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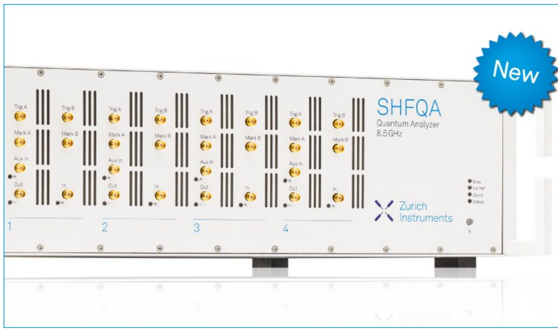

Comparison of Calorific Value of Corn Cobs, Areca Nut Fiber and Paper Waste as Alternative Fuel

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Abstract. Indonesia has targeted to reach 23% of renewable energy share by 2025. In order to meet the target, many researchers have focused on the explorations of renewable energy resources. One of the potential solutions to meet the target is the agricultural wastes, include corn cobs and areca nut fiber. In this study, the calorific value of corn cobs and areca nut fiber are tested. The corn cobs and areca nut fiber are collected from the farmers in Sumatera Utara province of Indonesia. In addition, the Paper waste is also tested. A bomb calorimeter of IKA C6000 is used to measure the energy content of the biomass. The results show that the calorific value of Corn cobs and Areca nut fiber is 5573 Cal/g and 4946 Cal/g, respectively.By using the average yearly production of Corn and Areca nut, these calorific values similar to 4,539 TOE and 4,653 TOE, respectively. If the potency can be used to replace the coal as an alternative fuel, this potency will reduce the Greenhouse gas (GHG) emission. The potency of mitigation GHG by replacing Corncob and Areca nut fiber are 18,306 and 18,491 ton of CO_{2e}.

INTRODUCTION

The increase in fossil energy consumption has resulted in a serious energy crisis that is experienced almost all over the world. Fossil fuel demand continues to increase during the period 2007 to 2030 with 53% coal, 42% gas, and 24% oil [1]. The similar growth energy consumption occurs in Indonesia. The energy demand is increasing as the population increases, economic growth, and technological development. Energy consumption in Indonesia is more than 90% supplied by fossil fuel sources. It is 33% of oil, 34% coal, and 24% of gas, while the rest is supied by reenewable energy (EBT). Based on data from the ministry of Energy and Mineral Resources (2017), Indonesia's oil reserves are expected to be exhausted in 12 years, natural gas will be exhausted in 30 years, and coal will be exhausted in 100 years.Thus, the alternative energy sources are extremely needed. 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 [2,3]. Studies on the biomass as a solid fuel have been reported in literature [4]. The agricultural wastes can also be converted into biogas and employed to fuel engine [5, 6, 7].

Indonesia is known as an agricultural country where agricultural waste can be easily found in the field. There are several agricultural wastes that can be used as solid fuel. They are, for instance, palm oil shell, palm oil fiber, 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, study on the utilization of biomass as a solid fuel is extremely needed. As a first step, the potency of energy in the agricultural wastes must be explored.

Utilization of agricultural waste as an alternative energy is one effective way in overcoming the energy crisis. Characteristics and quality of waste generated in an area indicates the standard of living in a city or country [8]. Biomass energy resources from solid waste estimated at 94,84 million tons per year [9]. The major advantage of energy production using agricultural waste or forest residues as raw materials is its insignificant

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purchase cost [10]. Syafriuddin and Rio 2012 [11], conducted experiments of fibers and shells of palm oil as fuel in a steam power plant. The first experimental is to knowing the calorific value of each, fiber is equal to 6.231 cal/gr and shell of 6.877 cal/g. Surono 2010 [12] suggested that one of the potential waste to be processed into alternative fuel is corn cob, where its availability is abundant but not fully utilized.

There are several sources of the biomass in Indonesia that are note explored, yet. Two of the sources are corn cobs and areca nut fiber. These sources are known as agricultural wastes that can be found in the agricultural fields. In this study, the calorific values of the corn cobs and areca nut fiber will be examined. In addition, the calorific value of the agricultural wastes will be compared with calorific value of the paper wastes. The objective is to examine the possibility of using these agricultural wastes used as solid fuel for power and or heat generation. The results are expected to supply the necessary information to Indonesia government in order to meet the renewable energy target.

