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Experimental investigation on pineapple leaf fiber as biomass source for renewable energy application

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Abstract. Depletion of fossil fuel reserves along with major environmental impacts needs the government and authorities to emphasis on renewable energy resources. Biomass from plantation waste is among the significant resource for renewable energy. Hence, this research was carried out with the primary objective is to evaluate the potential of pineapple leaf fiber (PALF) as an alternative for current biomass resources which are oil palm empty fruit bunch (OPEFB) and rice husk (RH). The PALF was obtained from pineapple leaf waste by using hand scrapping technique. Then the characterization process was conducted on the PALF used in the present study to investigate its cellulose contents. Five samples were tested for calorimetric value by using the calorimetric thermometer and bomb cylinder. The calorimetric value test shows that the PALF has a calorimetric average value of 16.93 MJ/Kg. Therefore, the finding reveals that the PALF has high potential as an alternative for current biomass resources for renewable energy application. The utilization of PALF with higher cellulose content compared with the present study expected capable of providing higher calorimetric value result in the future.

Keywords: Biomass; natural fiber; pineapple leaf fiber; calorific value.

1. Introduction

In most recent years, demand for petroleum-based fuels is increasing, especially in population and economy [1]. However, depletion of fossil fuel reserves as well as significant environmental impacts leads the government and authorities to focus on renewable energy resources [2-4]. Biomass from plantation waste is among the significant resource for renewable energy and in Malaysia for example, oil palm biomass and rice husk has been utilized as renewable energy resources. The annual energy value that has been produced by oil palm waste and rice husk (RH) is MYR 6,379 million and MYR 77 million respectively [5]. Among



the oil palm waste, the major part that has been utilized as a renewable energy resource is oil palm empty fruit bunch (OPEFB) with the quantity of 15.8 matrix tons per year. On the other hand, other portion of oil palm waste such as fiber, trunk and shell only produce 9.6, 8.2 and 4.7 matrix tons per year respectively [5].

Other than OPEFB, the pineapple leaf fiber (PALF) which is obtained from pineapple leaves also very attractive as alternative biomass sources due to its low cost and high availability. There are approximately 2.1 million acres of pineapple cultivations, covering some of the world's major pineapple producers, such as Malaysia, Indonesia, Philippines, Thailand, Costa Rica, Brazil and Hawaii [6, 7]. The primary problem with pineapple plantations to producer countries is the pineapple leaf waste, which is approximately 20,000 ton to 25,000 ton per acre after harvesting process [8]; hence, the utilization of PALF as biomass sources obtained from pineapple leaf waste is expected to provide an alternative and solution to the unused pineapple leaves problem after harvesting. On the other hand, PALF relatively has good potential as renewable energy sources due to its high cellulose content compared with other natural fiber [6, 7, 9]. Previous finding present that the fibers with high cellulose content have a high capability in producing high calorific value [10]. Then, the utilization of PALF expected capable of becoming an alternative in biomass sources for renewable energy application. Therefore, the present research was conducted to study and evaluate the potential of pineapple leaf fiber (PALF) as a renewable energy source.

2. Experimental set up

2.1. Material

Bundles of PALF were obtained from Permalang, Central Java, Indonesia. The fibers were extracted from a bunch of pineapple leaves by hand, which is called the scrapping technique. Figure 1 presents the appearance of the PALF fiber after the extraction process.



Figure 1. The appearance of the PALF fiber after the extraction process.

The fibers were firstly cut into 400 mm in length from their 450 mm to 950 mm original length before going to the crushing process before the PALF sample was send to chemical composition analysis and calorific value test. Figure 2 show the physical of PALF after crushing process.



Figure 2. The physical of the PALF fiber after the crushing process.

2.2. PALF chemical composition analysis

The composition analysis is function as a characterization process for PALF sample before it is used for calorific value analysis. Previous finding present that the major components in PALF were lignin, cellulose and hemicellulose [7]. As per discuss earlier, cellulose content has a significant effect on calorific value. Therefore, the investigation on the cellulose content of the PALF that has been used in this study is required. The cellulose contents were measured according to TAPPI T203 om-93 and method of Wise, Murphy and D'Addie, respectively [11, 12]. Figure 3 shows the procedure for the determination of cellulose content.

