Assessment of the Co-firing in a Portable Boiler Using Rice Husk Biopellets and Sub-bituminous Coal

Rusdianasari Rusdianasari[1*], Leila Kalsum[2], Abu Hasan[3], Hengky Saputra[4], Riztamala Diana[5], and Akhmad Rizal[6]

[1-6]Department of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang 30139, Indonesia
rusdianasari@polsri.ac.id

Abstract. Rice husks can be used to produce biopellets that can be co-fired in steam power plants. Performance testing investigations on portable boilers, using combinations of sub-bituminous coal and rice husk biopellets with varying ratios of 100%:0%, 95%:5%, and 85%:15%, reveal that the highest values are achieved with sub-bituminous coal alone, without any mixing. Rice husk bio-pellets provide a load of 17 watts with voltage parameters of 265V, a current of 1.17A, a temperature of 456°C and turbine rotation of 718 rpm. A voltage of 257V and a current of 0.83A is produced by sub-bituminous coal with a rice husk bio-pellet mixing ratio of 95%:5% and a load of 17 watts. The temperature produced at this ratio is 452°C, and the turbine rotates at 664 rpm. This is due to voltage losses in the conductor and the difference in calories caused by the mixing ratio. According to the results of combustion gas emissions, increasing the co-firing ratio with rice husk biopellets reduces CO_2 emissions. This is because the sulfur concentration of rice husk biopellets is lower than that of coal. However, the ash concentration, which is much higher than that of coal, affects the particle flow rate in the Electrostatic Precipitator (ESP) inlet area. Thus, while increasing the co-firing ratio, it is crucial to concentrate on improving ESP operation to ensure ESP conditions remain safe. The test results for NO combustion gas emissions were the highest (8 ppm) at a ratio of 95%:5%, caused by an unstable combustion temperature.

Keywords: biopellet, boiler, co-firing, rice husk

1 Introduction

Along with the rapid development and use of coal as the main energy source is also increasing in several countries, especially the use of coal in power plants. In accordance with government policies, especially regarding conservation, the means of countermeasures and stages for the use of environmentally friendly coal can be implemented through environmentally sound co-firing technology, useful in the context of sustainable development in the energy sector [1]-[4].

The government targets the achievement of Renewable Energy in the national energy mix as stated in the National Energy General Plan (RUEN) to reach 23% by 2025, divided into electricity and non-electricity according to the 2017 Presidential Regulation. In 2020, the implementation of renewable energy is still far from the target, which is 9.15%, there is a deviation of 13.75% which must be implemented in the next 5 years. Of the several renewable energy programs initiated and proposed to State Electricity Company (PLN), one of the programs is the application of co-firing in

N. L. Husni et al. (eds.), *Proceedings of the 7th FIRST 2023 International Conference on Global Innovations (FIRST-ESCSI 2023)*, Advances in Engineering Research 232,
https://doi.org/10.2991/978-94-6463-386-3_29

existing coal-fired power plants. Co-firing is used as one of the green boosters in accelerating the increase in the use of renewable energy with a minimum investment due to using existing facilities in the Steam Power Plant (PLTU) [5]-[10].

Energy derived from biomass plays a strategic role and ranks 3rd in national primary energy supply, amounting to 20.06% or 307,346,838 BOE. The first and second place is still supplied by petroleum and coal which are non-renewable fossil energy. Meanwhile, coal production is quite large but has not been matched by domestic utilization, which is only 20% of its production capacity. Industry globally as a large energy consumer has begun to utilize coal and biomass through co-firing combustion systems as an effort to utilize sustainable and environmentally friendly energy systems [11]-[14]. The utilization of biomass together with coal often requires improving the quality of the biomass, including through a torrefaction system. In order to optimize the utilization of coal-biomass combination for national industry, the composition and type of biomass in the form of torrefaction coal-biomass briquettes that meet industrial fuel criteria have been identified [15]. The results showed that 70% coal, 25% torrefaction cassava stems and 5% tapioca flour as a binder are the ideal briquette dough composition in terms of calorific value and ash content as fuel for thermal energy generation with the hope that it will have an impact on reducing emissions, especially CO_2, as well as efforts to utilize renewable energy sources and reduce non-renewable fossil energy [13]-[18].

