# Characterization of Empty Fruit Bunch of Palm Oil as Co-firing Biomass Feedstock

*by* Rusdianasari Rusdianasari

Asian Journal of Applied Research for Community Development and Empowerment. Vol 7 (2023), No.1

AJARCDE
ASIAN JOURNAL OF APPLIED RESEARCH FOR COMMUNITY DEVELOPMENT AND EMPOWERMENT

Journal home page: http://ajarcde-safe-network.org ISSN 2581-0405

# Characterization of Empty Fruit Bunch of Palm Oil as Co-firing Biomass Feedstock

*Rusdianasari[1], Iwan Arissetyadhi[2], Leila Kalsum[1], Yohandri Bow[3], Aida Syarif[1] and Fatahul Arifin[4].*

[1] *Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Indonesia*
[2] *PT. PLN (Persero) UIW S2JB, Indonesia*
[3] *Energy Engineering Department, Politeknik Negeri Sriwijaya, Indonesia*
[4] *Mechanical Engineering Department, Politeknik Negeri Sriwijaya, Indonesia*
*Corresponding author: rusdianasari@polsri.ac.id*

ARTICLE INFO

*Article History:*
Received: 02 November 2022
Final Revision: 30 December 2022
Accepted: 02 January 2023
Online Publication: 09 January 2023

KEYWORDS

*Biomass energy, Co-firing, Empty Fruit Bunch, solid waste*

CORRESPONDING AUTHOR

*E-mail: *rusdianasari@polsri.ac.id*

A B S T R A C T

Empty fruit bunches of Palm Oil (EFB) are a potential source of biomass energy because they contain lignocellulose (cellulose, hemicellulose and lignin) so that they can be converted into biopellets for co-firing. This research aims to determine the raw material properties of EFB in the form of proximate, ultimate, lignin, and biopellets. Using a pelletizer, biopellets are created by adding starch as an adhesive. The raw material characteristics of EFB from the proximate analysis revealed moisture content of 11.98%, ash content of 6.53%, volatile matter content of 65.15%, and fixed carbon content of 16.44%. According to the final study results, the biopellets from empty fruit bunches included 48.53% C, 6.05% H, 0.32% N, 36.8% O, and 0.08% Sulphure. The atomic ratio obtained from the final analysis results could be used to determine the calorific value that can be used for fuel; the biopellet calorific value of EFB is 4,583 kcal/kg, with Hardgrove Grindability Index (HGI) values of 78.6 and Ash Fusion Temperature (AFT) 1100°C. The lower the value of the atomic ratio contained, the higher the calorific value contained in a specific fuel.

## 1. INTRODUCTION

Indonesia has a variety of energy resources. Therefore, some action is required so that these reserves may be utilized to generate wealth for future generations rather than being wasted by present generations. This is because the long-term national energy problem concerns issues related to supply security and sustainability of energy supply so that it can support the long-term development and demands of all Indonesians. Long-term energy supply should consider environmental, economic, and social elements of humanity. The use of sophisticated technologies necessitates education and information reasonably sufficient to be accepted as a participant of the cultural community for those who have never interacted with a variety of new technologies and renewable energy and the influence on the usage of social humanity [1].

Almost 80% of global energy consumption is derived from fossil fuels, which pollute the environment and harm human health due to increasing $CO_2$, NOx, and $SO_2$ emissions. Biomass is a renewable energy source that provides clean energy with zero greenhouse carbon ($CO_2$) emissions and low NOx levels. After fossil fuels, biomass is the world's fourth largest energy source. Biomass provides about 11-12% of global primary energy consumption [2]. In developing nations, biomass is the most important primary energy source, representing approximately 38% of total energy consumption in rural areas and 90% of total energy supply. With an anticipated 90% of the world's population in the area by 2050, biomass energy will continue to be a significant reserve energy source [3],[4].

