



Physical Characteristics of Briquettes Made of Oil Palm Empty Fruit Bunches (EFB) Using Brown Algae Adhesive

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Article History

Received: 13 January 2020; Received in Revision: 21 January 2020; Accepted: 22 January 2020

Abstract

The charcoal produced from oil palm empty fruit bunches' pyrolysis can be utilised as environmentally friendly alternative fuel briquettes. This research studied the physical characteristics of EFB briquettes using brown algae as an adhesive. The effect of the concentration of brown algae adhesive on briquette quality was investigated. The briquettes were prepared from EFB charcoal by adding adhesive at various concentrations of 2.5%, 5%, 7.5% and 10% (w/w). Subsequently, proximate analysis was performed on EFB and brown algae. The best-quality briquettes were obtained by adding brown algae adhesive at 2.5% concentrate, which resulted in a calorific value of 21,405 J/g. Other characteristics, such as moisture content, ash content, volatile matter and fixed carbon, were found to be 7.4%, 4.9%, 79% and 8.7%, respectively. Thermal characteristics, such as density, flash point and burning time, were found at 0.96 g/cm³, 5.1 seconds and 300 minutes, respectively.

Keywords: briquettes, palm oil empty fruit bunch, alternative fuels, brown algae adhesives, calorific value

1. Introduction

Non-renewable fossil fuels, such as oil, coal and natural gas, are the main energy sources in the world. This energy source is expected to be exhausted within 40–50 years. The sustainable use of energy sources can cause environmental damage, such as global warming, acid rain, the production of gaseous emissions and urban smog. Researchers seek alternatives to reduce carbon emissions by 80% by utilising various renewable energy sources (Saidur *et al.*, 2011). Charcoal briquettes are alternatives to fossil fuels that are widely used to reduce pollution and, of course, are environmentally friendly (Teixeira *et al.*, 2010). Briquettes are produced by pressing a mixture of charcoal powder and adhesive.

In this research, EFB pyrolysis charcoal was used to make briquettes. Good briquettes must contain the proper raw material with the right adhesive concentrate. Adhesive binds particles so they are compact and easily shaped. There are three types of adhesive used in briquette making: organic, inorganic and compound. Adhesive plays an important role because it affects the strength, thermal stability, combustion performance, production cost and the resulting final quality (Zhang *et al.*, 2018).

The addition of adhesive aims to improve the quality of the physical properties of briquettes. The use of adhesives affects the density, power press, fuel calorific value, moisture content and ash content (Husain *et al.*, 2002). The selection of the type of adhesive affects the quality of the charcoal briquettes, as it will affect the calorific value at the time of combustion. Some researchers have used adhesive, among others, for example tar (Demirbas, 1999), tapioca/starch (Husain *et al.*, 2002), gum arabic and starch cassava (Sotannde *et al.*, 2010), cassava (Teixeira *et al.*, 2010), a deposition of sand and lime (Fengmin and Mingquan, 2011), sulfur, molasses and linobind (Acma *et al.*, 2013), corn stover and switchgrass (Kaliyan and Morey, 2013), molasses (Jittabut, 2015), rice bran (Ndindeng *et al.*, 2015), starch and clay bentonite (Deshannavar *et al.*, 2018), dust and molasses (Manyuchi *et al.*, 2018) and skin durian (Mitan *et al.*, 2018).

An alternative adhesive that can be used is brown algae because it contains alginate that functions as an adhesive. Alginate is a component found in brown algae's cellular walls and contains about 30–60% alginate acid. Alginate, usually extracted from brown seaweed (Santos, 2017), is used in the food industry, pharmacy and biotechnology (Nagasawa *et al.*, 2000). In these industries,

alginate serves as an important adhesive and gelation component (Nallamuthu, 2014). Brown algae is chosen due to its strong, smooth adhesion and abundance in nature. In addition, it has not been fully utilised, is easy to farm and is environmentally friendly (Chapman, 1980). The purpose of this research was to study the effect of brown algae adhesive on the physical characteristics and quality of these EFB briquettes.

2. Experimental

2.1. Materials

The EFB charcoal used in this study was obtained from the residue of liquid smoke preparation (Pyrolysis temperature of 400°C). The brown algae containing 82% sodium alginate (Ex. Japan Kimica) was purchased from PT. Subur Kimia Jaya, Indonesia.

2.2. Method

First, EFB charcoal was ground using a ball mill (Steel Alloy FFC 15, China) to produce 60-mesh powder in accordance with Indonesia's national standard (SNI) 01-6235-2000. Brown algae adhesive was subsequently added with various concentrates: 2.5%, 5%, 7.5% and 10% w/w. The mixture was then stirred to produce a homogenous mix at room temperature before being moulded into briquettes using a press machine (Astro ADR 6050, China) with four-ton pressure. Next, these briquettes were oven-dried (Memmert UN55, Germany) and packaged to maintain their quality.

