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Emission test for briquette mixture of cow manure, rice husk and wood dust

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Abstract

This research is experimental in nature, involving direct measurements of gas emissions from briquettes, Sentang wood (*Azadirachta excelsa*), Petai wood (*Parkia speciosa*), and Rambutan wood (*Nephelium lappaceum*). Tests were conducted using an exhaust emission measuring device for three main parameters: SO_2, NO_2, and CO. In this study, the mixed briquettes of cow manure, rice husk, and wood dust showed the lowest SO_2 emissions (1.2 mg/Nm³) compared to Rambutan wood, which had the highest SO_2 emissions (94.4 mg/Nm³), Petai wood (75.4 mg/Nm³), and Sentang wood (7.6 mg/Nm³). This indicates that briquette blends derived from cow manure, rice husk, and wood dust are relatively cleaner in terms of sulfur emissions. While Sentang wood produced the highest NO_2 emissions (12.8 mg/Nm³), the mixed briquettes of cow manure, rice husk, and wood dust came second (7.4 mg/Nm³), whereas Petai wood and Rambutan wood produced lower NO_2 values, 3.6 mg/Nm³ and 4.6 mg/Nm³ respectively. For CO emissions, briquettes of cow dung, rice husk, and wood dust mixture had the highest CO emission level (1,857.6 mg/Nm³). Petai wood and Rambutan wood showed slightly lower CO emissions than the briquettes, at 1,643.8 mg/Nm³ and 1,568.2 mg/Nm³ respectively. Sentang wood had the lowest CO emissions (1,502.4 mg/Nm³), indicating that combustion of this material was more efficient than the others.

Keywords: Briquettes, Cow manure, Emission.

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1. Introduction

Climate change is a major concern globally [1, 2]. The increasingly evident issue of global climate change is driving the need to develop renewable energy that is environmentally friendly [3]. One of the biggest negative impacts of fossil fuel-based energy use is greenhouse gas emissions, which trigger an increase in the earth's temperature and various other environmental problems such as air pollution [4]. To mitigate this impact, the transition towards renewable energy [5-8] including biomass, is becoming increasingly important in creating a cleaner and more sustainable energy system [9-13].

Biomass as a renewable energy source has many advantages and has enormous potential [14-16]. Besides coming from abundant raw materials, such as agricultural waste, animal waste, and crop residues, biomass can also be converted into various forms of alternative fuels [17-23], one of which is briquettes. Biomass briquettes are solid fuels made by compressing various organic materials, making them denser, more efficient, and easier to store than raw biomass fuels. In rural and remote contexts, biomass briquettes offer a practical and affordable solution to meet daily energy needs [24, 25] such as cooking, heating, or small industries.

In Research 2023, a briquette product made from cow manure, rice husk, and wood dust was produced. Figure 1 shows the dimensions of the briquette product, which are 20 cm x 10 cm x 12.5 cm. Based on the combination of dimensional measurements and mass weighing of briquettes, the average density of dry briquettes is 0.337 g/cm^3.