Co-firing can generally be expressed as a process of burning two different fuel materials that are operated simultaneously [19]. The advantage of co-firing operation is the reduction of CO_2, SO_x and NO_x gas emissions in fossil fuels. This makes co-firing systems desirable in coal-fired steam power plants. Biomass absorbs the same amount of CO_2 as it emits during its combustion, so co-firing biomass does not contribute to the greenhouse effect. Most biomass fuels have lower sulfur and nitrogen content than coal, so in many cases NOx and SOx emissions can be reduced by co-firing biomass. For this reason, co-firing biomass with coal has received great attention in recent years. [20]-[22]

2 Research Methods

The research was conducted in 2 stages, where the first stage was to make biopellets from rice husk and conduct ultimate and proximate analysis of rice husk biopellets and sub-bituminous coal. The second stage is the process of co-firing coal and rice husk biopellets carried out in a portable boiler by varying the ratio of sub-bituminous coal and rice husk biopellets 100%:0%, 95%: 5%, and 85%:15%. After the co-firing process in the portable boiler, an analysis of the varied electrical loads was carried out and an analysis was carried out on the emission of combustion gases and ash produced from the co-firing process. The portable boiler used for the co-firing process can be seen in Figure 1.

Fig 1. Boiler Portable

3 Results and Discussion

3.1 Proximate and ultimate analysis of co-firing sub-bituminous coal and rice husk biopellets

Prior to the combustion process in the combustion chamber of the portable boiler, the raw materials of sub-bituminous coal and biopellets are mixed together with a ratio of 100%:0%, 95%:5% and 85%:15%. The results of the mixing are used to determine the proximate and ultimate values. The results of the proximate analysis can be seen in Figure 2.

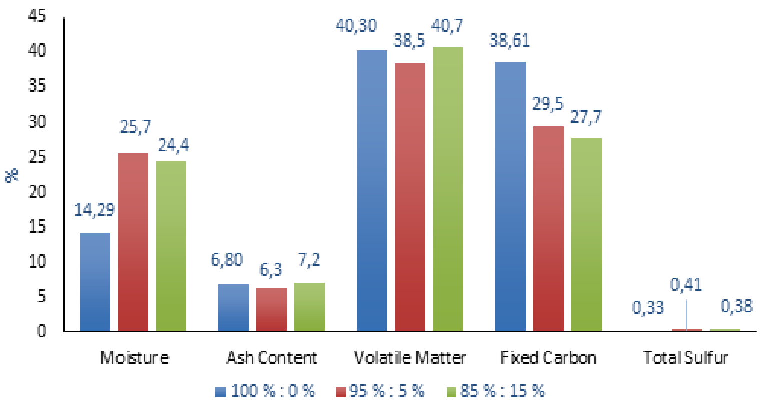

Fig 2. Fuel proximate analysis results based on mixture ratio of sub-bituminous coal and rice husk biopellets

The analysis results show that moisture in the use of pure coal in combustion has a low moisture value compared to the rice husk biopellet mixture ratio. This shows that the lack of maximum drying on the rice husk before the biopellet process.

From the analysis results conducted for proximate analysis, a comparison of the calorific value produced was obtained, where for 100% coal: 0% is 5,631 kcal, while using a biopellet mixture where the ratio is 95%:5% produces a value of 4,528 kcal, and those using a biopellet mixture with a ratio of 85%:15% produce a value of 4,428 kcal. This shows that the more the percentage of the use of rice husk biopellets, the smaller the caloric value produced. vice versa if the percentage of the use of rice husk biopellets is less, the greater the caloric value produced.