2.2. Characterisation of Briquettes

The briquettes were characterised by various methods. Their calorific value was analysed using a bomb calorimeter (Koehler K88890, Germany), their moisture content measured using an oven (Memmert UN55, Germany), and their ash content and volatile matter assessed using a furnace (EPTR-26R Isuzu, Japan). Other characteristics such as density, fixed carbon, flash point and burning time were assessed manually.

3. Results and Discussion

3.1. Effects of Adhesive Concentration on EFB Briquette to Calorific Value

Figure 1 shows that higher adhesive concentrates resulted in lower calorific

values. The highest value of 21,405 J/g and the lowest value of 18,181 J/g were obtained from 2.5% and 10% concentrates, respectively. Increasing the concentration will reduce burning power and result in low calorific value. The proper level of adhesive will bind EFB powder with adequate strength and density, resulting in high calorific value (Manyuchi, 2018). High density during pressing also influences said value (Sotannde *et al.*, 2010). Proximate analysis (wt. %) data from previous researchers found calorific values of EFB and brown algae to be 15,220 J/g (Lahijani P and Zainal ZA, 2011) and 12,600 J/g, respectively (Acma *et al.*, 2013).

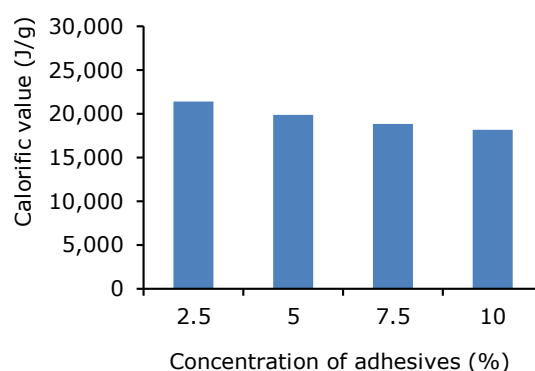


Figure 1. Effects of adding brown algae adhesive concentrate to calorific value at room temperature

Meanwhile, their proximate analysis showed EFB calorific values when added with 2.5% and 10% adhesive concentrates at 15,155 J/g and 14,958 J/g, respectively. That is, brown algae adhesive has a lower calorific value than EFB. The calorific values obtained in our research were 18,332-21,405 J/g, which not only met Indonesia's national standard (SNI) No. 01-6235-2000 (BSN, 2000) but were also higher compared to briquettes made of oil palm shells with tapioca adhesive at 16,400 J/g (Husain *et al.*, 2002), macrophyte briquettes using lake sand sediment adhesive at 10,700 J/g (Fengmin and Mingquan, 2011) and eucalyptus briquettes using starch adhesive at 20,080 J/g (Araújo *et al.*, 2016). However, these numbers are lower than *nimba* wood briquettes using arabic gum and starch adhesive at 32,000 J/g (Sotannde *et al.*, 2010).

3.2. Effects of Adhesive Concentration on EFB Briquette to Moisture

Figure 2 shows that higher adhesive concentrates resulted in lower moisture content. The highest (7.4%) and the lowest

(6.1%) moisture content was found at 2.5% and 10% adhesive concentrate, respectively. The water remaining during the charcoal powder's binding decreased as the brown algae adhesive concentrate increased. This water content causes a decline in fuel quality. It reduces calorific values since it takes some heat to evaporate it, therefore lowering the flash point, slowing the burning process and increasing emission volume. Briquettes' moisture content is expected to be as low as possible (Venter P and Naude N, 2015). Brown algae adhesive has 5% moisture content (Acma et al., 2013), while EFB charcoal powder has 7.8% moisture content (Lahijani P and Zainal ZA, 2011).

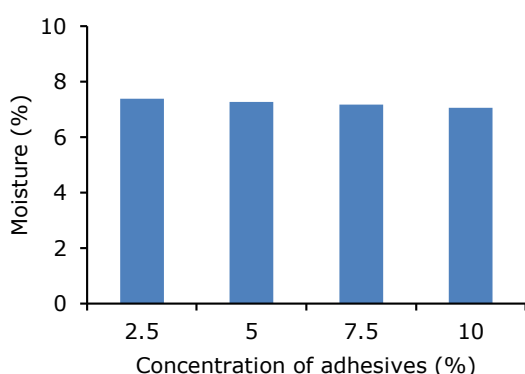


Figure 2. Effects of adding brown algae adhesive concentrate to moisture at room temperature

The moisture content found in the proximate analysis was in line with these previous studies: 7.73% at 2.5% concentrate; 7.66% at 5% concentrate; 7.59% at 7.5% concentrate and 7.52% at 10% concentrate, with a total of 100% EFB charcoal powder plus brown algae adhesive. The water content of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000 (BSN, 2000). In addition, it is 6.1–7.4% lower than briquettes made of oil palm shells with tapioca adhesive at 12% (Husain et al., 2002) and eucalyptus briquettes using starch adhesive at 11.9% (Araújo et al., 2016). However, this water content is the same value as that of macrophyte briquettes using lake sand sediment adhesive at 6% (Fengmin and Mingquan, 2011) and nimba wood briquettes using arabic gum and starch at 6% (Sotannde et al., 2010).

