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Nofriady Handra
*Department of Mechanical Engineering, Institut Teknologi Padang, Padang 25143, Indonesia*, nof.hand11@gmail.com

Ade Indra
*Department of Mechanical Engineering, Institut Teknologi Padang, Padang 25143, Indonesia*



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# Briquette of Empty Fruit Bunch Fiber as an Alternative Substitution for Binderless Fuel Methods

Nofriady Handra* and Ade Indra

Department of Mechanical Engineering, Institut Teknologi Padang, Padang 25143, Indonesia

*E-mail: nofriady.h@itp.ac.id*

## Abstract

Biomass development has been a key issue for the past few decades and will remain attractive in the future because of its cleanliness, renewability, carbon neutrality, and other advantages. This study aims to determine the optimal holding time for heating system briquettes by testing the heating value of empty fruit bunches fibers. The process of this research involves the use of one unit of briquette molding equipment by providing a heating system to the mold cylinder. Fibers were manually finetuned until they reached a size of 20 mesh (0.84 mm). Densification temperature is an essential factor that could affect the combustion properties, especially the calorific value. The Arduino program is used for setting the heating resistance time of the mold, which is 15, 20, and 25 min at a temperature of 200 ºC, and the thermal controller is used to adjust the temperature variation. Results showed that the highest calorific value of the three varieties of holding time was at 25 min with a calorific value of 4480.2 cal/g, and the lowest cost at 15 min was 4022 cal/g. Meanwhile, a calorific value of 4432.5 cal/g was found at 20 min. This finding is due to the low moisture content and high charcoal content of the sample in the 25 min briquette mold. Therefore, briquettes at 25 min have a higher heating value compared with those at 15 and 20 min holding time.

*Keywords: binderless, briquette, calorific value, EFB, fiber*

## 1. Introduction

The development of biomass has been a carbon-neutral issue for the past several decades and will remain attractive in the future due to its clean, renewable, and carbon-neutral properties. Apprehension toward increasing dependence on environmental and energy problems has become a motivation for the rising application of bioenergy in the future as a substitute for fossil energy in space heating and as a power plant. Biomass is organic material produced through a photosynthetic process, either in the form of products or waste, such as plants, trees, sweet potatoes, grass, livestock manure, and agricultural waste in the form of products and waste. Biomass products can be used as a source of renewable energy originating from organisms on Earth. Research on technological innovation using fibers and empty fruit bunches (EFBs) as alternative energy has been conducted at laboratory and pilot scales. Investigations on fibers and EFB as a source of energy are performed through the process of normal combustion, gasification, and charcoal briquettes [1]. Agricultural waste is an example of such alternative energy sources [2]. Coal and biomass are some alternative energies that can be developed as substitutes for fuel oil. Coal is the energy of fossil fuels, while biomass is a natural ingredient that is typically considered waste and often destroyed by burning. Agricultural waste can be processed into a solid fuel that can be extensively used as an alternative fuel called bio-briquette.

Biomass briquettes are made from agricultural waste and are a replacement for fossil fuels such as oil or coal. Thus, they can be used to heat boilers in manufacturing plants. Biomass briquettes are a renewable source of energy, thereby avoiding the addition of fossil carbon to the atmosphere [3]. Indonesia is one of the largest oil palm-producing countries in the world, with an area of 3.76 million hectares, accounting for 31.4% of the world's total area of oil palm plantations. Therefore, the amount of EFB waste can reach 1.7 million tons/year [4]. This number continues to increase along with oil palm cultivation. The lack of utilization of palm oil waste leads to environmental pollution. In oil palm, EFB contains various kinds of fibers with compositions such as cellulose (45.9%), hemicellulose (16.5%), and lignin (22.8%). The content in empty oil palm bunch waste can be utilized in developing biomass as an alternative energy source.

As one of the potential energy alternatives, biomass energy has attracted increasing attention because it is an ideal renewable energy source with several advantages, such as low sulfur and abundant availability generally in the form of waste from agriculture as well as other sources. Bioenergy derived from biomass is a promising, inexhaustible, and sustainable source and can help minimize the rising environmental, economic, and technological issues related to depleting fossil fuels [5].

Based on numerous studies, briquettes are one of the most promising technologies for alleviating the aforementioned problems. This technology may be defined as a densification process for improving the handling characteristics of the raw material and enhancing the volumetric calorific value of the biomass. A considerable amount of research on briquette technology has been conducted [5, 6].

