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Experimental study on candleberry shell and areca palm fibre as a solid fuel for boiler

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Abstract. Candleberry shell and Areca Palm fibre are known as agricultural waste and easily found in Indonesia. This waste can be considered as a renewable energy resource that can be used as solid fuel for boiler. In this study, the burning characteristics of the combination of Candleberry shell and Areca Palm fibre are explored experimentally. The effect of mass ratio of Candleberry shell and Areca Palm fibre is investigated. Six different type of solid fuels made of Candleberry shell and Areca Palm fibre are tested. The results show that the highest High Heating Value shown by the solid fuel with ratio 25% Candleberry shell and 75% Areca Palm fibre. The highest efficiency is shown by the solid fuel with ratio 0% Candleberry shell and 100% Areca Palm fibre. The conclusion can be drawn here is that the combination of Candleberry shell and Areca Palm fibre can be used as a solid fuel of boiler and thermal efficiency comparable with conventional solid fuel.

1. Introduction

Indonesia has a very ambitious target on developing its renewable energy potency. According to the Government of Indonesia, the target of the renewable share of energy primer in 2025 and 2050 is 23% and 31%, respectively. As a note, the present energy share of renewable energy in Indonesia is less than 5%. Thus, there is a big challenge for researchers to provide better solutions to meet the Indonesia target [1]. One of the potential solutions to meet the target is to explore the potency of agricultural waste such as biogas to fuel internal combustion engine [2-7]. It is obvious that solid fuel from agricultural waste has a potency for replacing fossil fuel. The agricultural waste such as biomass can be employed as biofuel [8,9]. Studies on the biomass as a solid fuel for boiler have been reported in the literature [10].

Indonesia is known as an agricultural country where agricultural waste can be easily found in the field. There are several agricultural wastes can be used as solid fuel. They are, for instance, palm oil shell, palm oil fibre, woods, etc. According to the ministry of energy and mineral resources of Indonesia, the potency of bioenergy (includes the biomass) is 32,654 MW. However, only 1,671 MW of electricity has been produced. In other words, only 5.1% of the potency has been explored. In order to enhance the utilization of the potency of biomass, the study on the utilization of biomass as a solid fuel is extremely needed.

As a note, there are several sources of the biomass in Indonesia that are not explored, yet. Two of the sources are candleberry shell and areca palm fibre. These sources are known as agricultural wastes that



can be found in the agricultural fields. In this study, characteristics of candleberry shell and areca fibre as solid fuel for boiler are investigated experimentally. The objective is to examine the possibility of using these agricultural wastes used as solid fuel for boiler. The results are expected to supply the necessary information to Indonesia government in order to meet the renewable energy target.

2. Methods

The solid fuel that consists of candleberry shell and areca palm fibre were collected from Sumatera Utara province. There are six types of fuel combination were tested. They are explained in Table 1. In the first sample, named as CSAF-1000, the solid fuel consists of 100% of candleberry shell without areca palm fibre. The second sample CSAF-7525, the candleberry shell is 75% and areca palm fibre 25%. In the third, fourth and fifth samples the content of candleberry shell is 60%, 40% and 25%, respectively. Finally, the last sample consists of 100% areca palm fibre. The candleberry shell and areca palm fibre are treated before used as solid fuel. They are powdered as shown in Figure 2.

Table 1. The tested solid fuel

No	Sample Name	Composition [%]	
		Candleberry Shell	Areca Palm fibre
1	CSAF-1000	100%	0
2	CSAF-7525	75%	25%
3	CSAF-6040	60%	40%
4	CSAF-4060	40%	60%
5	CSAF-2575	25%	75%
6	CSAF-0010	0	100%



(a)



(b)

Figure 1. Prepared samples; (a) Candleberry shell and (b) Areca Palm fibre

2.1. Experimental apparatus

In this study four type experiments were carried out. The first experiment is to estimate heating value of the solid fuel. The heating value is tested using Boom Calorimeter as shown in Figure 2(a). The experiment is ultimate analysis using Ultimate analyser furnace as shown in Figure 1. The objective is to measure the content of Carbon, Hydrogen, Oxygen, Sulphur, Nitrogen and water content. The third experiment is proximate analysis in order to explore the ash content and fixed carbon. The last test is exhaust gas emission analysis.

