THE POTENTIAL UTILIZATION OF COFFEE WASTE INTO BIO-BRIQUETTE AS ENVIRONMENTALLY FRIENDLY FUEL

POTENSI PEMANFAATAN LIMBAH KOPI MENJADI BIO-BRIQUETTE SEBAGAI BAHAN BAKAR RAMAH LINGKUNGAN

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Abstract

The coffee industry produces a large amount of waste in the form of coffee grounds, which is about 45% of the processed coffee beans. This research aims to study the potential of waste produced by the coffee industry as an environmentally friendly alternative fuel (green energy) in the form of biomass briquettes. The results show that coffee waste briquettes have a fairly good performance as fuel, are easily burnt, and have an energy content that is almost the same as dry wood. By using the “hot pressing” method in the mechanical pressing machine, bio briquettes with a fairly good density and strength level can be obtained. The briquettes have a heating value of 5169 – 5500 kcal/kg at water content of 12-12.5%, and a density of 0.35 – 0.86 g/cm^3.

Keywords: Bio-briquettes; Biofuel; Used Coffee Grounds; Hot Pressing; Environmentally Friendly; Renewable Energy

Abstrak

Industri kopi menghasilkan limbah dalam bentuk butiran ampas kopi dalam jumlah yang cukup besar, yaitu sekitar 45% dari biji kopi yang diolah. Penelitian ini bertujuan untuk mempelajari potensi limbah industri kopi tersebut sebagai bahan bakar alternatif yang ramah lingkungan (green energy) dalam bentuk briket biomassa. Hasil penelitian menunjukkan bahwa briket limbah kopi memiliki performa cukup baik sebagai bahan bakar, yaitu relatif mudah terbakar dan memiliki kandungan energi hampir sama dengan kayu bakar. Dengan menggunakan metode “hot pressing” pada mesin pengempa mekanis, diperoleh briket ampas kopi dengan tingkat kepadatan dan keteguhan yang cukup baik. Briket biomassa yang dihasilkan tersebut memiliki nilai kalor sebesar 5169 – 5500 kcal/kg pada kadar air 12 – 12,5% serta densitas 0,35 – 0,85 g/cm^3.

***Kata Kunci**: Briket Biomassa; Bahan Bakar Hayati; Ampas Kopi; Pengempaan Panas; Ramah Lingkungan; Energi Terbarukan*

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INTRODUCTION

Coffee is one of Indonesia’s mainstay export commodities. Finished coffee products are generally available in the form of roasted green beans (coffee beans) and ready to be ground down, in coffee powder form, and even available in the form of ready-to-consume drinks[1)]. There are 2 types of coffee powder, i.e., the coffee powder obtained from roasted and ground coffee beans (in the market, it is referred to as "coffee powder"), and coffee extract powder obtained from the extraction process using high-temperature steam and then dried-up into powder through the process of spray drying (this product is referred to as "instant coffee"). Coffee powder is consumed by brewing it with hot water, and it produces residues in the form of used coffee grounds. In comparison, instant coffee may be brewed with hot water at low temperatures and leaves no residue.

In turning coffee beans into “coffee powder," the process produces no residues/by-products because coffee beans are fully grounded down into a powder. Coffee residues/by-products are produced when the coffee is brewed[2-3], and the brewed water is drunk. Whereas in the processing of coffee into instant coffee powder, it produces residues/by-products because the coffee substances are extracted through high steam pressure technology. The excellent and effective extraction process will produce by-products/residues with no coffee scent. Residues that still produce coffee scent indicate a less efficient extraction process. According to Dwi Khusna and Joko Susanto (2015), the instant coffee production process at PT Santos Jaya produces residues/by-products (45% of the total processed coffee[4]). Such a considerable number of residues definitely requires proper handling to avoid any environmental problem, and it may bring economic benefits[5].