Indonesia is a tropical country with a significant potential for biomass. According to ESDM, Indonesia's waste biomass potential for large electrical energy conversion is comparable to 50 GWe and has already been utilized by 1,600 MW, or 3.25%. As previously said, biomass can be used as an energy source. The expansion of bioenergy through the production of empty fruit bunch pellets is especially promising, given that potential biomass pellets are used as fuel for both industrial and co-firing applications. Biomass pellets have been employed as a fuel widely used on a global scale; as a tropical country, the market potential in Indonesia is also expanding [5], [6].

In 2015, Indonesia generated 64 million tons of landfill garbage each day. If waste management is not done effectively, garbage will cause environmental degradation and health concerns. It would be fantastic if it could be recovered by processing waste energy fuel conversion, where the majority of garbage is formed from organic waste components, with a proportion of up to 32% [7]. As a result, organic waste can be employed as a raw material mixture of biomass to increase the calorific value of waste energy fuel conversion.

Oil palm plantation area expanded by 1.88% in 2019 to 14.60 million hectares, with Crude Palm Oil (CPO) production increasing by 12.92% to 48.42 million tons [8]. South Sumatra Province is one of Indonesia's top six largest oil palm farms, with 1.22 million hectares capable of producing over 4.3 million tons of CPO [9]. Increased output of oil palm farms will result in an increase in solid or liquid waste. On the other hand, each hectare of oil palm plantation produces around 1.5 tons of EFB [10].

EFB contains organic matter high in the nutrients N, P, K, and Mg. Each ton of EFB contains 1.5% N, 0.5% P, 7.3% K, and 0.9% Mg, which may be used to supplement fertilizer in oil palm plants [11].

The utilization of this type of palm oil waste is limited by processing technology that is relatively inexpensive in material preparation, and a process is required to reduce the water content, which is still quite high, despite the fact that the lignocellulose content of EFB is quite high, namely cellulose (41-46.5%), hemicellulose (25.3-33.8%), and lignin (27.6-32.5%) [12]. Based on these chemical components, EFB has the potential to be utilized as an environmentally friendly energy resource with small levels of nitrogen, sulfur, and ash [13],[14]. Thus, pelletization is a cutting-edge approach to using biomass for energy that is both effective and efficient.

As a result, this research focuses on improving the performance of pellet production with various processes ranging from pre-treatment of feedstock materials to treatment of physical parameters on multiple pellet presses.

It is predicted that utilizing the sort of biomass palletization technology created today would stimulate energy optimization of biomass as renewable energy as feedstock to co-firing. Co-firing, also known as co-combustion, is the act of burning two distinct types of fuel in the same combustion equipment, which is often a steam boiler. Co-firing coal and biomass may be considered part of a system that supports coal-fired boilers.

## 2. MATERIALS AND METHODS

### 2.1. *Research Framework*

A biomass pellet, especially an empty fruit bunch of palm oil, represents 30-35% of the weight of fresh fruit bunches and are one of the most prevalent forms of solid waste produced by palm oil mills. (EFB) is a plentiful palm oil mill byproduct. Each ton of FFB (Fresh Fruit Bunches) processed yields 22-23% EFB or 220-230 kg of EFB. Suppose a facility with a processing capacity of 100 tons/hour and an operational time of 24 hours produces 23 tons of EFB [15]. At the same time, EFB from oil palms is potentially abundant lignocellulosic biomass derived from palm oil mill waste. The volume is enormous and has not been exploited. EFB is made up of three essential components: cellulose, hemicellulose, and lignin. However, it has previously only been utilized as animal feed, fertilizer, and direct boiler, fuel to generate electricity [16].

It is believed that using the type of biomass palletization technology produced today would encourage energy optimization of biomass as renewable energy and environmentally friendly [17], [18], [19]. In this context, preliminary research is needed to establish the influence of palletization technology and its products in small and medium industries, particularly electric steam power plants. This study relies on establishing technological implementation objectives and determining the readiness of science resources such as human resources, infrastructure, money, and the industrial infrastructure itself. This study is intended for all stakeholders downstream of palletization technology research to the industry capable of synergy in their tasks and responsibilities based on their competence and capacity to achieve the identified goals and timelines measurable and transparent.

