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MECHANICAL AND PHYSICAL PROPERTIES OF BIO-BRIQUETTE PRODUCED FROM GAYO ARABICA COFFEE-SKIN

*Adi Setiawan *[,1], Juwaini[1], Ahmad Nayan[1], Fauzan[1] and Faisal[1]*
[1]Mechanical Engineering Department, Faculty of Engineering, Malikussaleh University
Kampus Bukit Indah, Lhokseumawe, Aceh, Indonesia
*Corresponding Author : adis@unimal.ac.id

ABSTRACT

Enormous amount of Gayo Arabica coffee-by-products highlights its potential as source of renewable energy. Utilizing coffee skin as a raw material for bio-briquettes is considered as an effective way to minimize their wastage as landfill. This study aims to examine the characteristics of bio-briquettes produced through the cold-forming process at a pressure of 100, 150 and 200 kg/cm^2 without binder. Prior to briquetting process, the raw material was sun-dried, ground and sieved to 0.841 mm. A mixture was then made by adding water followed by molding and drying processes. Characterization of the briquette employs a number of techniques including DSC, TGA, bomb calorimeter and proximate analyses as well as mechanical testing. The results show that the calorific value of the coffee-skin briquette is 4764 cal/g containing 16.5 wt% of moisture, 12 wt.% ash. The rate of combustion is 0.019 g/s with ignition time of 196 s. Varying briquetting pressure results in a change in ignition time of bio-briquettes as the density is increased. However, no significant change was observed on the rate of combustion upon increasing the briquetting pressure. This investigation concludes the potential use of coffee industry by-product as feedstock for solid biomass fuel production.

KEY WORDS: Gayo Arabica; Coffee skin; bio-briquettes; rate of combustion.

INTRODUCTION

Coffee is considered as one of the most popular drinks in the world. Increase in the number of coffee consumers in either importing or exporting countries, leads to an increase in annual coffee production. In term of currency traded throughout the world, coffee is the second largest commodity where in September 2018, total world coffee exports reached 9.43 million 60-kg-bags (ICO, 2018). In fact, processing of coffee produces waste of around 30% - 50% of its total weight depending on the type of processing (Oliveira & Franca, 2014). Coffee husk and skin are the main residues obtained after removing coffee beans during the dry or wet process. This requires an effective method of use as disposing this residual into the environment can bring serious environmental problems.

In many countries, a number of studies have been devoted to investigate the potential utilization of coffee waste however profitable and technically feasible methods are still under development. There are two main challenges faced when developing suitable technologies for coffee skin and husks (Oliveira & Franca, 2014), including:

(a) coffee husk contains low digestible protein so it is not safe for animal feed,
(b) the presence of caffeine, tannin and polyphenols which known as toxic substances.

Currently, there are a number of scenarios have developed for utilizing coffee industry-by-product including (1) mushroom cultivation, (2) production of enzymes, (3) biofuel production, (4) organic acid production, (5) bioactive compounds, (6) dietary fiber, (7) composting and vermicomposting (Janissen & Huynh, 2018). Among these options, the conversion of coffee waste into biofuel looks like more potential and applicable for agriculture regions.

Basically, this biomass waste can be directly used as fuel, however the combustion process cannot be maximized due to several factors, including low density, non-competitive calorific value per unit volume, higher moisture contains and produces smoke (Yaman, 2010). Thus, briquetting is one of the most common strategies used for enhancing fuel quality and helps in establishing more effective fuel distribution, storage and utilization.

In this study, coffee skin will be processed into solid fuel through a thermal decomposition process to produce bio-char and subsequently pressed without binder to produce a bio-briquette. The main objective is to examine the characteristics of bio-briquettes produced through the cold-forming process (without binder) as well as finding the effect of briquetting pressure on the characteristic of briquette

MATERIALS AND METHODS

Preparation of bio-briquettes

Wet-processing residue of Arabica coffee was collected from Bener Meriah District of Aceh Province, Indonesia. Initially, coffee skin was sun-dried and ground by adding water sufficiently. Cold-forming process of briquettes employs a home-made briquetting machine at a pressure of 100, 150 and 200 kg/cm^2 where each samples were respectively denoted as KK100, KK150 and KK200. Resulting briquette has diameter of 45 mm and 60 mm height. Briquette was then naturally dried for five days. Fig.1 shows a photograph of bio-briquette produced from Arabica coffee skin after drying.