Figure 1.
Residual Waste/Used Coffee Grounds in the Coffee Production Process

Based on the initial observation against the physical nature of used coffee grounds produced from the coffee process (Figure 1) and the phases of process passed, there are several alternative ideas for utilization of instant coffee residual waste/used coffee grounds worth studying for implementation, such as turning it into active charcoals and utilization into fuel in the form of briquette. The utilization as fuel in the form of briquette may have several positive values at once, i.e., reducing the cost of fuel, participating in the energy mix national program, participation in the effort to reduce greenhouse gas emission and environmental damage due to the reduced use of fossil fuel, as well as the “green product” label in the international market[6-7].

As a fuel, the briquette produced from the used coffee grounds/residues must meet the general criteria of fuel, i.e., possesses high heat (calor) energy value, ignites easily but does not burn out easily, and can be handled easily in terms of its operation/use[8]. Dwi Khusna and Joko Susanto (2015) had tried to research its utilization as briquette by using raw materials from one of the instant coffee powder manufacturers in East Java. However, the results had been less satisfying because the briquette produced had been fragile, had taken some time to ignite, and had produced a great deal of smoke[4].

This research aimed to implement the technology of densification against the waste produced by the coffee industry to produce bio-briquettes and conduct the analysis of the potential of bio-briquette as one of the environmentally friendly alternative fuels.

MATERIALS AND METHODS

This research was conducted during the period of May 2019 at the IPB Darmaga - Bogor campus, supported by the results of analysis by the laboratory of the Center for Forest Product Research & Development – Ministry of Environment & Forestry of the Republic of Indonesia, and the laboratory of the Livestock Research Institute – Research and Development Agency of the Ministry of Agriculture of the Republic of Indonesia.

The phases of research conducted include the analysis of raw materials (used coffee grounds/residual waste) and continued with the determination of initial treatment of the raw materials and the briquette composition, briquetting, briquette performance test, and analysis of the test results to determine the best and recommended type of briquette. Figure 2 describes the phases of research conducted.

The purpose of the analysis of the raw materials (used coffee grounds/residual waste) conducted in the initial phase is to identify substances in the raw materials. This is important because it will be used as the primary basis in determining the phases of the process required to be conducted, determination of the adhesive agent or the additive that may be used, as well as an overview of the power requirement needed in the pressing (briquette moulding) process.

The data on raw materials needed are physical conditions (particle size, colour, scent), moisture content (% wet basis), ash content (%), volatile matter content (%), fixed carbon content (%), lignin content (%), and energy content or calorific value (kcal/kg). If the moisture content is too high, initial treatment in the form of the raw material drying process is needed to achieve the ideal moisture content for the briquetting process, i.e., around 15%. Preliminary research in the form of briquetting uses a standard adhesive in the standard composition for the rice husk charcoal briquette material using the manual pressing machine (Figure 3). The standard adhesive in briquetting is the tapioca solution (75 grams of tapioca flour dissolved in 1 litre of water) cooked into a gel (glue)[9]. Briquetting through mixing raw materials with adhesive and then pressing the mix into briquette is known as the "cold pressing" method.