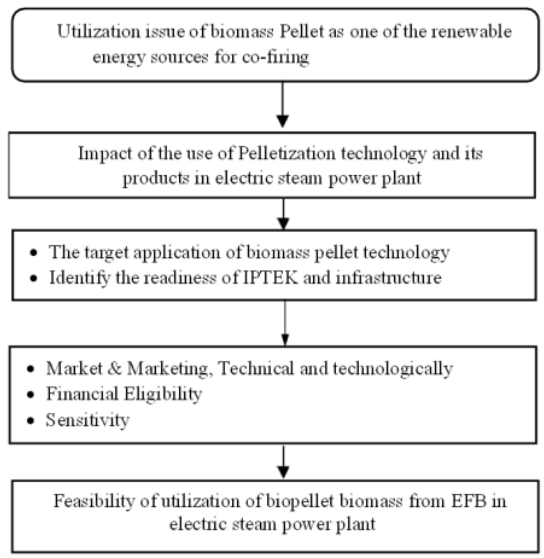


**Fig.1**. Research Framework

### 2.2. *Preparation Raw Material*

Pure feedstock materials used in this study was empty fruit bunch collected by collecting waste in the oil palm plantation. EFB are washed and dried for two days to remove bound water content. EFB that have been dried are chopped and dried again. After that, the size is reduced using a grinding machine to 1-2 mm. EFB as a raw material for making biopellets can be seen in Figure 2.


**Fig. 2**. Empty fruit bunch

Figure 3 shows the equipment used to reduce the size of the EFB to 60 mesh.


**Fig. 3.** EFB Size Reduction

### 2.3. *Pre-treatment*

Pretreatment is intended to improve the quality of prepared raw materials. The Klason Method was used to treat EFB in four stages: without delignification, with aquadest, and with acids of 5% and 10% HCl [20]. Delignification tries to increase the calorific value of oil palm empty fruit bunches by dissolving the lignin linkages in the cellulose [21]. During the delignification procedure, the raw materials and the solution were heated to 121°C for 30 minutes before being filtered and rinsed with water to a neutral pH. The resulting residue was weighed and then dried for one hour at 105°C [22],[23]. To eliminate binding water content, fruit bunches are rinsed and dried for two days. Dried EFB is cut and dried once more. The size is then decreased to 1-2 mm by grinding. Then, using size reduction and sieving equipment, ground it to 60 mesh.

The adhesive used is tapioca flour in the amount of 50 grams and mixed with 100 mL of water amylum 50%), mixed thoroughly and heated the mixture at 40°C until the mixture thickens and follows by cooling to room temperature.

### 2.4. *Production of Biopellets*

Empty palm fruit bunches of 60-100 mesh are blended in a 60:40 ratio with glue (50% starch). A pelletizer with a diameter of 6 mm is used for biopellet printing. The resulting biopellets are analyzed to obtain their characteristics according to the Indonesian national standard SNI 8951: 2020, includes proximate and ultimate analysis and heating value of biopellets.


**Fig. 4.** Pelletizer

Fig. 4 shows the equipment used to produce biopellets, whereas Figure 5 shows the finished products.

**Fig. 5**. Biopellet from pelletizer


https://doi.org/ 10.29165/ajarcde.v7i1.237

### 2.5. *Biopellet Analysis*

SNI 8951: 2020 analysis was performed on biopellet products, which covered proximate and ultimate analysis as well as the levels of sulfur, total hardgrove grindability index (HGI), and ash fusion temperature (AFT).

## 3. RESULT AND DISCUSSION

### *3.1 Raw Material Analysis*

According to its proximate and ultimate analysis, EFB can be used as a raw material to produce biopellets. The final analysis atomic ratio may be utilized to calculate the quantity of calorific value used for fuel [24]. In addition to proximate and ultimate analyses, the researchers used the Klason technique to estimate lignin concentration to determine the properties of EFB.
Figure 6 depicts the results of the residual lignin content in EFB during the delignification process using HCl at 121°C.