The effects of raw materials, binders, operating temperatures, pressures, and treatments on the combustion properties of densified palm biomass, such as calorific value, moisture content, and ash content, are reviewed. The review in terms of burning rate is also enclosed in individual sections that are related [7]. Biomass is the result of the photosynthesis of plants and their derivatives. The selection of biomass as fuel has additional value because it is green energy. Burning biomass does not disturb the environment because it can be replanted (renewable), and the combustion of $CO_2$ will be reabsorbed by the plant (zero emission). Biomass waste can be obtained from byproducts from plantation industries, agricultural products, or industries that utilize raw materials derived from forests [5, 8].

Processing of EFBs into solid briquettes in the form of small powder particles has been conducted. However, the production of biomass briquettes still uses adhesives in their formation. Meanwhile, in this study, briquettes were produced without adhesives. Several previous studies have researched and made briquettes using adhesive materials. Adhesives strengthen the structure of briquettes, allowing for easy handling and production. One of the weaknesses of adhesives lies in their economical use, which will then increase production costs.

In this study, briquettes were produced using a heat application system in the mold. The heat is regulated based on the volume of the mold, the diameter of the briquettes produced, and the fiber grain size. The importance of determining the fiber grain size lies in its effect on qualities such as strength, briquette burning time, and the calorific value produced.

## 2. Methods

The material used in this study is EFB, which is the basic ingredient of bio-briquette production. EFB waste obtained from the palm oil processing industry in the area of West Pasaman, West Sumatra, is utilized in the production. The use of EFB is a major factor in obtaining good-quality briquettes, especially by selecting fresh and new EFB conditions. Waste treatment is conducted in several stages before performing the experimental process of briquette production. Figure 1 shows the waste EFB used in this experiment.

The EFB was dried in the sun. Fibers were manually finetuned until they reached a size of 20 mesh (0.84 mm). Cut fibers produce various nonuniform sizes, and some products are in the form of powder. Figure 2 shows the powdered EFB and fiber. The fibers that were cut into pieces were then filtered to obtain a uniform size using the Aperture 850 Mic 20 mesh 9 (Milano, Italy). The calorific value of the EFB fiber was determined using an oxygen bomb calorimeter (OBC)-type ignition unit (2901 EE). The OBC is a tool used to measure the amount of calorific value possessed by a material.

The current research uses one unit of briquette molding by providing a heating system on the mold cylinder wall at a constant heating temperature of 200 ºC and giving holding time variations of 15, 20, and 25 min, as shown in Figure 3. The average mold pressure is 58 Psi. Under the mass of the holding time, the heated fiber will undergo chemical and physical compaction. Briquetting pressure and temperature, as well as coal moisture content, are important parameters in the binderless briquette process [9]. The Arduino Board Model UNO R3 program (Italy) is used to regulate the heating resistance time of the mold with time variations of 15, 20, and 25 min at a temperature of 200 °C as a fixed variable, and a thermos controller unit is used to regulate temperature variations.