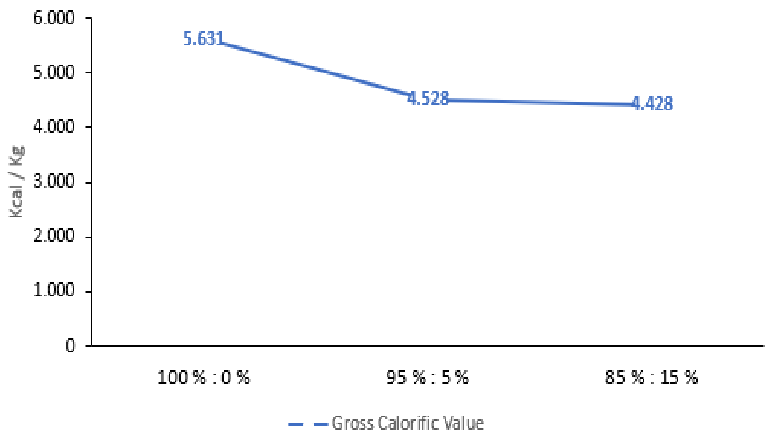

Fig 3. Calorific value based on the mixture ratio of sub-bituminous coal and rice husk biopellets

The ultimate analysis on the mixture ratio of coal and rice husk biopellets can be seen in Figure 4.

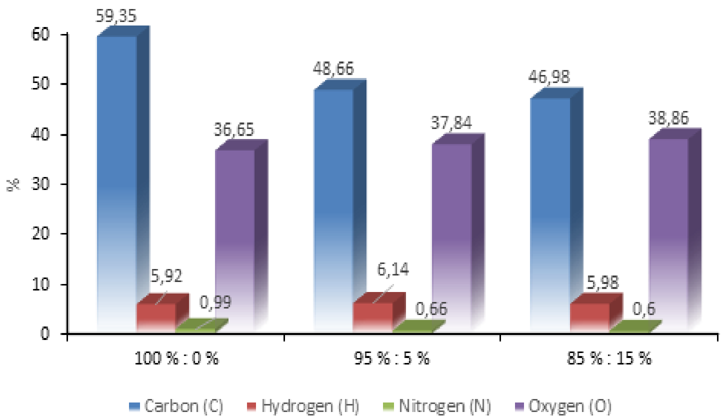

Fig 4. Fuel ultimate analysis results based on mixture ratio of sub-bituminous coal and rice husk biopellets

From the results of the ultimate analysis conducted in the laboratory, the values of Carbon, Hydrogen, Nitrogen, Oxygen are obtained, where carbon in pure coal without a mixture of rice husk biopellets has a high value compared to the value of carbon after the coal is mixed with rice husk biopellets. This shows that the lower the use of coal, the smaller the carbon value, where carbon is useful for accelerating the combustion process.

3.2 Analysis co-firing of sub-bituminous coal and rice husk biopellets in portable boiler

Analysis of the use of mixing ratios of sub-bituminous coal and rice husk biopellets with a load of 17 watts are listed in Table 1.

Table 1 Blending ratio of coal and rice husk biopellets at 17 watts load

Sub-bituminous Coal %	Rice Husk Biopellets %	Voltage (V)	Current (A)	Temperature (^{O}C)	Turbin Rotation RPM	Load (W)
100	0	265	1.17	456	718	17
95	5	257	0.83	452	664	17
85	15	217	0.65	438	617	17

From the analysis results of the mixing ratio of sub-bituminous coal and rice husk biopellets in portable boilers with variations of 100%:0%, 95%:5%, 85%:15% obtained the highest data is on sub-bituminous coal fuel without a mixture of rice husk biopellets with the resulting load of 17 watts, voltage 265V, current 1.17 A, temperature 456°C and turbine rotation 718 RPM.