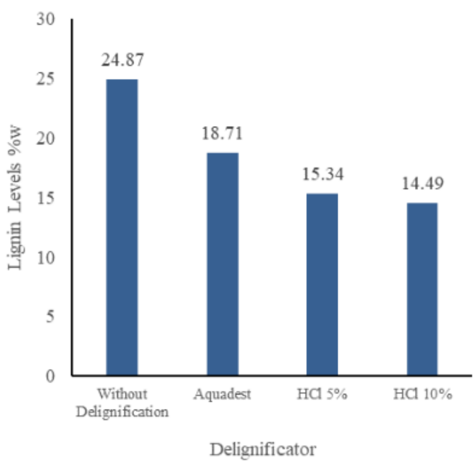


**Fig. 6**. Lignin Levels

Figure 6 depicts the observed lignin levels. The lignin concentration in EFB was 15.34% for HCl 5% delignification, 14.49% for HCl 10% delignification, 18.71% with aquadest treatment, and 24.87% without delignification. According to this study, the higher the concentration of HCl, the lower the residual lignin content in the raw material. However, in this investigation, delignification with aquadest was not significantly different from delignification with HCl. This is because lignin's solubility in acid is limited, or there is still a lot of lignin that is still linked (not soluble in acid). Several investigations have shown that lignin inhibits the reactivity of the acid catalyst, thus it cannot considerably decrease the lignin concentration and requires a large amount of energy or a high temperature (100-230°C) [25],[26]. Lignin is a polymeric organic compound present in higher plants that is important.

### *3.2 Biopellet Production Analysis*

Pellets produced following analysis and selection based on the characteristics of the feedstock material pellet product. The heating value of the feedstock materials was tested using a bomb calorimeter in the first selection procedure. The objective was to get high calorific value and physically strong feedstock material for pellet production. The optimum calorific value will be chosen to be processed into pellets. The results of biopellet from EFB using a pelletizer can be seen in Figure 7.

**Fig. 7.** Biopellets from EFB

Using biomass as renewable energy (RE) has the advantage of being carbon neutral, as the $CO_2$ produced during the combustion process may be reabsorbed by plants and used to produce energy again during the photosynthesis process.

Proximate analysis of EFB raw material properties indicated moisture content of 11.98%, ash content of 6.53%, volatile matter content of 65.15%, and fixed carbon content of 16.44%. The biopellets from empty fruit bunches included 48.53% C, 6.05% H, 0.32% N, 36.8% O, and 0.08% Sulphur, according to the final study results. The atomic ratio determined by the final analysis findings may be used to calculate the calorific value that can be utilized for fuel; the biopellet calorific value of EFB is 4,583 kcal/kg, with Hardgrove Grindability Index (HGI) values of 78.6 and Ash Fusion Temperature (AFT) values of 1100°C. The higher the calorific value of a certain fuel, the lower the value of the atomic ratio included.

Biopellets derived from agricultural waste biomass frequently include chemical content, such as high ash content (over 1.5%), which lowers heating value and causes damage to boiler engines during the co-firing process of power plants.

## 4. CONCLUSION

Empty fruit bunches (EFB) of oil palm are a potential source of biomass energy because they contain lignocellulose (cellulose, hemicellulose and lignin) so that they can be converted into biopellets for co-firing. Proximate study of EFB raw material properties indicated moisture content of 11.98%, ash content of 6.53%, volatile matter content of 65.15%, and fixed carbon content of 16.44%. The biopellets from empty fruit bunches had 48.53% C, 6.05% H, 0.32% N, 36.8% O, and 0.08% S, according to the final study. The ultimate and proximate analyses findings indicate that biopellets from EFB can be employed as co-firing in power plants.

## ACKNOWLEDGMENT

Authors gratefully acknowledged for the State Electricity Company, PT PLN (Persero), UIW S2JB which has financed this research.

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