ANALYSIS OF COMBUSTION

The analysis of combustion process are explained here [13]. The combustion of solid biomass as a fuel is a complicated problem. However, it can be predicted using two different methods, differential and integral methods. The basic rate rate equation can be written as

$$\frac{\partial \alpha}{\partial t} = k(T) f(\alpha) \tag{1}$$

In the above equation k and $f(\alpha)$ are the rate constant and the reaction model, respectively. As a note, reaction model is a function depending on the actual mechanism. The Arrhenius equation can be used to formulate temperature dependence rate constant as given below.

$$\frac{\partial \alpha}{\partial t} = A \exp\left(-\frac{E_a}{RT}\right) f(\alpha) \tag{2}$$

In non-isothermal thermogravimetric analysis. The Arrhenius equation can be modified by using a function of constant heating rate, $H_r = dT/dt$. Thus it can be expressed as

$$\frac{\partial \alpha}{\partial t} = \frac{A}{H_r} \exp\left(-\frac{E_a}{RT}\right) f(\alpha) \tag{3}$$

The method of estimating kinetics information mainly depend on the experimental conditions and mathematical analysis. Both simple and complex kinetics reactions can be calculated using an iso-conversional method as formulated below.

$$\int \frac{\partial \alpha}{f(\alpha)} = \frac{A}{H_r} \int \exp\left(-E_a/RT\right) dT \tag{4}$$

The temperature integral in the right side of the above equation can be approximated by

$$\int_{T_0}^{T} \exp\left(-E_a/RT\right) dT \approx R/E_a T^2 \exp\left(E_a/RT\right) \tag{5}$$

By substituting equation (5) into equation (4) the below equation will be resulted.

$$\ln\left(\frac{H_r}{T^2}\right) = \ln\left[\frac{RA}{E_a g(\alpha)}\right] - \frac{E_a}{RT} \tag{6}$$

where $g(\alpha)$ is the integral conversion function. As a note, the above combustion biomass model can be applied if at least three different heating rates are obtained. As a first step, heat from combustion biomass should be explored numerically.

APPARATUS AND METHODS

The present work is carried out at Renewable Energy Research Center, Faculty of Engineering, University of Sumatera Utara. The sample of agricultural wastes are collected from local market in Medan city of Indonesia. The sample are cleaned from any contaminant and dried. The amount of the sample are shown in Table 1.

TABLE 1. Sample of agricultural wastes and paper waste

No	Sample	Mass (g)
1	Corncob	0.53
2	Areca nut fiber	0.52
3	Paper waste	0.50

The measurement equipment consists of Bomb calorimeter, Analytic balance, RC 2 control, digital scales, cotton thread, thermometer and stopwatch. The commercial name of Bomb calorimeter is IKA C600 electronic calorimeter. The specifications of the calorimeter are as follows. Measuring range maximum is 40 kJ and working temperature is 22 - 30^{o}C. The temperature measurement resolution and cooling medium permissible operating pressure are 0.0001 K and 1.5 bar, respectively. The picture of the samples and Bomb calorimeter are shown in Figure 1.

FIGURE 1. Experimental setup

The experiment is explained as follows. The Bomb calorimeter unit is prepared at oxygen pressure of 30 bar and the chiller pump is regulated at 3600 rpm and 17^{o}C. The dried sample is prepared in the vessel and weighted. The vessel is the inserted into the calorimeter tube. The ignition wire pairs are placed in the ignition handle. After the start button is hit, the temperature rise is observed in every 0.2 minutes.

RESULTS AND DISCUSSIONS

The experiments have been carried out. The typical experimental results obtained from the bomb calorimeter is shown in Figure 2. The history of temperature during the test is shown in the figure. In the beginning, the temperature start from 22.5040^{o}C. The maximum temperature in the runs is 23.91^{o}C. The calorific value of the experiment is 14469.00 J/g as shown in the right side.

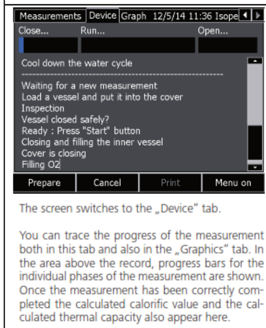
Close		Runs				Open	
Time	Temp (der Celc)	Time	Temp (der Celc)	Time	Temp (der Celc)	Result	Unit
		Main Test		Post Test			
		5.40	22.5040	11.40	23.2391	14469.00 J/g	
		5.60	22.5080	11.60	23.2391		
		5.80	22.5903	11.80	23.239		
		6.00	22.7898	12.00	23.239		
		6.20	22.9873	12.20	23.2388		
		6.40	23.0932	12.40	23.2386		
		6.60	23.1448				
		6.80	23.1736				
		7.00	23.1922				
		7.20	23.2042				
		7.40	23.2124				
		7.60	23.2183				
		7.80	23.2227				
		8.00	23.2261				
		8.20	23.2290				
		8.40	23.2312				
		8.60	23.2329				
		8.80	23.2342				
		9.00	23.2354				
		9.20	23.2363				
		9.40	23.2370				
		9.60	23.2377				
		9.80	23.2382				
		10.00	23.2384				
		10.20	23.2387				
		10.40	23.2389				
		10.60	23.2390				
		10.80	23.2391				
		11.00	23.2391				
		11.20	23.2391				

FIGURE 2. The results of measurements

In this work, three different biomass sources have been tested. They are Corncob, Areca nut fiber and Paper waste. Every test is replied three times. Thus a total of 9 experiments is carried out. The calorific values of the biomass tested are shown in Table 2. It can be seen that the highest calorific value is shown by Corncob biomass, it is 5573 cal/g. The followed by Areca nut fiber with value of 4946 cal/g. The lowest is Paper waste with calorific value of 3455 cal/g.