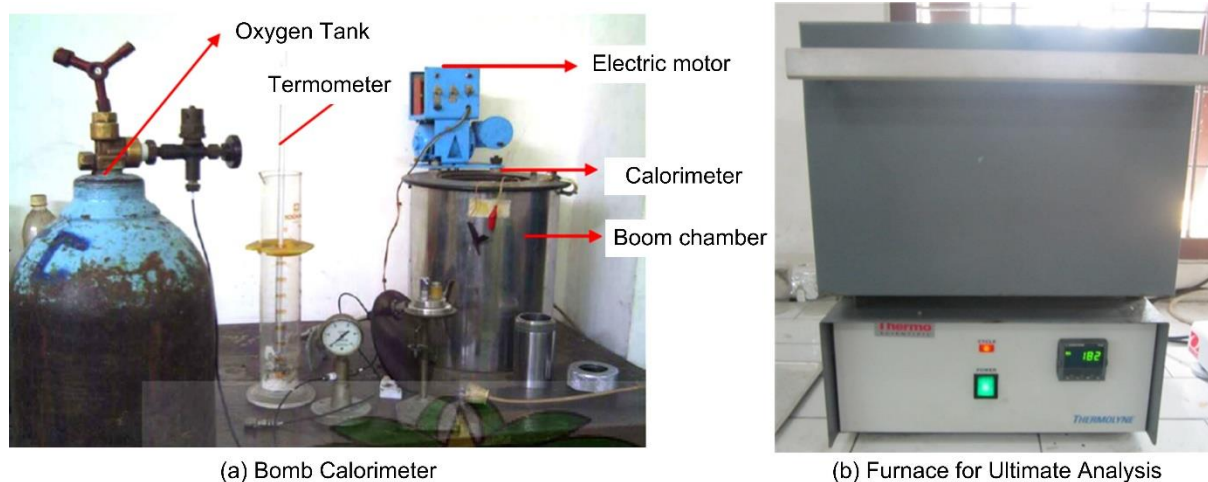


Figure 2. Experimental apparatus

3. Results and Discussions

In this work, every sample is tested in every experiment. Each test is repeated five times. As a note number of samples is five, and they are tested in four experimental apparatus and each test is repeated five times. Thus, a total of 120 tests are carried out. The results will be discussed in four subsections as presented as follows.

3.1. Heating value

The heating values for all solid fuels are shown in Figure 3. In the figure, the high heating value is presented instead of low heating value. The horizontal axis shows the sample number as shown in Table 1. As a note, increasing sample number related to increasing areca palm fibre. The figure shows that, there is no strong effect of the composition of solid fuel to the heating value. The lowest and the highest heating values are shown by CSAF-1000 and CSAF-2575, respectively. Decreasing the composition of candleberry shell is not related to the heating value.

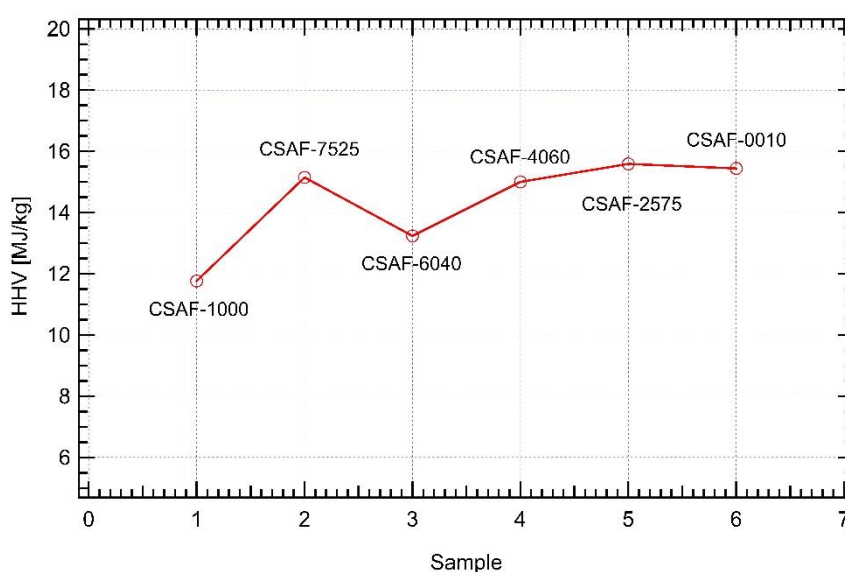


Figure 3. High Heating Value of the fuels

The ultimate analysis of the solid fuel has been carried out and the results are shown in Table 2. In the table the compositions of the solid fuel are shown. The carbon in the solid fuel increases as the areca palm fibre increases. On the other hand, the composition of Hydrogen in the solid fuel decreases as the areca palm fibre increases. The same trend is also shown by Oxygen, Sulphur and Nitrogen.

Table 2. The ultimate analysis of the solid fuel

No	Sample Name	Parameters					
		C [%]	H ₂ [%]	O ₂ [%]	S [%]	N ₂ [%]	Others [%]
1	CSAF-1000	45.81	6.46	42.40	0.44	0.69	4.2
2	CSAF-7525	47.13	6.33	40.90	0.36	0.58	4.7
3	CSAF-6040	47.92	6.25	40.00	0.31	0.52	5.0
4	CSAF-4060	48.98	6.14	38.80	0.25	0.43	5.4
5	CSAF-2575	49.70	6.06	37.90	0.20	0.37	5.7
6	CSAF-0010	51.90	5.93	36.40	0.12	0.26	6.2