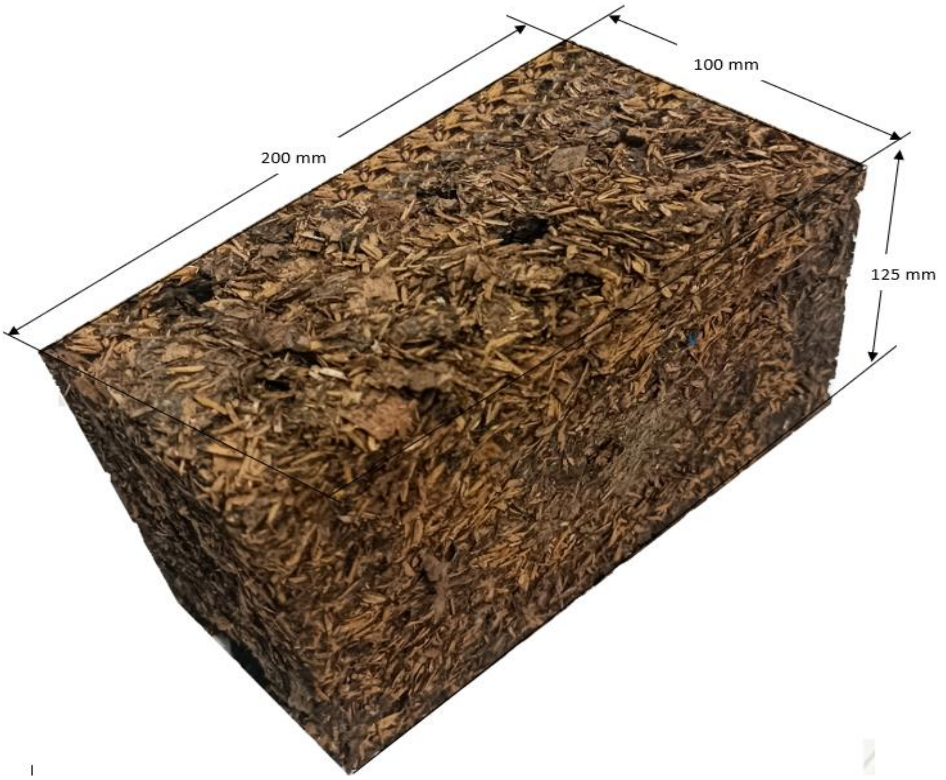

Figure 1.
The briquette product, made from a mixture of cow manure, rice husks, and wood dust, was manufactured based on research conducted in 2023 [26] with dimensions of 20 cm x 10 cm x 12.5 cm.

The use of briquettes from a mixture of cow manure, rice husk, and wood dust as an alternative fuel has shown significant results in various quality tests. Based on the results of previous research [26], the moisture content of the briquettes is 12% and is still within the ideal range between 5%-20% [27]. An appropriate moisture content is essential to ensure the combustion quality and energy efficiency of the briquettes. In addition, ash content is acceptable, although this value is relatively high. A low ash content is more desirable as it can reduce the residue left over from combustion. The test result of briquette calorific value is 3,009 cal/gram. The greater the calorific value, the better the quality of the briquettes.

In addition, the financial feasibility analysis of this briquetting project showed very positive results. An NPV of 144,074,566, an IRR of 72.154%, a Net B/C of 4.37, and a relatively short payback period (PBP) of 3.22 years all indicate that the project is economically viable. In addition to the economic benefits, the success of this project is also expected to reduce the community's dependence on firewood, which has contributed to deforestation and environmental degradation.

However, while the quality and financial viability of these briquettes are promising, further studies need to be conducted on the greenhouse gas emissions and carbon footprint resulting from burning the briquettes. The carbon emissions generated from biomass-based briquettes must be accounted for to ensure that the use of this alternative fuel does not negatively impact the environment in the long term. Further research into the emissions and environmental impacts of these briquettes is essential to ensure that this alternative fuel solution is not only energy- and economically efficient but also environmentally friendly [28].

This research will focus on the burning of smallholder salt in Pidie District, Aceh Province, Indonesia. Researchers have tested briquettes on salt, testing to boil 864 liters of salt water until it becomes salt. The briquettes used for testing the burning rate are briquettes that have a high calorific value of 3,009 cal/gram. Tests conducted to boil 864 liters of salt water to salt required 84 briquettes for 5 hours of combustion. From the results of these calculations, the value of the briquette combustion rate is 3.41 g/s. From the energy test results, the total energy consumption to boil 864 liters of water to salt is 184.764 Mcal.

For now, salt farmers in Pidie district still use firewood to cook salt. The wood often used by salt farmers includes Petai wood (*Parkia speciosa*), Sentang wood (*Azadirachta excelsa*), and Rambutan wood (*Nephelium lappaceum*). It is necessary to study the comparison of emissions from the use of wood with the use of biomass briquettes made from a mixture of cow manure, rice husks, and wood dust.

Figure 2.
The wood used for salt production by salt farmers in Pidie Regency, Aceh Province.

In particular, agricultural and animal wastes, such as rice husks, wood dust, and cow dung, are widely available in rural Indonesia. The potential to utilize these wastes as an alternative energy source is significant, especially in areas where electricity and gas are not readily available. By converting these wastes into briquettes, we not only provide cheap and sustainable energy but also reduce the pollution problem caused by the waste itself. However, despite the availability of many raw materials, each type of biomass has different combustion characteristics, so its effect on the environment also varies.

