mater.*, vol. 19, p. e02550, 2023, doi: https://doi.org/10.1016/j.cscm.2023.e02550.

[11] Y. Cheng and H. Li, ‘Utilization and development of biomass energy’, *Energy Sci. Policy*, vol. 1, no. 1, pp. 1–6, 2023, doi: 10.61187/esp.v1i1.12.