Briquettes characterization

In order to understand the physical and chemical properties of bio-briquette produced from Arabica coffee skin, a number of experiments were performed including thermo gravimetry analysis (TGA), differential scanning calorimeter (DSC) and bomb calorimeter analyses. Ignition time, flame duration and rate of combustion of the briquette were also tested. Mechanical properties were analyzed in term of compression strength, size stability and porosity.

Fig.1 Arabica coffee-skin briquettes

RESULTS AND DISCUSSIONS

In order to understand the thermo-physical properties of bio-briquettes, thermo gravimetry and differential scanning calorimeter analyses were performed up to 600° Cat heating rate of 20 °C/min and 15 °C/min, respectively. Fig. 2 displays decreases in weight versus temperature where a significant weight of sample was lost during heating in nitrogen. In general, there are three-stage of weight loss observed from this experiment i.e. room temperature to 220 °C, 220 °C< T <350 °C and 350 °C < T < 600 °C. This thermal degradation profile is relatively similar to what has been reported in the literature (Singh, Mahanta, & Bora, 2017). During the first stage, *ca.* 8% of weight is lost which is mostly due to removal of moisture and weak-bonded compounds. The weight of sample is significantly lost (24 %) within the second stage as most of volatile matter is decomposed. Decrease in weight is continued upon heating to 600 °C where 15% of weight is lost during 3rd stage. Most of biomass is typically contained a high volatile matter compared to coal, thus reactivity of fuel derived from biomass is better (Mckendry, 2002).

Fig. 3 shows DSC curve of KK150 sample upon heating up to 600 °C at a rate of 15 °C/min. This curve indicates an endothermic reaction takes place within a temperature range of 41.6 °C to 124.9 °C where the maximum peak is at 86.7 °C. An exothermic reaction is started above 125 °C. Integration of area within endothermic curve suggests amount of heat adsorbed by sample is 320.3 J/g. This amount of heat is mostly required for removing moisture content and other weak-bonded species.

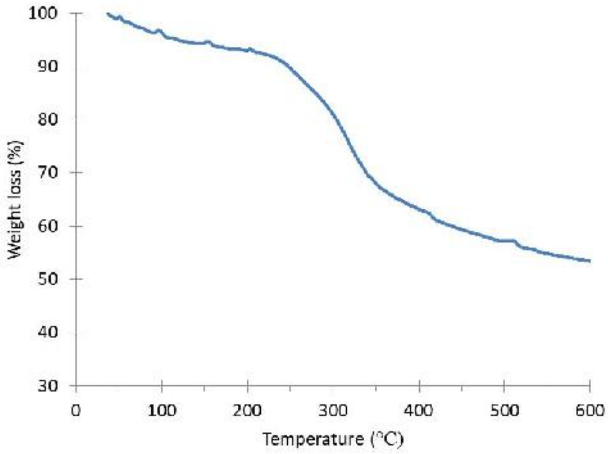

Fig. 2. TG curve of Arabica coffee-skin briquette. Heating rate is 20 °C/min.

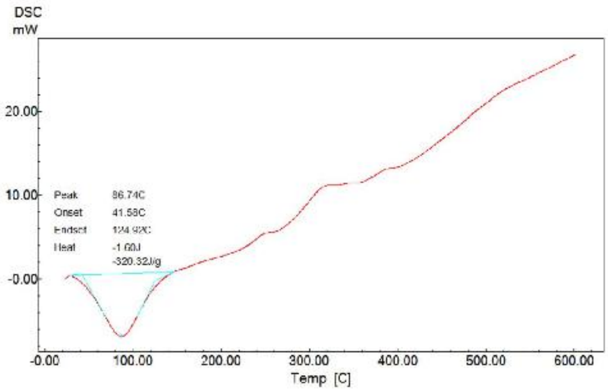

Fig. 3. DSC curve of Arabica coffee-skin briquette. Heating rate is 15 °C/min.