Although biomass is often regarded as an environmentally friendly energy, its combustion still produces potentially polluting gaseous emissions, such as sulfur dioxide (SO_2), nitrogen oxides (NO_2) and carbon monoxide (CO) [29-31]. The level of these emissions varies greatly depending on the type of feedstock used as well as the combustion method. Therefore, it is important to conduct more in-depth research into the emission characteristics of different types of biomass briquettes to ensure that their use can reduce negative impacts on the environment.

As air quality concerns increase, research on emissions from biomass combustion is becoming increasingly important. Several studies have shown that burning biomass with high sulfur content can produce significant SO_2 emissions, which contribute to acid rain and human respiratory distress. Meanwhile, carbon monoxide (CO) produced from incomplete combustion is harmful to health and can degrade indoor air quality. Therefore, it is important to understand which types of biomass fuels produce the lowest emissions, so that they can be the best choice in achieving a clean energy transition.

2. Materials and Methods

This study aims to evaluate the emissions produced during the combustion of briquettes made from a mixture of cow manure, rice husks, and wood dust, compared to petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*), using a Garden Incinerator. A generic emission analyzer was employed to measure gas emission concentrations. The procedures carried out are as follows:

2.1. Calibration

The briquettes tested were composed of a mixture of cow manure, rice husks, and wood dust. For comparison, petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*) were used. The combustion was conducted using a Garden Incinerator, which was ensured to be clean and free of any residual materials or prior combustion residues to prevent measurement interference and to ensure controlled and efficient burning. A generic emission analyzer was used to monitor the exhaust gas emissions.

Prior to testing, both the Garden Incinerator and the generic emission analyzer were calibrated to ensure measurement accuracy. Zero calibration was conducted on the generic emission analyzer to eliminate the influence of other ambient gases by connecting the analyzer to a zero-gas source, selecting the zero-calibration mode, and allowing the analyzer to measure a zero-gas concentration (0 ppm). Once the reading stabilized, the zero value was saved. Span calibration was performed to ensure accurate readings of emission gas concentrations by connecting the analyzer to a span gas source, selecting the span calibration mode, allowing the analyzer to measure the span gas concentration, and adjusting the readings as needed. The calibration was validated by cross-checking the results with a reference gas.

2.2. Combustion Testing of Briquettes

Briquettes composed of cow manure, rice husks, and wood dust, as well as petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*), were combusted separately in the Garden Incinerator. The combustion process was carried out at an air temperature of 33°C with a tolerance of ±1°C, and the oxygen flow rate was set at 19% with a tolerance of ±1%. During combustion, the following emission parameters were monitored: sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), oxygen, and opacity.

2.3. Emission Measurements

During the combustion process, a generic emission analyzer was used to monitor and measure the gases released from the combustion of briquettes, petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*). Measurements were conducted based on the following parameters and methods: sulfur dioxide (SO_2) using Method Ik.5.04.02.01, carbon monoxide (CO) using Method Ik.5.04.02.03, nitrogen dioxide (NO_2) using Method Ik.5.04.02.02, and opacity using SNI 19.7117.11.2005. These methods complied with the Ministry of Environment and Forestry Regulation Appendix 1 No. 11 of 2021 on Emission Standards for Combustion, as tested by the Industrial Standardization and Service Agency of Banda Aceh (Balai Standardisasi dan Pelayanan Jasa Industri Banda Aceh).

2.4. Data Analysis

The emission data recorded by the generic emission analyzer for each gas during combustion were analyzed to evaluate the emission levels of the briquettes made from cow manure, rice husks, and wood dust compared to the emissions from the combustion of petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*). This analysis aimed to assess the combustion efficiency of the briquettes and the environmental impact of the resulting emissions.

Figure 3.
Emission test using Garden Incinerator for combustion and generic emission analyzer to monitor exhaust gas emissions.

2.5. Research Flow Chart

A flowchart is used to visually represent the process or sequence of steps undertaken in this research. It illustrates the procedures, starting from the preparation of equipment and materials to the data analysis phase. The flowchart in this study is as shown in Figure 4.