**Figure 1. EFB Waste as the Basic Material for Making Bio-Briquettes**

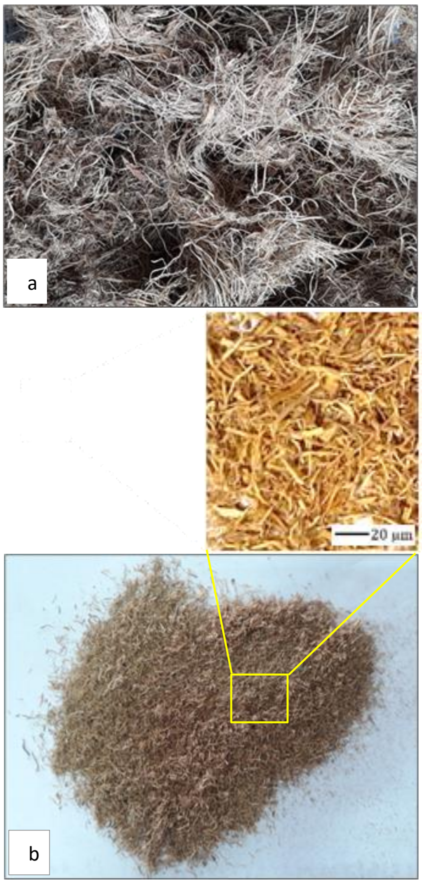


**Figure 2. EFB : (a). Fiber Before Chopping; (b). Fiber After Being Chopped and Filtered on a 20 Mesh**

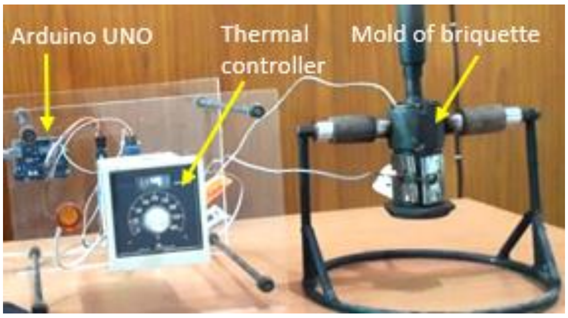


**Figure 3. Heater Systems using the Arduino, Thermal Controller, and Mold of Briquettes with Heater**

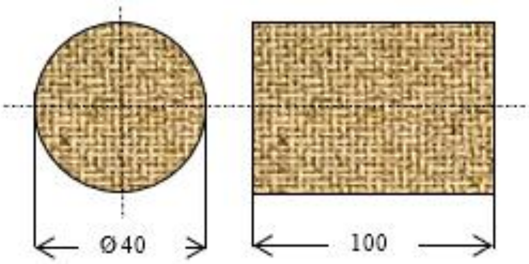


**Figure 4. Dimensions of the Mold Cylindrical**

Arduino UNO is a microcontroller board based on the AT mega 328 data sheet. This controller board is open source because it is designed to facilitate electronic control. Arduino controls electronic signals through input and output pins on the microcontroller board. The input pin can be used to read values from sensors, while the output pin controls the motors or LED lights.

The densification temperature is a crucial factor that could affect the combustion properties especially calorific value. When the operating temperature is relatively high, the calorific value of the densified products increases compared to that of the raw materials [10]. The samples are tested in terms of toughness, heat value, and ash and charcoal contents. Briquetting is the process of increasing the density of biomass through using compaction of the original loose particles by application of mechanical force. Among the advantages of bio-briquetting include creating a bond within the particles to form a solid fuel, decreasing the moisture content of the biomass, increasing the net caloric value per unit volume because of the removal of volatile matter, producing uniform size and quality fuel, ease transportation and storage, and help addresses residue disposal problem [11]. Several characteristics, such as strength and durability, must be considered to produce high-quality briquettes [12].

Figure 3 shows one of the supporting unit parts for the research process of the production of EFB bio-briquette fiber samples. The mold is used to shape briquettes with a predetermined classification. The working process of this mold compresses one part of the suppressant to produce optimal density. Figure 4 is the dimensions of the mold cylindrical, the total length is (100 mm, ø 40 mm), and the resulting high briquettes are 50 mm. The volume of the briquettes is determined by Equation (1) as follows [5–13]:

$$V = \pi \ r^2 t \qquad (1)$$

where V is the volume of the number of fibers ($mm^3$), π is a Constanta (3.14), t is the length of the mold (mm), and r (radius) is the diameter of the mold (mm).

Regarding density, most technological processes produce bio-briquettes with densities above 1000 $g/cm^3$, which sink in water during testing for quality. The physical upper-density limit for lignocellulosic materials is approximately 1500 $g/cm^3$. The process of applying high pressure to the mold, such as mechanical piston and pellet press, or the process of using screw extruders, increases the compactness of briquette structures in the density range of 1200–1400 $g/cm^3$. Hydraulic piston pressing of briquettes produces less dense bio-briquettes, occasionally below 1000 kg. The formation of excessively dense bio-briquettes is ineffective because it will affect the combustion properties produced.

## 3. Results and Discussion

This research is on biomass briquettes and the simple process of converting agro wastes into biomass briquettes. All materials in the composition containing lignite, ash, and cellulose are suitable for densification. The current research focuses on the production of bio-briquettes, which are made from EFB waste to produce calorific value. As an organic material, EFB has a basic characteristic in the form of physical and chemical properties. Nasrin *et al*. (2008) and Handra *et al*. (2018) investigated the chemical composition of the fiber content of EFB, as shown in Table 1.

The experimental study performed by Nasrin on the binderless EFB briquettes revealed that the physical appearance of a binderless palm biomass briquette is best when the smallest particle size is used. This finding is mainly due to the increase in contact surface area when a small size is used, thus stimulating the production of lignin, which, in turn, improves the effectiveness of lignin as a natural binder. Figure 5 shows a sample of bio-briquette fibers in variations of each time holding at 15, 20, and 25 min. The average piston pressure on the mold cylinder is 58 Psi, with a briquette volume of 32.7 g/cm$^3$. Physically, the briquettes produced at a holding time of 25 min yield a darker color compared with those at 15 and 20 min warmup time. Therefore, the fiber or briquettes will experience maximum heating during an extended period, thereby yielding charred briquettes. Thus, further study is necessary at a holding time of 1 min. EFB briquettes produce optimal conditions in terms of holding time.