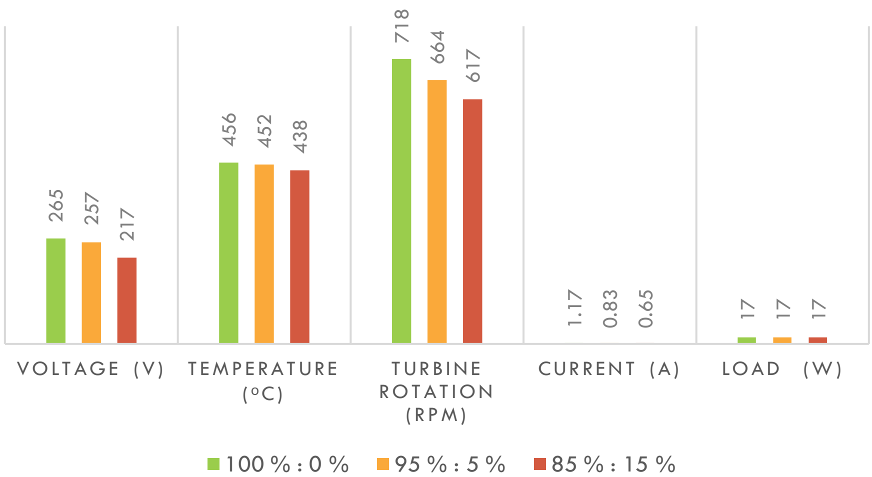

Fig 5. Mixing ratio of coal and rice husk biopellets at 17 watts load

For sub-bituminous coal with rice husk biopellet mixture, the ratio is 95%:5% with a resulting load of 17 watts produces a voltage of 257V, a current of 0.83 where for the temperature produced at this ratio 452oC and a turbine rotation of 664 RPM. For sub-bituminous coal with a mixture of rice husk biopellets, the ratio of 85%:15% with the same resulting load of 17 watts produces a voltage of 217V, a current of 0.65A while the resulting temperature is 438oC with a turbine rotation of 617 RPM.
This shows with the same load of 17 watts between the use of pure coal or by mixing rice husk biopellets the resulting value of voltage, current, temperature and turbine rotation is not the same due to the occurrence of voltage loss losses in the conductor.

Analysis of using the mixing ratio of sub-bituminous coal and rice husk biopellets with a load of 10 watts are shown in Table 2.

Table 2 Blending ratio of coal and rice husk biopellets at 10 watts load

Sub-bituminous Coal %	Rice Husk Biopellets %	Voltage (V)	Current (A)	Temperature (^{O}C)	Turbin Rotation RPM	Load (W)
100	0	258	0,97	451	650	10
95	5	231	0,96	377	584	10
85	15	167	0,93	388	563	10

From the analysis results of the mixing ratio of sub-bituminous coal and rice husk biopellets in portable boilers with variations of 100%:0%, 95%:5 %, 85%:15% obtained the highest data is on sub-bituminous coal fuel without a mixture of rice husk biopellets with a load generated 10 watts, voltage 258V, current 0.97 A, temperature 451^{O}C and turbine rotation 650 RPM.

For sub-bituminous coal with rice husk biopelet mixture, the ratio is 95%:5% with a resulting load of 10 watts produces a voltage of 231 V, a current of 0.96 where for the temperature produced at this ratio 377℃ and a turbine rotation of 584 RPM. For sub-bituminous coal with a mixture of rice husk biopellets, the ratio of 85%:15% with the same resulting load of 10 watts produces a voltage of 167 V, a current of 0.93 A while the resulting temperature is 388°C with a turbine rotation of 563 RPM.

This shows that with the same load of 10 watts between the use of pure coal or with the mixing of rice husk biopellets, the value produced in voltage, current, temperature and turbine rotation is not the same due to the difference in calories produced at the mixing ratio.