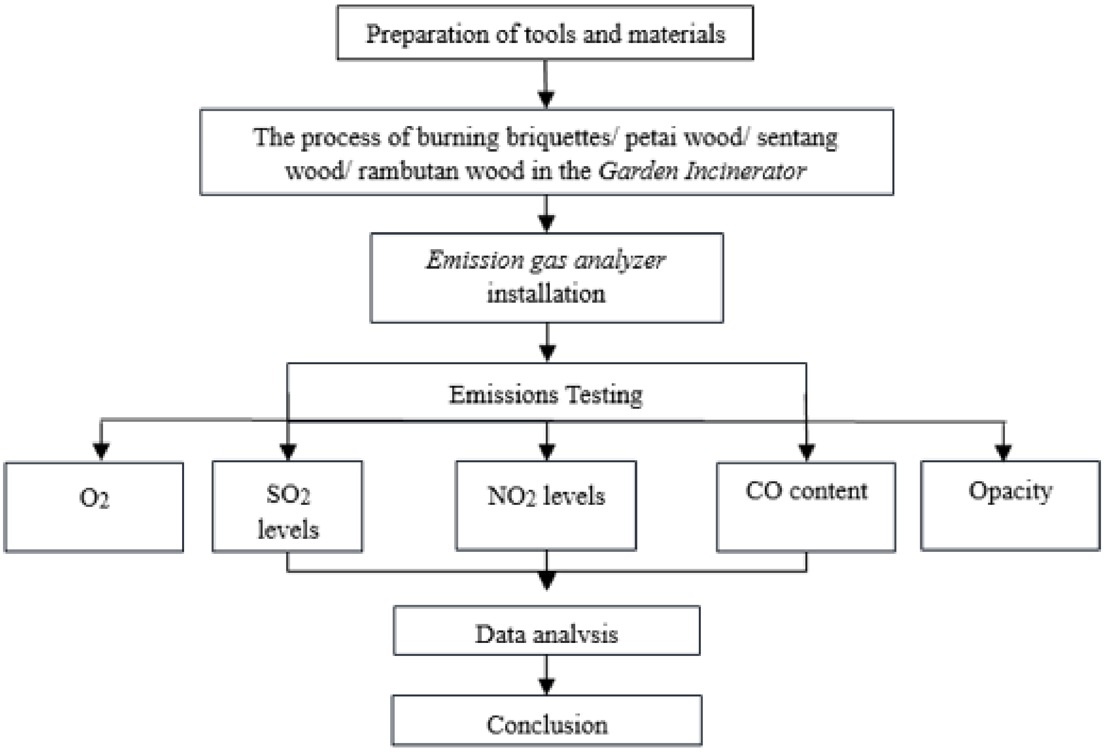

Figure 4.
A flow chart of the emission research that illustrates the stages involved in the implementation of the study.

3. Results and Discussion

3.1. Results

The results of the gas emission study were obtained from burning four different types of materials: mixed briquettes (cow dung, rice husk, and wood dust), petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*). Each fuel type was tested for five key emission parameters, namely sulfur dioxide (SO_2), nitrogen oxides (NO_2), carbon monoxide (CO), opacity (smoke density), and oxygen remaining in the flue gas (O_2). The variation in results among these four fuels provides important insights into the effectiveness, environmental friendliness, and potential problems of each material and can offer recommendations for salt farmers in Pidie district on using fuels for salt burning.

Table 1.
Emission Test Results.

No.	Test Parameters	Briquettes	Petai	Sentang	Rambutan
1	SO_2 (mg/Nm³)	1.2	75.4	7.6	94.4
2	NO_2 (mg/Nm³)	7.4	3.6	12.8	4.6
3	CO (mg/Nm³)	1,857.6	1,643.8	1,502.4	1,568.2
4	Opacity (%)	20	20	20	20
5	Oxygen (O_2 %)	18.9	19.53	18.72	19.39