The EFB fiber moisture content determines the quality of the bio-briquettes produced. Thus, bio-briquettes with a low water content will produce high heat values. Briquettes are produced from a type of fiber with a low moisture content. Meanwhile, briquettes with a high water content yield low calorific values.

This finding is due to the initial heat generated, which is used to evaporate water in the fiber before producing heat for combustion. Thus, the water content is directly related to the heating value. Figure 6 shows a graph of the relationship between holding time, briquette water, and charcoal contents. The cellulose content in the fiber will affect the amount of charcoal bound in the briquette. A high cellulose content yields a high level of charcoal binding because the constituent components of cellulose are carbon. In EFB microfiber there are cellulose, lignin, and hemicellulose as the main components [14]. High carbon contents in the substance linked to the raw material lead to high calorific values.

In Figure 6, briquettes with a heating time of 25 minutes have a high charcoal content, namely 20.7%, meanwhile, at a holding time of 20 minutes it produces 18.7% and at 15 minutes 15.2%. The difference in the value of char content between the holding times of 15, 20, and 25 min did not show significant differences in cost. The increase in the amount of charcoal content will affect the calorific value produced, as shown in Figure 6. The water content in EFB briquettes will influence the quality of the briquettes produced. Briquettes with low water content will generate high calorific values. These briquettes are produced from a type of fiber with a low water content. A high fiber content in water results in low calorific values. This finding is due to the heat generated, which is first used to evaporate the water in the fiber before producing heat for combustion.

**Table 1. Chemical Composition of EFB Fiber**

| No | Chemical Components | Composition (wt %) |
|---|---|---|
| 1 | Lignin | 15 until 17 |
| 2 | Cellulose | 36 until 42 |
| 3 | Hemicellulose | 25 until 27 |
| 4 | Ash | 0.7 until 6 |

Nasrin *et al*. 2008, Handra *et al*. 2018

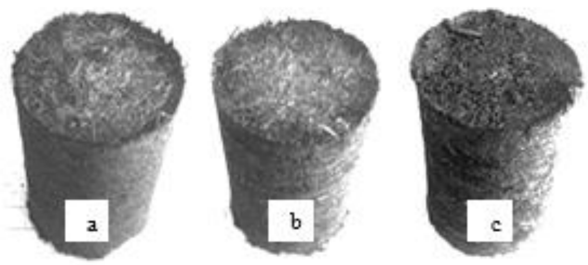


**Figure 5. Sample of Bio-Briquette EFB Fiber at Holding Times of (a) 5, (b) 20, and (c) 25 Minutes**

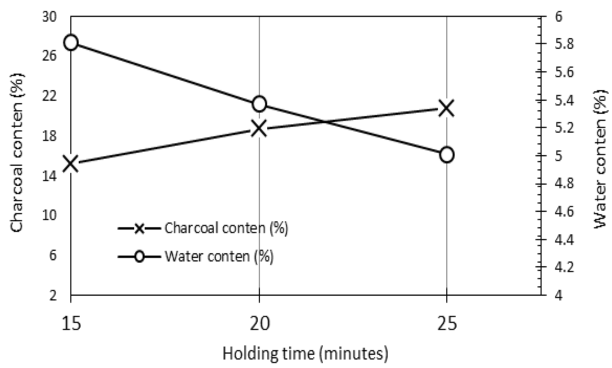


**Figure 6. Graph the Relationship Between Holding Time and Water and Charcoal Contents Produced**

The figure also shows that the water content is 5.8% and 5.0% at 15 and 25 minutes. The difference in water content loss is due to the long holding time given to the briquette mold. Thus, when the water content contained in the briquette is low, the moisture content in the fiber evaporates during the printing process. A low water content may increase the generated calorific value. This value is generally below the water content standard price according to SNI 01-6235-2000 considering the quality standards of charcoal briquettes that are equal to a maximum of 8%.

One of the essential characteristics of a fuel is its calorific value, which is the amount of energy per kg produced during burning. Thus, the calorific value can be used to calculate the competitiveness of a processed fuel in a given market situation.

Toughness in a briquetted product is very necessary, especially during the handling, processing and packing process, which affects product marketing. However, the calorific value is the most critical factor and thus should be recognized when selecting the raw material input. The calorific value determines the quality of briquettes. A high heat value yields good-quality briquettes. Low water content, ash content, and volatile matter can also increase heating values. High carbon content can raise heating values. The test of the calorific value aims to determine the extent of the combustion heat value produced by briquettes.