TABLE 2. The results of testing the caloric value

No	Sample	Calorific Value (cal/g)
1	Corncob	5573
2	Areca nut fiber	4946
3	Paper waste	3455

In order to make comparison to fossil fuel, the calorific values of the present biomass and fossil fuel are shown in Figure 3. It can be seen that, as expected, the calorific values of Crude oil is higher than all biomass tested. The calorific value of the coal is also higher than the biomass tested. However, the calorific value of the biomass tested are higher than Coal (lignite). These facts reveals that the present biomass wastes are possible to be explored as alternative fuel.

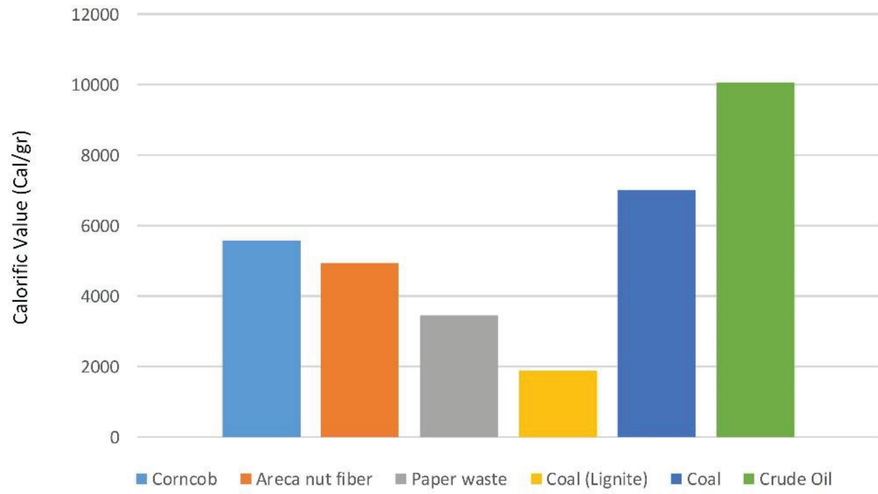


FIGURE 3. Comparison of calorific values

In order to explore the potency of the biomass agricultural waste, an analysis has been made. Since the Corncob and Areca nut fiber show the first and the second highest calorific value, the analysis is made based on the potency of Corncob and Areca nut fiber. According to Ministry of Agriculture of Republic of Indonesia, average production of Corn is estimated to be 12.193.101 tons per year. The corn production is estimated to produce as much as 8.128.734 tons of corn cobs per year. In addition according to Food Agriculture Organization, Indonesia is fifth largest producer of areca commodities in the world, Indonesia's areca nut production was recorded at 46.9 thousand tons, which produces coir as a waste that has not fully utilized. The composition of fiber in the Areca nut fruit is 15 – 30 % of the weigh [10]. By using the average value of 20%, the average production of the Areca nut fiber in Indonesia is 9.38 million ton in a year. The total potency of renewable energy from Corncob and Areca nut fiber are shown in Table 3.

TABLE 3. The potency of renewable energy from Corncob and Areca nut fiber

No	Sample	Yearly production (ton)	Renewable Energy (Ton of Oil Equivalent)	Mitigation (Ton CO_{2e})
1	Corncob	8,120	4,539	18,036
2	Areca nut fiber	9,380	4,653	18,491

Data of Table 2 shows that the potency of renewable energy in the Corncob and Areca nut fiber in Indonesia are 4,539 TOE and 4,653 TOE, respectively. If the potency can be used to replace the coal as an alternative fuel, this potency will reduce the Greenhouse gas (GHG) emission [14]. The potency of mitigation GHG by replacing Corncob and Areca nut fiber are 18,306 and 18,491 ton of CO_{2e}.

CONCLUSIONS

One of the solution to meet the Indonesian target to reduce the Greenhouse gas emission and Renewable energy share of 23% by 2025 is to enhance the utilization of renewable energy resource. The agricultural waste and municipal waste have a good potency on the enhancement of Renewable energy utilization. In this study, the calorific value of Corncob, Areca nut fiber and Paper waste are analyzed experimentally using Bomb calorimeter. The results show that the calorific value of Corncob, Areca nut fiber, and Paper waste are 5,573 cal/g, 4,946 cal/g, and 3,455 cal/gr, respectively. By using the average yearly production of Corn and Areca nut, these calorific values similar to 4,539 TOE and 4,653 TOE, respectively. If the potency can be used to replace the coal as an alternative fuel, this potency will reduce the Greenhouse gas (GHG) emission. The potency of mitigation GHG by replacing Corncob and Areca nut fiber are 18,306 and 18,491 ton of CO_{2e}.

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