3.2. Ash content

The ash contents of the solid fuels have been analysed and results are shown in Table 3. In the table, the used parameters are Ash content, Volatile matter and Fixed carbon content. In addition, the moisture content in the solid fuel is also shown in the table. It can be seen that increasing the composition of the areca palm fibre in the solid fuel will decrease moisture content in the solid fuel. When the areca fibre content is 100% the moisture content of the solid fuel is 5.7% and when the fibre content is 0% the moisture content increases to 10.2%. The Ash content increase with increasing the areca palm fibre. This is because the areca palm fibre produces more ash in comparison with candleberry shell. The volatile matter shows affected by the composition of the solid fuel. The volatile matter increases as areca palm fibre percentage increases. The highest volatile matter shown by the sample CSAF-0010 which has the highest composition of areca palm fibre, it is 100%. On the other hand, the lowest volatile matter is shown by sample CSAF-1000 which has the lowest areca palm fibre. Fixed carbon content is also strongly affected by the composition of the solid fuel. The lowest and highest fixed carbon content is shown by CSAF-0010 and CSAF-1000, respectively. Here the lowest and the highest areca palm fibre content is also shown by CSAF-0010 and CSAF-1000, respectively. This suggests that increasing candleberry content in the solid fuel will increase the fixed carbon content in ash content.

Table 3. Ash content

No	Sample Name	Parameters			
		Moisture content	Ash content	Volatile Matter	Fixed carbon
1	CSAF-1000	10.20%	4.2%	67.51%	18.09%
2	CSAF-7525	9.07%	4.7%	68.66%	17.56%
3	CSAF-6040	8.40%	5.0%	69.35%	17.25%
4	CSAF-4060	7.50%	5.4%	70.27%	16.82%
5	CSAF-2575	6.82%	5.7%	70.97%	16.51%
6	CSAF-0010	5.70%	6.2%	72.12%	15.98%

3.3. Boiler efficiency

The final comparison parameter is the boiler efficiency. The boiler efficiency is estimated using the indirect method as shown in the below equation.

$$\eta = 100 - Q_i - Q_{ii} - Q_{iii} - Q_{iv} - Q_v - Q_{vi} - Q_{vii} \quad (1)$$

Where Q_i is the heat flows out with the exhaust gas. The parameter Q_{ii} , Q_{iii} and Q_{iv} is the heat evaporation of the water formed by Hydrogen in the solid fuel, water within the solid fuel, and water in the air for burning, respectively. In addition, the parameter Q_v and Q_{vi} is defined as heat within the unburned fuel in the fly ash and bottom ash, respectively and the parameter Q_{vii} is the radiation heat and the other heat losses. By using equation (1), boiler efficiency has been estimated and the results are presented in Figure 4. It can be seen in the figure that the minimum boiler efficiency is 62% shown by CSAF-1000 and the maximum boiler efficiency is 81% shown by CSAF-0010. The efficiency of other solid fuels varies between these values. This fact suggests that the highest boiler efficiency shown by the solid fuel with composition 100% areca palm fibre.

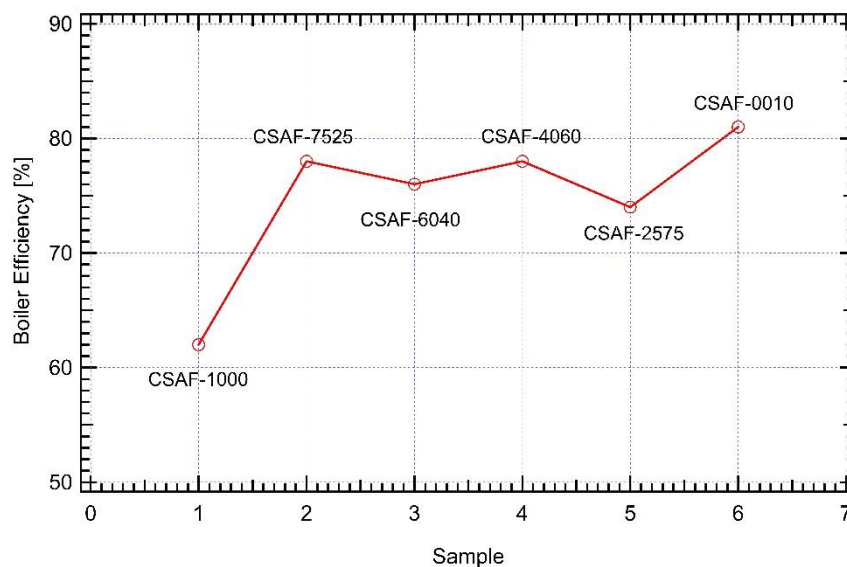


Figure 4. Boiler efficiency

4. Conclusion

In this study characteristics of the candleberry shell and areca palm fibre when used as solid fuel for boiler have been investigated. The used parameters to examine the characteristics are high heating value, ultimate analysis, ash content and boiler efficiency. Six types of solid fuels have been examined. The conclusions are as follows. The candleberry shell and areca palm fibre can be used as alternative fuel for boiler. This is because the heat generated by the solid fuel is within the range of acceptable fuel. The optimum composition of the solid fuel is 75% candleberry shell and 25% areca palm fibre. Thus it is suggested to investigate further the feasibility of using compound candleberry shell and areca palm fibre as solid fuel in the form of palette.

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