Heating value of coffee-skin briquette was analyzed using bomb calorimeter resulting higher heating value of 4764 cal/g. Tabel 1 summarizes density, water and ash content of each samples. Initially, 80 % of mixture is water. After pressing process, water content is decreased to 60~66.6 %. A decrease in water content is obviously observed when briquetting pressure is increased. After drying, the average water contents is 15.67 wt. %. Density of briquette is obviously affected by briquetting pressure. KK200 briquettes recorded the greatest density (0.31 g/cm^3), then KK150 (0.30 g/cm^3) and KK100 briquettes (0.28 g/cm^3). Instead of briquetting pressure, the resulting density is mostly affected by particle size and moisture content of the raw material The percentage of ash measured after burning the sample at 600 °C for 4 h is 10 wt. % for KK100 sample. The amount of ash is slightly higher for higher briquetting pressure which is due to higher briquette density.

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Table 1. Water and ash content of coffee-skin briquettes

Sample code	Water content (wt.%)			Density (g/cm^3)	Ash content (wt. %)
	Mixture	After press	After drying		
KK100	80	66.6	15.7	0.28	10
KK150	80	65	16.5	0.30	12
KK200	80	60	14.8	0.31	13

The combustion properties of Gayo Arabica coffee-skin briquettes has been investigated and summarized in Tabel 2. Results show that the ignition time is ranging from 192 to 252 s. The higher pressure for briquetting, the longer time is needed for ignition. Flame duration for one piece of KK100 briquette is 1380 s, while increasing briquetting pressure to 200 kg/cm^2 leads to a longer duration of flame, *i.e.* 1470 s. In average, the rate of combustion of three kinds of sample is 0.020 g/s.

Table 2. Combustion properties of coffee-skin briquettes

Sample code	Ignition time (s)	Flame duration (s)	Rate of combustion (g/s)
KK100	195	1380	0.021
KK150	196	1415	0.019
KK200	252	1470	0.020

Correlation between briquetting pressure and size stability as well as porosity is explained by data in Table 3. Briquette KK100 has size stability of 82.09 % while pressing briquette at 150 kg/cm^2 and 200 kg/cm^2 enhances the size stability to 87.42 % and 94.00% respectively. As suggested in the literature that lower weight to mass reductions leads to a higher durability at higher hydraulic pressures of the briquettes (Amarasekara, Tanzim, & Asmatulu, 2017). As can be seen in this table, higher densification pressure results in smaller porosity. In term of compression strength, this kind of briquette has low ability to receive compressive load since no binder was added during production. The maximum compression strength is only 0.10 kg/cm^2 which is obtained from KK200 sample. This low compressive strength has correlation to higher percentage of porosity measured from any type of sample. Indeed, higher porosity benefits ignition of the briquette as shown in Table 2 where all samples can be ignited within 252 s.

Table 3. Size stability and porosity of coffee-skin briquettes

Sample code	Compression Strength (kg/cm^2)	Size stability (%)	Porosity (%)
KK100	0.07	82.09	98.00
KK150	0.07	87.42	95.00
KK200	0.10	94.00	92.00

CONCLUSIONS

Gayo Arabica coffee-skin has been used as raw material for bio-briquettes and tested to know its properties. The calorific value of the coffee-skin briquette is 4764 cal/g containing in average 15.67 wt% of moisture, 11.67 wt.% ash. The rate of combustion is 0.019 g/s with ignition time of 196 s. Varying briquetting pressure results in a change in ignition time of bio-briquettes as the density is increased. However, no significant change was observed on the rate of combustion upon increasing the briquetting pressure. Results show a potential use of coffee industry by-product as feedstock for solid biomass fuel production.

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