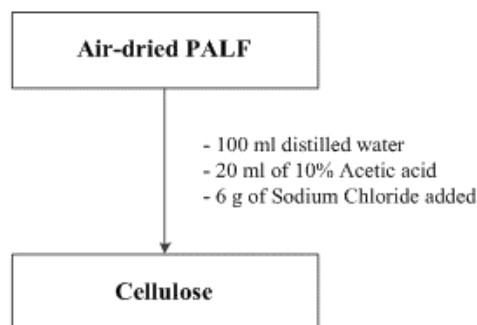


Figure 3. Procedure for the determination of cellulose content.

According to figure 3, two grams of air-dried sample was put into the 250 ml conical flask. After that, 100 ml of distilled water, 6 gram of Sodium Chloride and 20 ml of 10% Acetic acid was added into the conical flask which is placed in the water bath. The water bath set on the hot plate and the temperature maintained at 70°C. After 3.5 hours, the mixture was cooled in the ice bath, filtered by using coarse porosity, washed using distilled water and cleaned by using acetone. Then, the crucible was transferred to the desiccator and weighed up to a constant value.

2.3. Calorimetric value testing

Calorific value test was conducted by using PARR 6772 Calorimetric Thermometer and 101A bomb cylinder according to ASTM D2015 [13]. Before the measurement of calorific value started, the bomb calibrated using reagent grade benzoic acid from Parr Instrument. Figure 4 shows the calorimetric thermometer used in present study.



Figure 4. PARR 6772 Calorimetric Thermometer.

In calorimetric value analysis, 0.9g of PALF sample was placed into combustion cup. Then, 10 cm Parr 45C10 nickel alloy wire was placed into bomb cylinder and filled with pressurized 30 atm of O₂. The bomb cylinder placed inside an oval bucket that filled with 450 ml of distilled water and combustion started. Then, the calorimetric value result was obtained after 19 minutes of test duration. Total of five specimens were tested to get the calorimetric value of PALF used in present study. The calculation of the calorimetric value calculated as follows:

$$H_c = \frac{WT - e_1 - e_2 - e_3}{m} \quad (1)$$

where H_c is the gross heat of combustion of the sample in calories per gram, W is energy equivalent of the bomb calorimeter, T is the observed temperature rise, e₁ is heat produced by burning the nitrogen portion of the air trapped in the bomb to form nitric acid, e₂ is the heat produced by the formation of sulfuric acid from the reaction of sulfur dioxide, water and oxygen, e₃ is heat produced by the heating wire and cotton thread. Meanwhile, the m is the mass of the sample in gram.

3. Results and discussion

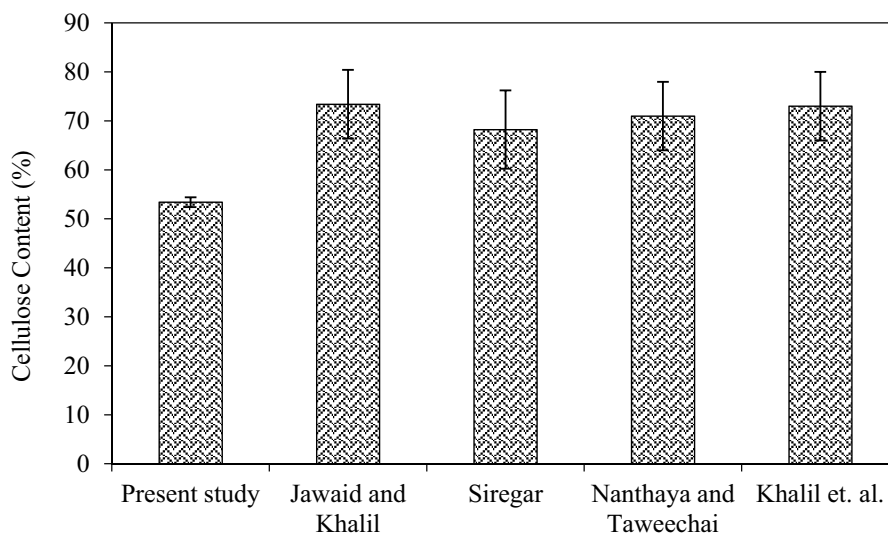
3.1. PALF chemical composition

Table 1 indicated the percentage of cellulose content for PALF that has been used for the present study. According to table 1, the percentage of cellulose for PALF used in present study is between 52.9 to 54.0% with the mean value is 53.4%. On the other hand, previous findings present that cellulose content for current biomass resources which are OPEFB and RH is 41% and 35% respectively [14, 15]. The findings of this study present that PALF has higher cellulose content compared with current biomass resources. The previous study also states that PALF is among the highest in cellulose content when compared with other natural fiber [16]. Therefore, PALF expected capable of producing higher calorimetric value compared to OPEFB and RH.

