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The Effect of Pressure and Heating on Biocoke Fuel from Empty Fruit Bunches

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ABSTRACT

Bio-coke, derived from renewable biomass sources has gained significant interest as a sustainable alternative to conventional fossil fuels. Understanding the influence of pressure and heating on bio-coke properties and combustion characteristics is crucial for optimizing its production and utilization. This study investigates the impact of pressure and heating on the biocoke fuel obtained from empty fruit bunches of biomass waste. Biomass waste, a byproduct of the palm oil industry, offers a potential feedstock for biocoke production, thus addressing waste management and promoting circular economy principles. The experimental approach involved subjecting biomass waste to different pressure levels and heating conditions during biocoke production. The results show that applying pressure during the biocoke production can reduce the water content significantly. The carbon content recorded in biocoke reached 45.87% compared to 43.70% in raw EFB. The proximate and ultimate analysis results show that biocoke fuel shows better results. Thus, biocoke produced using EFB biomass waste is very suitable as an alternative energy to reduce dependence on fossil energy.

1. Introduction

In an era characterized by increasing concern for environmental sustainability and the urgent need to switch to renewable and more environmentally friendly energy sources, the exploration of alternative fuels derived from biomass has gained significant momentum. Solid biomass-based biocoke fuel has high carbon content, so it appears as a promising candidate and has the potential to

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replace traditional fossil fuels while reducing greenhouse gas emissions. The availability of solid biomass waste that can be converted into energy is relatively abundant, as reported in previous publications [1-9]. Policies related to the use of renewable energy implemented by the government are the proper steps to advance the development and development of renewable energy nationally [10-15]. Meanwhile, various technologies to support renewable energy development have also been developed [16-19]. One solid biomass waste source attracting attention for energy conversion is empty palm oil bunches (EFB).

Empty fruit bunches, a by-product of the palm oil industry, have long been recognized as a sustainable raw material option for various bioenergy applications. The availability and abundance of renewable energy make it an attractive prospect in the search for sustainable energy solutions. Analysis of the availability of EFB biomass waste, specifically in Aceh Province and generally in Indonesia, has been reported in several previous studies [20]. Investigations through direct combustion in boilers using EFB fuel have also been carried out in several previous studies [21-25]. Direct combustion in the boiler through different plate modifications aims to investigate the maximum temperature of the EFB fuel. The results showed that the temperature of direct EFB combustion reached 823°C. Investigations into combustion in a pilot-scale boiler with a capacity of 150 kW using EFB fuel have also been carried out [26]. Research has also been discussed via wet torrefaction at temperatures up to 240°C to remove K, Ca, and Cl from EFB [27-29]. So far, fuel production from EFB biomass waste has generally been carried out as briquette fuel. Most briquette production is done through torrefaction first, so much energy is not utilized correctly.

The process of making fuel briquettes using EFB biomass waste by adding starch as an adhesive has been carried out by Amalia *et al.,* [30]. The research results show that adding 5 grams of starch can produce a calorific value of 21.68 MJ/kg. Meanwhile, adding 30 grams of starch produces a calorific value of 15.75 MJ/kg. Meanwhile, in a different study, briquette production by adding 60% adhesive could produce a calorific value of 5.914,81 kcal/kg [31]. In another study, it was reported that the use of EFB biomass waste for steam power plants, which was produced into briquettes with the addition of 15 ml of adhesive, could produce a temperature of 450°C [32]. Biocoke fuel production has also started in Japan, but only for analysing various biomass [33-35].

Meanwhile, the production of biocoke from corncob biomass waste has also recently been carried out by Gani *et al.,* [36,37], and Prasetiawan *et al.,* [38]. From the many studies that have been carried out, it can be concluded that there is still minimal investigation into the production of biocoke fuel by applying pressure and heating in the literature. Thus, the potential for further research into the influence of stress and heating during biocoke production needs to be investigated further because the availability of EFB as an alternative energy source is very promising.