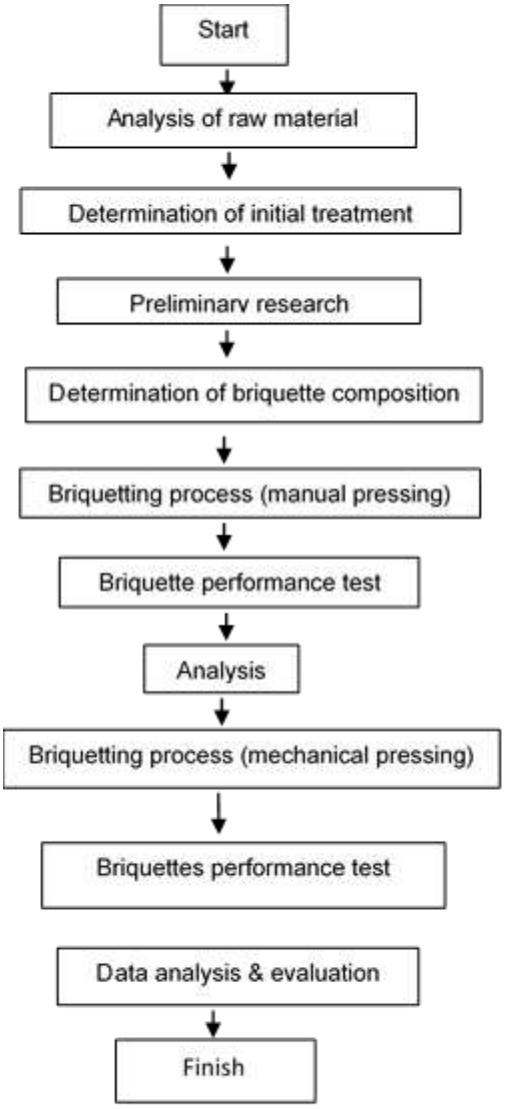

Figure 2.
The Phases of Research Activity Conducted
Sources: Processed Results of Research Data

Figure 3.
Briquetting using Manual Pressing
Designed by IPB University

The briquette performance test is an evaluation of the performance of briquette as fuel. The testing parameters used are ignition time (second or minute), combustion rate (gram/minute), flame colour, smoke, scent/aroma, ember formation, briquette shape stability when burning and after burning, and other burning characters (if any). Such parameters are used in the preliminary research phase or the core research phase. The additional parameter not less important is the strength (the briquette is robust, is not fragile), which is performed by means of dropping the briquette from the height of 1 meter.

The observation results against the performance of briquette resulting from the manual pressing are used to determine the necessity for using the mechanical pressing machine, which may produce higher pressing pressure or the application of the "hot pressing" method. The "hot pressing" method is pressing, accompanied by the heating process so that the resulting briquette will be more solid and strong (is not fragile). Figure 4 is the mechanical pressing machine used in this research, i.e., a pressing machine designed and made by the Renewable Energy Engineering Division, Mechanical Engineering & Bio-system Department of FATETA – IPB University.

Figure 4.
Mechanical Briquette Pressing Machine

RESULTS AND DISCUSSION

A. Analysis of Coffee Residual Waste/ Used Coffee Grounds

The analysis results of the used coffee grounds to be used as materials in briquetting may be seen in Table 1 as follows.

Table 1.
The Results of Laboratory Analysis of the Used Coffee Grounds

No	Analysis Component	Grade
1	Initial Moisture Content (M/C) received from the factory *	25% – 26%
2	The caloric value resulting from the laboratory test (M/C 42.29%) **	3390 Kcal/kg
3	Ash Content ***	0.406%
4	Volatile matter content ***	12.5%
5	Fixed carbon content ***	87.09%
6	Lignin content ***	40.99%

Remarks:
* Renewable Energy Engineering Laboratory, FATETA – IPB University;

** Laboratory of Livestock Research Institute – Ministry of Agriculture – the Republic of Indonesia, testing methods of IKM 01 and 04;
*** Laboratory of the Centre for Forest Product Research & Development – Ministry of Environment and Forestry of the Republic of Indonesia, methods of SNI 01-1683-1989 and SNI 14-0492-1989.

The analysis results indicate that the calorific value of residual coffee waste/used coffee grounds was 3390 kcal/kg at the moisture content (M/C) of 42.29%. Meaning that the calorific value would range between 4000 to 5000 kcal/kg in dry condition (M/C 15% – 20%). This indicates that used coffee grounds have a high potential to be used as fuel. However, the combustion test against the briquette with the standard adhesive composition in the preliminary experiment indicates that the briquette ignition process was relatively slow, i.e., around 1 minute (Table 2). Therefore, the addition of another material was needed for faster ignition time. In this case, paraffin was chosen as the material to be added into the briquette composition. Paraffin's characteristics, which are similar to a candle, are expected to help facilitate the combustion reaction so that the initial ignition time becomes shorter.