Table 1. The cellulose content of PALF used.

	Cellulose contents (%)
Sample 1	53.4
Sample 2	52.9
Sample 3	54.0
Sample 4	53.2
Sample 5	53.5
Mean	53.4
Standard Deviation	0.41

However, the cellulose content of PALF used in this study relatively lower value as compared to the other PALF cellulose content finding which is between 68% to 73%. Figure 5 illustrates the comparison of cellulose content between current PALF used and previous results.

**Figure 5.** Comparison of PALF cellulose content [8, 17-19].

According to the figure, the differences in cellulose content between PALF occurred because of the chemical composition of PALF varied, depending on the location of the pineapple plant, species of pineapple, the age of fibers and the process used to obtain the fibers [8, 16].

3.2. Calorimetric Value

Table 2 indicated the findings for PALF calorimetric value is between 16.38 to 17.51 MJ/Kg with 16.93 MJ/Kg as a mean value. The results are as follows as the PALF calorimetric value is competitive compared to existing biomass OPEFB and RH as shown in figure 6.

Table 2. The PALF calorimetric value.

	Calorimetric value (MJ/Kg)
Sample 1	17.51
Sample 2	16.76
Sample 3	17.06
Sample 4	16.92
Sample 5	16.38
Mean	16.93
Standard Deviation	0.41

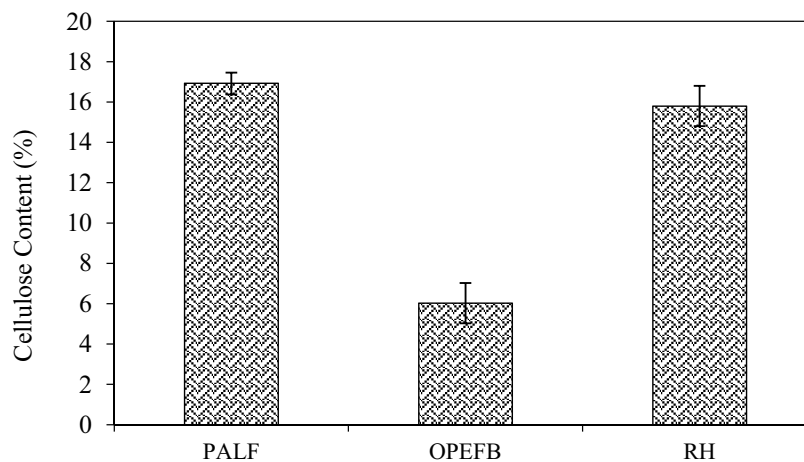


Figure 6. Comparison of calorimetric value between PALF, OPEFB and RH [2, 20].

According to figure 6, PALF relatively presents the highest result which is 16.93 MJ/Kg compared with current biomass resources for renewable energy application which are OPEFB and RH with the calorimetric value of 6.03 MJ/Kg and 15.8 MJ/Kg respectively. Therefore, the finding reveals that the PALF has good potential as biomass resources for renewable energy application. In PALF characterization before, the PALF in present study presents the lowest cellulose content compare with other PALF sample due to factors of location, species, age and fiber extraction method. Therefore, the utilization of PALF with higher cellulose content in the future expected capable of producing higher calorimetric value results.

4. Conclusion

Biomass from plantation waste is among the significant resource for renewable energy as an alternative and solution for the depletion of fossil fuel. Therefore, the evaluation of the potential of PALF as an alternative

in biomass sources for renewable energy application has been conducted. The high cellulose content of PALF compared with other natural fiber provides advantages to PALF to become alternative for the current biomass resources which are OPEFB and RH. The calorimetric value test presents that the calorimetric value of PALF is between 16.38 to 17.51 MJ/Kg with the mean value is 16.93 MJ/Kg. The finding is very interesting due to current biomass resources which are OPEFB and RH only have 6.03 MJ/Kg and 15.80 MJ/Kg respectively. Also, the utilization of PALF with higher cellulose content compared with the present study expected capable of providing higher calorimetric value result. Therefore, the study reveals that the PALF has high potential as an alternative for current biomass resources for renewable energy application.

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