This study investigates the effect of pressure and heating on the results of efficient and environmentally friendly biocoke fuel production. Pressure and heating, as essential variables in the biocoke production process, have the potential to significantly influence the physical and chemical characteristics of the resulting fuel. Pressure-induced densification can improve fuel quality, while carefully controlled heating conditions can optimize carbonization, resulting in higher energy content and better combustion characteristics. By systematically studying the interrelationships between these factors, this research aims to uncover the complex mechanisms that govern the transformation of EFB into valuable carbon-rich energy sources.

2. Methodology

The fuel used in this research is empty oil palm fruit bunch (EFB) biomass waste collected from palm oil mill processing waste. The accumulated EFB biomass waste is first dried before further processing. After the EFB biomass waste has dried, it is cut into small pieces and crushed using a flouring machine. The crushed EFB sample must reach <500 microns to make it more accessible during the biocoke production. EFB biomass samples before grinding and after grinding are presented in Figure 1.

(a) EFB before milling (b) EFB after milling

Fig. 1. Sample of Biomass EFB

Biocoke production using EFB biomass waste is carried out using a hydraulic press machine. A schematic diagram of the biocoke production experiment carried out in this research is presented in Figure 2. The biocoke fuel mould uses an iron pipe adjusted to the desired size. To produce biocoke with a diameter of 12 mm x 12 mm, a sample weighing 2 grams is required. Meanwhile, maximum heating is 190°C with adjustable pressure (22 MPa). An example of the biocoke fuel produced is presented in Figure 3.

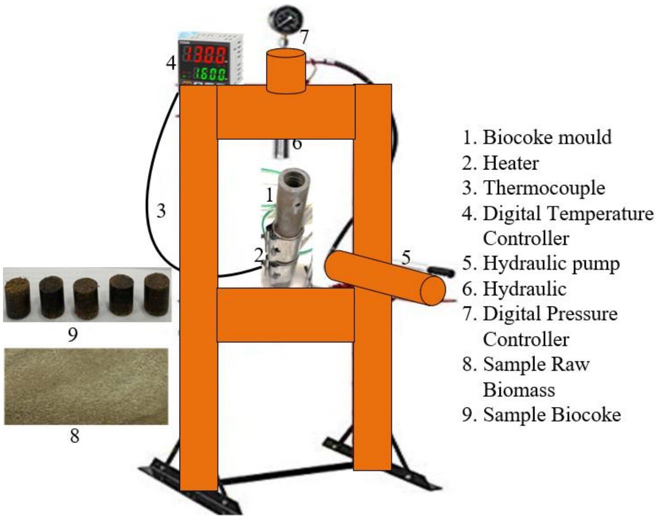

Fig. 2. Schematic Diagram Experiment for Production Biocoke

Fig. 3. Sample of Biocoke Fuel

3. Results

Thermogravimetric analyzer (TGA) analysis was carried out to investigate the mass reduction rate of raw EFB and biocoke. Figure 4 shows the results of thermogravimetry analysis of the differences between EFB raw materials and bio-coke fuel from EFB solid waste. Heating simultaneously with pressure during the biocoke-making process can significantly reduce the water content, so the energy value is higher than raw EFB. The same results also apply to volatile matter (VM) values. The VM value decreases because the water content in the biocoke is getting lower. However, the residual ash obtained from biocoke is slightly higher than raw EFB. The increase in residual ash in biocoke is influenced by heating biocoke production. An increase in temperature will result in a decrease in water content and an increase in carbon, thereby increasing the ash content in biocoke.