The considerably high lignin content affords the possibility of briquetting without using any additional adhesive agent. However, it needs to be accompanied by heating so that the lignin contained in the materials may be activated to function as an adhesive[10]. Therefore, it is necessary to see the possibility of using the "hot pressing" in briquette pressing. This hot pressing is possible when using the mechanical pressing machine, i.e., by installing a heated filament on the briquette die pipe[10].

Since the initial moisture content (M/C) of the material was quite high (25% - 26%), it was necessary to dry it first before briquetting. Figure 5 shows the material's physical comparison between the initial factory state and after being dried up.

Figure 5.
The Physical Appearance of the Material Before and After Drying

B. Determining the Briquette Composition and the Pressing Method

Based on the results of the laboratory analysis, the briquette composition scenario was determined as follows:

1. The briquette material with the addition of tapioca gel/glue adhesive, with the composition:
   2:1 and 3:1 (for the manual pressing machine), and 4:1 (for the mechanical pressing machine);
2. The briquette material with the addition of tapioca gel/glue adhesive and (also) paraffin, with the additional composition 0.5%, 1%, and 1.25% in each scenario of the comparable composition of raw materials and adhesive in item (1).

The pressing method used was the “cold pressing” method, either using the manual pressing machine (Figure 3) or the mechanical pressing machine (Figure 4). Meanwhile, the "hot pressing" method used in the mechanical pressing utilizes the 1200-Watt heat filament set with a thermostat at the heating level of 50°C. This heating temperature level is considered ideal for producing briquettes of desirable density. Higher temperature seems to produce briquettes of less density due to melting paraffin in the briquette material.

Figures 6 through 11 show the briquetting process and the resulting briquette, using either the manual pressing machine or the mechanical pressing machine.

Figure 6.
Briquette Material Production/ Preparation Process

C. Research Results / Discussions

C.1. Briquette Products

The following figures show briquettes resulting from pressing by using the manual pressing machine or the mechanical pressing machine, in several briquette material compositions described in sub-chapter B.

Figure 7.
Briquettes Resulting from the Manual Pressing Process, without the Addition of Paraffin

Figure 8.
The Appearance of Briquettes with the Addition of Paraffin Mix

Figure 9.
The Comparable Appearance of Briquettes Resulting from the Mechanical Pressing, with Heating, and without Heating

Figure 10.
The Appearance of Briquettes with the Paraffin Composition and the Non-Paraffin Composition, Using the “Hot Pressing” Method

Figure 11.
Briquettes Resulting from the Mechanical Pressing with the “Hot Pressing” Method

C.2. Briquette Test Performance

The summary of briquette performance test data with various compositions and scenarios of the pressing process may be seen in full in Table 2. The following Figures 12 through 15 display the briquette performance starting from the ignition process until the end of combustion (the briquettes were burned out and turned into ashes).

Overall, it may be explained that the burning of residual coffee waste/used coffee grounds produced a great of smoke at the start of the ignition (Figure 10), in their original form, or after being pressed into briquettes. However, the smoke would disappear after the briquettes were ignited (burned and produced flame), as seen in Figure 12.

Initial ignition directly using the lighter and some kerosene or any other fuel takes a long time because it is hard for the fuel to achieve the burning point temperature. Therefore, direct ignition is "not recommended." Ignition by placing the briquettes on the ember (charcoal) is highly effective because the ember's heat produces the required burning point temperature. This is evidenced by the ignition time achieved within seconds and a maximum of 1 minute (Figure 12 and Table 2).

Figure 12.
Initial Ignition Using the Aid of Coconut Shell Charcoal Ember

Figure 13.
The Burning Briquettes, to be Moved into an Empty Furnace (without Ember) in order to Observe their Combustibility and Combustion Rate

Figure 14.
The Briquettes were still Burning Well without the Aid of Ember Heating.