Sulfur dioxide (SO_2) emissions are harmful gases that often result from burning sulfur-containing fuels, such as coal and biomass with high sulfur content. In this study, the briquette blend of cow manure, rice husk, and wood dust showed the lowest SO_2 emissions (1.2 mg/Nm³). This indicates that mixed briquettes derived from cow manure, rice husk, and wood dust are relatively clean materials in terms of sulfur emissions. In contrast, rambutan wood (*Nephelium lappaceum*) produced the highest SO_2 emissions (94.4 mg/Nm³), indicating that this wood is either high in sulfur or has the potential for incomplete combustion, resulting in more pollutant gases. Petai wood (*Parkia speciosa*) also showed high levels of SO_2 emissions (75.4 mg/Nm³), while sentang wood (*Azadirachta excelsa*) produced lower values (7.6 mg/Nm³). The lower sulfur levels in sentang wood (*Azadirachta excelsa*) indicate that it is more environmentally friendly than other woods in terms of SO_2 emissions.

Nitrogen Oxide (NO_2) emissions are an important indicator in understanding combustion efficiency, as they are usually produced at high combustion temperatures. Sengon wood produced the highest NO_2 emissions (12.8 mg/Nm³), which can be interpreted as the combustion of this wood occurring at relatively high temperatures compared to other materials. Briquettes of cow dung, rice husk, and wood dust were in second place (7.4 mg/Nm³), while petai wood (*Parkia speciosa*) and rambutan wood (*Nephelium lappaceum*) produced lower NO_2 values of 3.6 mg/Nm³ and 4.6 mg/Nm³, respectively. This suggests that petai wood (*Parkia speciosa*) and rambutan wood (*Nephelium lappaceum*) combustion may occur at lower temperatures, which may reduce NO_2 emissions but increase potential CO emissions, as discussed next.

Carbon monoxide (CO) emissions indicate how efficiently the combustion process is taking place. Carbon monoxide is usually produced when incomplete combustion occurs, where not enough oxygen is available to convert all the carbon into carbon dioxide (CO_2). In this study, the cow manure, rice husk, and wood dust mixture briquette had the highest CO emission level (1,857.6 mg/Nm³), indicating that the combustion in this briquette was incomplete. This could be due to the less homogeneous composition of the materials. Petai wood (*Parkia speciosa*) and rambutan wood (*Nephelium lappaceum*) showed slightly lower CO emissions than the briquettes, 1,643.8 mg/Nm³ and 1,568.2 mg/Nm³ respectively. Sentangle wood had the lowest CO emissions (1,502.4 mg/Nm³), indicating that the combustion of this material was more efficient than the others.

Opacity (%) Opacity is a measure of the density of smoke produced during the combustion process. In this study, all materials showed the same opacity value of 20%. This indicates that from a visual perspective, the density of smoke produced by all fuel types is relatively similar. However, despite the same opacity value, the chemical composition of the smoke from each material can be very different, as seen from the variations in SO_2, NO_2 and CO emissions.

The mixed briquettes of cow manure, rice husk, and wood dust showed the lowest remaining oxygen content (18.9%), indicating that this material burns relatively more efficiently than petai wood (19.53%) and rambutan wood (19.39%). Sentang wood also had a fairly low residual oxygen (18.72%), which supports the results of low CO emissions and suggests that this material may have undergone a better combustion process overall.

From the results of this study, it can be seen that each type of fuel has different combustion characteristics, and therefore produces different gas emissions. Briquettes of cow manure, rice husk, and wood dust mixtures performed well in terms of low SO_2 emissions but still need to be optimized to reduce the high CO emissions. In contrast, rambutan wood and petai wood (*Parkia speciosa*) show less potential as environmentally friendly fuels due to their high SO_2 emissions, although both produce slightly lower CO emissions than briquettes. Sentangle wood is the most balanced option, with lower CO emissions and less residual oxygen, suggesting that sentangle wood combustion is more efficient. However, the high NO_2 emissions from sentangle wood indicate an increased risk of higher levels of air pollution if this material is used on a large scale, especially in densely populated areas.

3.2. Discussion

Based on the results of this study, briquette mixtures of cow manure, rice husk, and wood dust can be the best choice as an environmentally friendly biomass fuel, provided that the combustion method is optimized to reduce CO emissions. Further research is needed to develop more efficient combustion technologies, such as the use of furnaces with better airflow, to ensure complete combustion and minimize harmful gas emissions. In addition, the health and environmental risks posed by using fuels with high SO_2 emissions, such as rambutan wood *(Nephelium lappaceum)* and petai wood (*Parkia speciosa*), should also be considered.