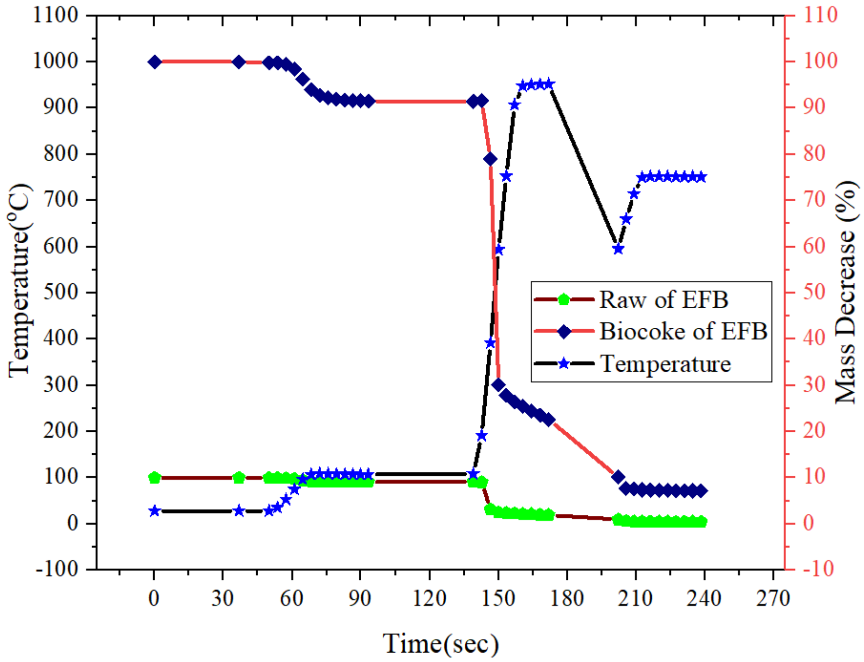

Fig. 4. Mass Decrease of Empty Fruit Bunches

The energy value recorded from biocoke was higher at 17.50 MJ/kg compared to 16.57 MJ/kg recorded from raw EFB. The results of the ultimate analysis of biocoke produced using EFB have increased compared to raw EFB. Ultimate analysis was carried out using the ASTM D5373 method, resulting in a carbon content in raw EFB of 43.70% compared to 45.87% in biocoke. Meanwhile, the proximate raw EFB analysis results using the ASTM D5142 method were volatile matter at 71.20%, fixed carbon at 14.76%, and moisture content at 9.34%. Meanwhile, the results obtained from biocoke were 71.11% volatile matter, 17.53% fixed carbon, and 6.26% moisture content. Comparison of proximate and ultimate analysis results between EFB and bio-coke raw materials as presented in Table 1. The proximate analysis results recorded from biocoke production in this study were higher than the energy value of Bamboo biomass in the study by Chen and Kuo [39]. At the same time, the research results with Coconut shell biomass waste reported in the study by Chen and Kuo [39] were also higher than those recorded in this study.

The results of TGA analysis show that the water content in biocoke produced by heating during pressing is lower than raw EFB. The amount of energy produced in biocoke is also higher than raw EFB. Thus, biocoke fuel using EFB biomass waste is suitable as an alternative energy to replace fossils. The availability of EFB raw materials for biocoke production is also very adequate in the long term.

Table 1
Proximate and ultimate analysis

Sampel	Moisture	Volatile	Ash	Fixed Carbon	C	H	N	Method
Raw EFB	9.34	71.20	4.70	14.76	43.70	6.37	0.06	ASTM D5142
Bio-coke	6.26	71.11	5.09	17.53	45.87	7.53	0.07	

4. Conclusions

This research aims explicitly to analyze energy availability in EFB fuel through biocoke fuel production. Biocoke production is carried out by heating simultaneously with pressure for a specific time. The heating provided reaches 190°C with pressure reaching 22 MPa and a retention time of 4.5 minutes for one production. The resulting water content shows a decrease compared to raw EFB. The carbon content resulting from biocoke analysis reached 45.87% compared to 43. 07% in raw EFB. The proximate and ultimate study recorded in biocoke overall showed better results than raw EFB. Biocoke fuel based on EFB waste shows the feasibility of being an alternative energy in reducing dependence on fossil energy today.

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