Figure 15.
The Condition of Briquettes Post-Burning, where after Being Burned Out, Embers Formed, which still Produced Considerably High Heat Radiation (a), and after Being Burned Out into Ashes (b)

Based on observation, the additional adhesive content increased the calorific value (energy) of the briquette, although not too significant. The additional adhesive content had a negative impact on the quality of briquettes as fuel because it caused an increase in ash content (Table 2). For machine pressing, the adhesive content must be reduced to prevent the adhesive from melting away due to the screw pressure. Therefore, with machine pressing, the raw material to adhesive ratio was changed to 4:1. Meanwhile, the adhesive formula was changed into the solution of 100 gr of tapioca in 1 litre of water to obtain gel/glue thicker than the adhesive used for the manual pressing (75 grams of tapioca in 1 litre of water).

Testing against the strength of briquettes has not been conducted with the strain gauge. The testing shall only be conducted in a simple manner, i.e., by putting them on a free fall. Based on the observation, the briquettes made with the "hot process" method had fairly high strength and did not break when dropped from the height of 1 m.

Another factor affecting briquettes' quality in terms of combustibility is briquette density (particle density = gram/cm^3). The fuel density rate affects the fuel combustion rate. The briquettes resulting from manual pressing have a lower density rate than the briquettes resulting from the machine pressing so that in

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the same air supply condition, the combustion rate would be faster. However, the main factor determining the combustion rate or the fuel combustion rate is the combustion air velocity. The higher the air velocity blown into the fuel, the greater the amount of oxygen available for the combustion process. The greater the oxygen's capacity to penetrate/enter the fuel pores, the faster and perfect the combustion. Perfect combustion would produce maximum heat energy. Therefore, the use of a blower is recommended both when lighting the briquette and during the burning process to ensure the stable speed of thermal energy - the following Table 2 presents a summary of the briquette test with several compositions and briquetting methods. The following Table 2 presents the summary of briquette test results with several compositions and pressing methods.

Table 2.
The Summary of Test Results for Briquettes Made of
Residual Coffee Waste/Used Coffee Grounds

No	Briquette type	M/C (%)	Density (g/cm^3)	Calorific Value (kcal/kg)	Ignition time (second)	Combustion rate (g/minute)
1	Manual 2:1	12	0.47	4702 (M/C 20%)	36	2.83
2	Manual 3:1	12	0.51	5026 (M/C 14.6%)	60	1.99
3	Mechanical (cold process) 4:1	NA	NA	NA	NA	NA *)
4	Mechanical (hot process) 4:1	11	0.55	NA	100	3.23

*) briquettes are considered to have failed due to being broken/fractured.

CONCLUSION

Based on the test results and discussions above, the following conclusions may be obtained:

a. The residual waste/used coffee grounds in the coffee production process have the potential to be utilized as bio-briquettes (biomass briquettes = bio-briquettes) because they have the basic properties of the fuel, i.e., combustible (ignitable) at a specific burning point, and have the calorific value (energy content) of 3390 kcal/kg in wet condition (M/C 42.3%), meaning that they may achieve the calorific value of 4000 - 5000 kcal/kg in dry condition (M/C 15% - 205%). In addition, these materials also have low ash content (0.4%), so that technically they are very good for use in a stove or industrial-scale furnaces.
b. The use of tapioca solution as an adhesive agent in the form of gel/glue is technically appropriate for use in the production of briquettes made of coffee residual waste/used coffee grounds. The addition of such an adhesive is to increase the calorific value, although it increases the ash content.
c. The application of the "hot pressing" method produces briquettes with better strength and a more stable shape. Meanwhile, “cold pressing” either by manual pressing machine or mechanical pressing machine, produces briquettes with poor (vulnerable) strength or crumbles during the combustion process.

Some recommendations for the effort to utilize the coffee residual waste/used coffee grounds in the form of briquette are as follows:

a. Using the "hot pressing" method in the mechanical pressing machine to obtain briquettes with a fairly good density and strength level.
b. Further research is required to determine the optimal briquette composition.
c. The initial ignition process of briquettes should use ember heat as a starter to achieve the burning (point) temperature needed by the briquettes.
d. Use a blower during the combustion process to stabilize the combustion, produce maximum energy, and generate no smoke.

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