Figure 7 shows the relationship between holding time, calorific value, and the time of ignition/burning of briquettes. The highest and lowest calorific values occur at holding times of 25 and 15 min, with values of 4480.3 and 4022.2 cal/g, respectively. The results of the combustion test with ignition timing at 25 min revealed a burning time of 13.2 min, while the 15 min holding time only resulted in the ignition of briquettes for 12.2 min. Figure 8 shows the toughness test graph of briquettes for each sample holding time. This test aims to obtain samples that exhibit resistance or strength to the treatment if the briquette sample is dropped at an altitude of 1.8 m. Moreover, determining the amount of briquette resistance when impacted is useful during the packaging, distribution, and storage processes. This test is performed in accordance with ASTM D 440-86 R02 standards.

The test results showed that at a 15 min warmup time, the fibers were damaged or detached from the structure by 5.3% after the briquettes were dropped at an altitude of 1.8 m, thereby reducing the initial weight of the briquettes from 27.2 to 26.6 g. Meanwhile, the heating time of 25 min produces a fiber percentage that is 3.6% off, where the initial weight of the briquette drops from 29.2 to 25.2 g. Testing conducted at a temperature heating of 200 °C with a 25 min holding time results in better briquette resistance compared with that at 15 and 20 min. Increasing the duration of briquette heat will optimize the formation process of compaction of produced briquettes from elements of lignin and cellulose in fibers and adhesion between particles by lignin. Therefore, the durability of briquettes during impact will suffer minor damage.

Fraction size considerably influences the briquetting process. A high compacting power is necessary for the briquette of a coarse fraction. Briquettes also have low homogeneity and stability. The binding forces inside the material decrease with increasing fraction size, which results in rapid decay by burning (a disadvantage of briquette lies in its rapid burning). The enlargement of fraction size raises the compacting pressure and decreases briquette quality. Small and uniform fraction dimensions will provide numerous advantages in the drying process, thus impacting the combustion quality. Increased in compaction pressure automatically increased the density of briquettes and consequently, delayed the ignition time of the briquettes. Furthermore, briquettes compressed to a higher density will tend to have a lower porosity, and thus elongate the ignition time [15]. The drying process ends fast, and superior drying quality is achieved. Therefore, the waste material should be ground into a suitable fraction size and dried to a certain moisture content before the briquette process.

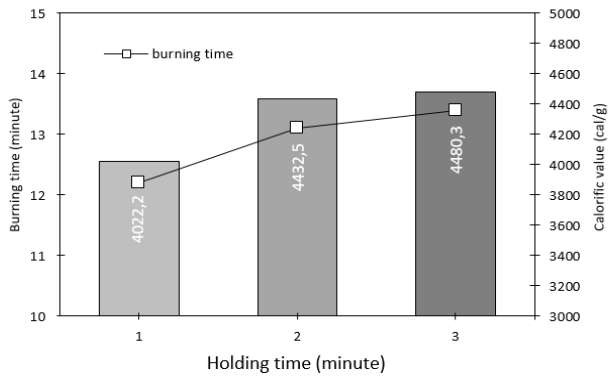


**Figure 7. Graph of the Relationship Between Holding Time, Briquette Time, and Calorific Value**

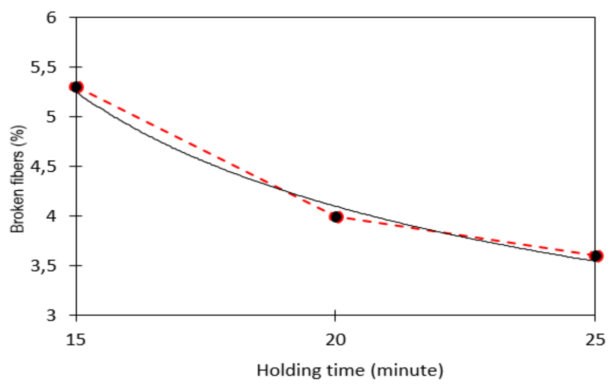


**Figure 8. Graph of Relationship Between Holding Time vs Broken Fibers**

## 4. Conclusions

This study proved that EFB briquettes can be used as biomass-based fuels. Empty bunch briquettes can potentially burn almost the same as coal energy for electricity generation. Moreover, these briquettes can be used on industrial and household scales as an environmentally friendly renewable energy sources. The results of the study showed that the highest calorific value of three holding time variations was at 25 min with a value of 4480.2 cal/g, the lowest value was at 15 min with a value of 4022 cal/g, and the 20 min holding time had a calorific value of 4432.5 cal/g.

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