Briquettes can be a preferable option due to their lower SO_2 emissions compared to petai wood (*Parkia speciosa*), sentang wood (*Azadirachta excelsa*), and rambutan wood (*Nephelium lappaceum*). Furthermore, from an environmental perspective, the use of briquettes made from a mixture of cow manure, rice husks, and wood dust provides significant environmental benefits. It utilizes residual waste materials, thereby reducing waste, and serves as a sustainable alternative to wood, helping to mitigate deforestation.

Table 2.
Comparison of research results with other briquettes with cow manure base material.

No.	Test Parameters	Cow manure, rice husk, and wood dust	Petai wood	Sentang wood	Rambutan Wood	Cow Manure and Coffee Dregs [32]	Cow Manure and Straw [32]
1	SO_2 (mg/Nm³)	1.2	75.4	7.6	94.4	4.23	2.75
2	NO_2 (mg/Nm³)	7.4	3.6	12.8	4.6	0.02	0.6
3	CO (mg/Nm³)	1,857.6	1,643.8	1,502.4	1,568.2	34.13	34.38
4	Opacity (%)	20	20	20	20	-	-
5	Oxygen (O_2 %)	18.9	19.53	18.72	19.39	8.3	10.7

3.3. SO_2 (Sulfur Dioxide) Emissions

Sulfur dioxide is one of the main gases that contribute to the formation of acid rain. Test results showed that burning rambutan wood *(Nephelium lappaceum)* and petai wood (*Parkia speciosa*) resulted in high SO_2 emissions of 94.6 mg/Nm³ and 75.4 mg/Nm³, respectively, which were much higher than those of cow dung and other biomass-based briquettes. Rice husk cow dung briquettes had the lowest emissions at 1.2 mg/Nm³, followed by straw cow dung at 2.75 mg/Nm³.The low SO_2 emissions indicate good potential as an environmentally friendly fuel. The results of SO_2 testing on the research samples are shown in Figure 5.

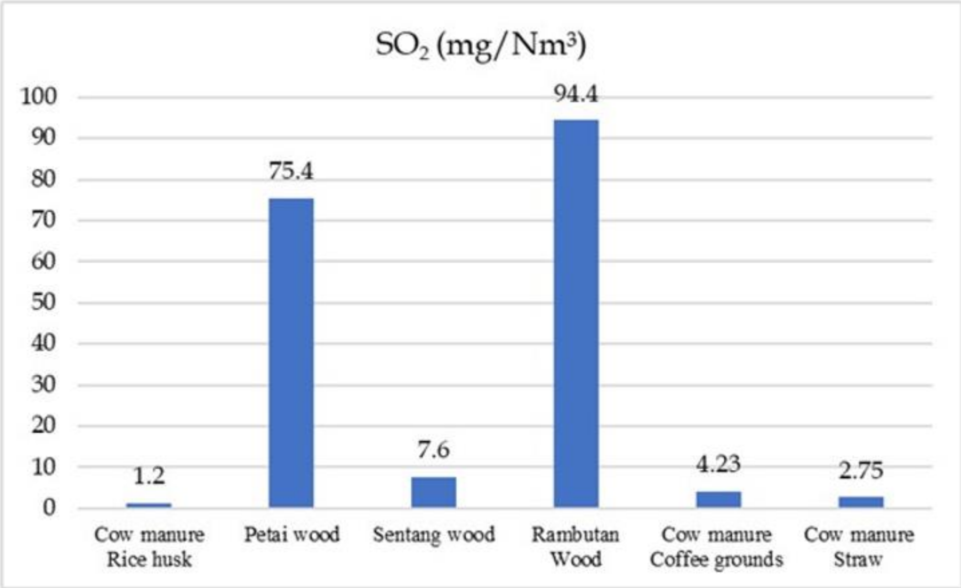

Figure 5.
Comparison of SO_2 Testing Results in This Study with Other Studies.

3.4. NO_2 (Nitrogen Dioxide) Emissions

Nitrogen dioxide is a pollutant gas that is harmful to respiratory health. The test results show that coffee grounds cow dung and straw cow dung-based briquettes have very low NO_2 emissions, 0.02 mg/Nm³ and 0.6 mg/Nm³, respectively, compared to other biomass. Sentangle wood produces NO_2 of 12.8 mg/Nm³, much higher than other alternative fuels. Figure 2 shows the NO_2 emission test results for all samples.