3.3 Combustion Gas Emissions Analysis of Co-firing

Analysis of combustion gas emissions from the use of fuel ratios between coal and rice husk biopellets are in Table 3.

Tabel 3. CO dan CO_2 Emission Analysis Results

Fuel Ratios		Parameter		
Coal	Rice Husk Biopellets	CO	CO	CO_2
%	%	(ppm)	%	%
100	0	8615	0.8615	5.51
95	5	4967	0.4967	4.76
85	15	2835	0.2835	2.82

Based on Table 3, it can be seen that the results of emission analysis show that the percentage value of CO_2 < CO. This provides information that the combustion emission analysis results are in the good category, because the CO emission value obtained a maximum result of 0.8% and a minimum of 0.2% for each coal and biomass combustion ratio.

In terms of emissions, it shows that the increasing ratio of co-firing using rice husk biopellets decreases the CO_2 emissions produced. This condition occurs because the sulfur content in rice husk biopellets tends to be lower than coal. Meanwhile, the ash content which is much higher than coal has an impact on increasing the particulate flow rate at the ESP inlet area. Thus, in increasing the co-firing ratio, it is necessary to consider the increase in ESP work so that the ESP condition remains safe.

Analysis of combustion gas emissions from the use of fuel ratios between coal and rice husk biopellets are in Table 4.

Tabel 4. NO dan NOX combustion gas emission analysis results

Coal	Rice Husk Biopellets	Parameter	
%	%	NO	NOX
		ppm	ppm
100	0	7	7
95	5	8	8
90	10	7	7
85	15	7	7

Analysis the results of NO combustion gas emissions can be seen in Table 4 shows the highest emission results (8 ppm) at the ratio of fuel use (95:5). This is due to the unstable combustion temperature with the highest combustion temperature of 452°C.

3.4 Ash Sample Analysis of Co-firing

Ash sample analysis was used to characterize the amount of elements and metal oxides contained in the ash. The results of the combustion ash sample analysis are shown in Figure 6 where the SiO_2 result is greater than the other ash analysis results, reaching 59.95%.

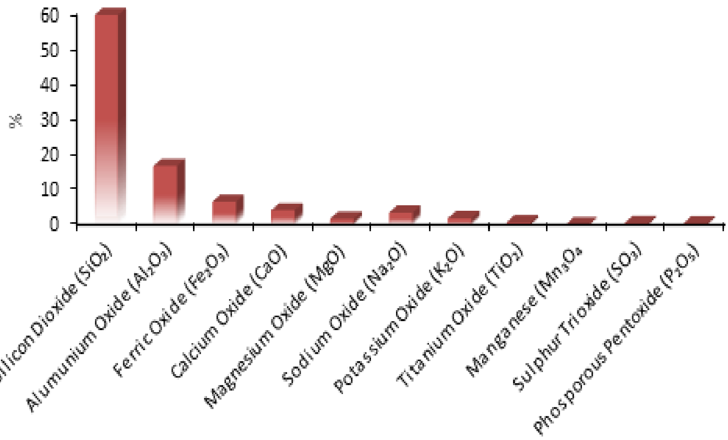

Fig 6. Characteristics of co-firing ash

4 Conclusion

Assessment of the mixing ratio of sub-bituminous coal and rice husk biopellets in portable boiler with variations of 100%:0%, 95%:5%, 85%:15% shows that the highest data is found in sub-bituminous coal fuel without a mixture of rice husk biopellets which produces a load of 17 watts with voltage parameters 265 V, current 1.17 A, temperature 456^{O}C and turbine rotation 718 RPM. Sub-bituminous coal fuel with rice husk biopelet blending ratio of 95%:5% with a resulting load of 17 watts produces a voltage of 257 V, a current of 0.83 A, where the resulting temperature at this ratio is 452^{O}C and the turbine rotation is 664 RPM. This shows the existence of voltage losses in the conductor, as well as the difference in calories produced at the mixing ratio.

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