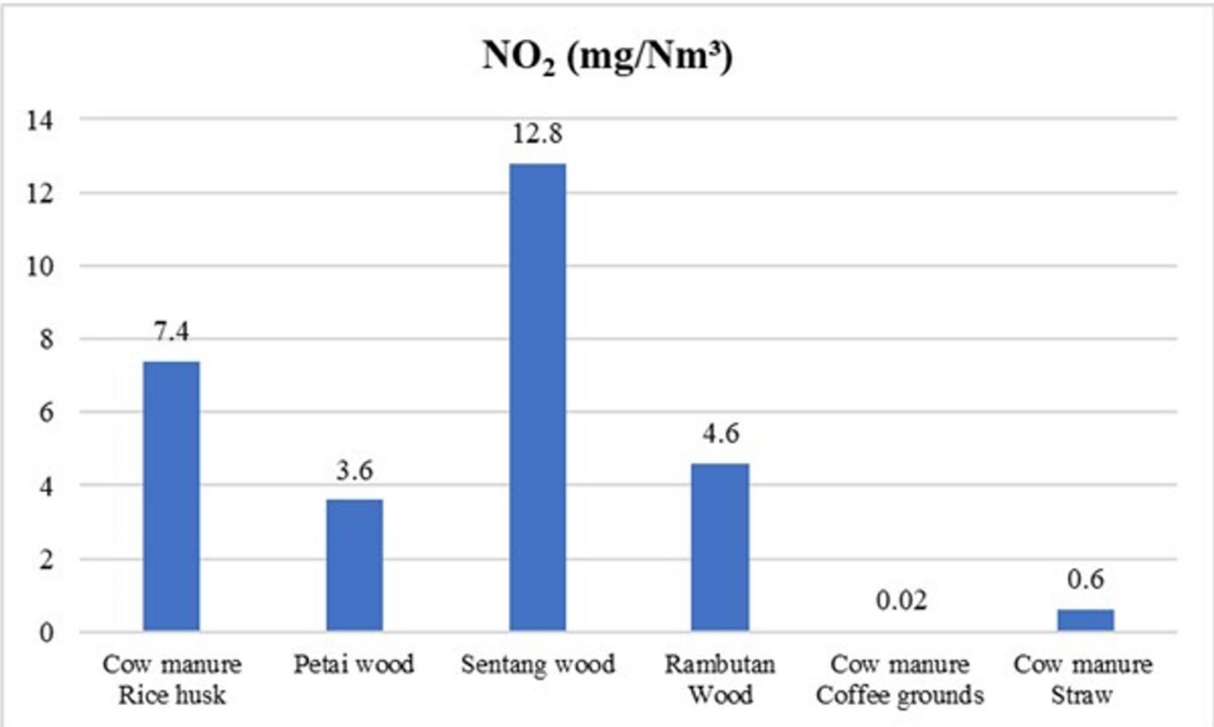

Figure 6.
Comparison of NO_2 Testing Results in This Study with Other Studies.

3.5. CO (Carbon Monoxide) Emissions

Carbon monoxide is a harmful gas that results from incomplete combustion. Briquettes based on cow dung, coffee grounds and straw showed significantly lower CO emissions of 34.13 mg/Nm³ and 34.38 mg/Nm³, respectively, whereas all wood-based fuels showed very high CO emissions, with values exceeding 1,500 mg/Nm³. Figure 7 shows the CO emission test results for all samples.

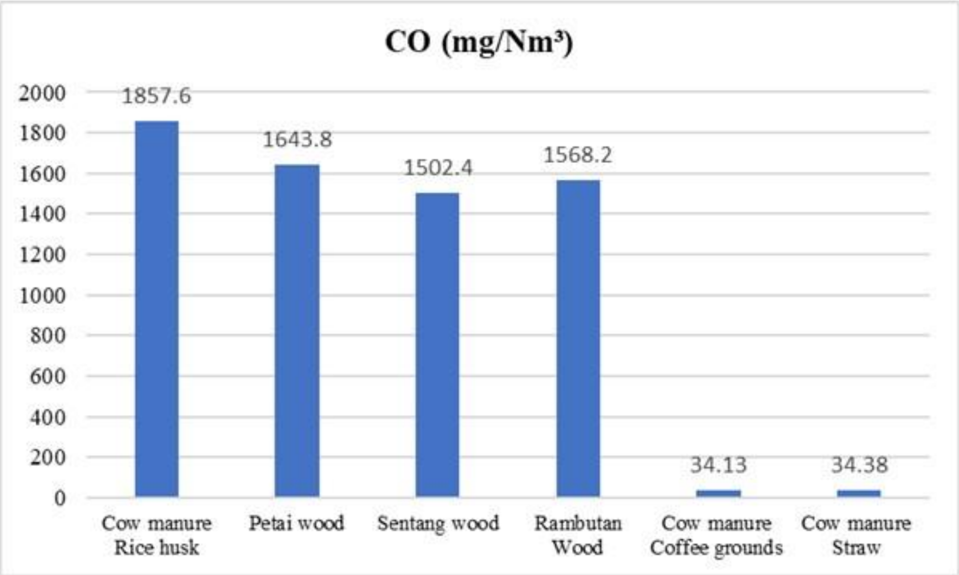

Figure 7.
Comparison of CO Testing Results in This Study with Other Studies.

3.6. Opacity and Oxygen Content

All wood- and dung-based briquettes have the same percentage opacity (20%), while no data is available for briquettes with coffee grounds and straw. Oxygen content measurements show that cow dung-based briquettes have relatively low oxygen content: cow dung rice husk and wood dust 18.9%, straw 10.7%, and coffee grounds 8.3%.

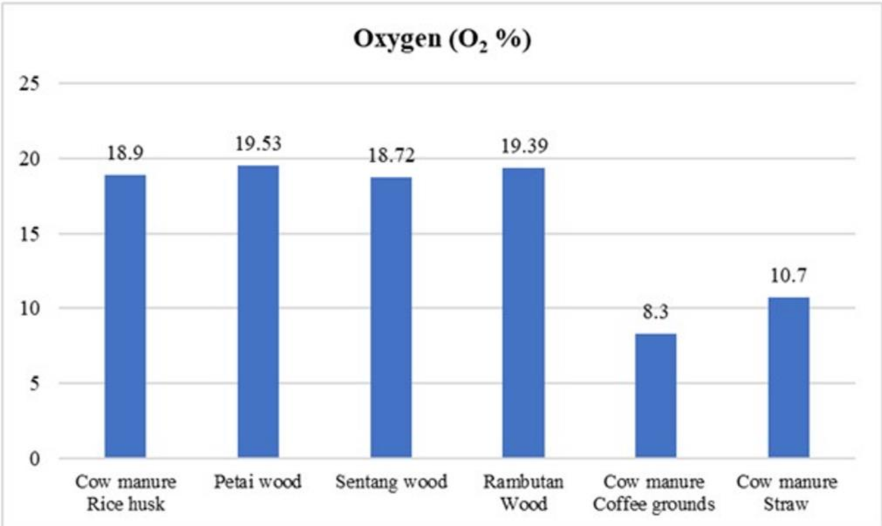

Figure 8.
Comparison of O_2 Testing Results in This Study with Other Studies.

4. Conclusions

Based on the results of this study, the mixed briquettes of cow manure, rice husk, and wood dust showed the lowest SO_2 emissions (1.2 mg/Nm³). This indicates that mixed briquettes derived from cow manure, rice husk, and wood dust are relatively clean materials in terms of sulfur emissions. Mixed briquettes of cow manure, rice husk, and wood dust can be the best choice as an environmentally friendly biomass fuel, provided that the combustion method is optimized to reduce high CO emissions. Furthermore, the use of briquettes made from a mixture of cow manure, rice husks, and wood dust provides significant environmental benefits. It utilizes residual waste materials, thereby reducing waste, and serves as a sustainable alternative to wood, helping to mitigate deforestation. Further research is needed to develop more efficient combustion technologies, such as the use of furnaces with better airflow, to ensure complete combustion and minimize harmful gas emissions.

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