3.3. Effects of Adhesive Concentration on EFB Briquette to Ash Content

Figure 3 shows that higher adhesive concentrate increases the ash content. The

lowest (4.9%) and the highest (6.3%) ash contents were found at 2.5% and 10% adhesive concentrate, respectively. This is due to brown algae's inherent ash content at 22.5% (Acma et al., 2013) and that of EFB charcoal powder at 4.5% (Lahijani P and Zainal ZA, 2011). Ash content brings undesirable effect to briquettes' calorific value. Ash is an impurity that will not burn, so high ash content means lower briquette quality.

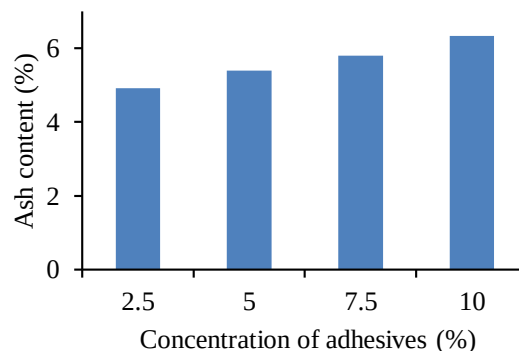


Figure 3. Effects of adding brown algae adhesive concentrate to ash content at room temperature

The ash content found in the proximate analysis was in line with these previous studies: 4.95% at 2.5% concentrate, 5.4% at 5% concentrate, 5.85% at 7.5% concentrate and 6.3% at 10% concentrate, with a total of 100% EFB charcoal powder plus brown algae adhesive (Acma et al., 2013; Lahijani P and Zainal ZA, 2011). The ash content of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000 (BSN, 2000). In addition, it is 4.9–6.3% lower than briquettes made of oil palm shells with tapioca adhesive at 6% (Husain et al., 2002) and macrophytes' briquettes using lake sand sediment adhesive at 17.2% (Fengmin and Mingquan, 2011). However, this ash content is higher than nimba wood briquettes using arabic gum and starch at 4% (Sotannde et al., 2010) and eucalyptus briquettes using starch adhesive at 0.81% (Araújo et al., 2016).

3.4. Effects of Adhesive Concentration on EFB Briquette to Volatile Matter

Figure 4 shows that higher adhesive concentrates resulted in less volatile matter. The highest (79%) and the lowest (77.7%) volatile matter was found at 2.5% and 10% adhesive concentrate, respectively. Overall, volatile matter analysis shows desirable

results. Volatile matter affects the ease of burning briquettes. It affects burning and flame intensity. The high content of volatile matter will speed carbon burning and vice versa. The content ratio between carbon and volatile matter is called the fuel ratio. A higher fuel ratio represents more unburned carbon (Zhang *et al.*, 2018).

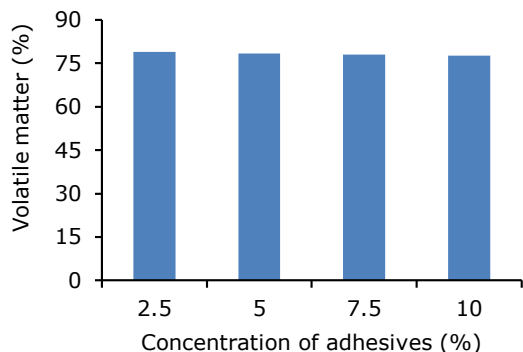


Figure 4. Effects of adding brown algae adhesive concentrate to volatile matter at room temperature

The content of volatile matter decreases as adhesive concentrate increases. This is found in the proximate analysis in line with these previous studies: 78.94% at 2.5% concentrate, 78.54% at 5% concentrate, 78.14% at 7.5% concentrate and 77.74% at 10% concentrate, with a total of 100% EFB charcoal powder plus brown algae adhesive (Acma *et al.*, 2013; Lahijani P and Zainal ZA, 2011). The volatile matter content of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000 (BSN, 2000). In addition, it is 77.7–79% lower than macrophyte briquettes using lake sand sediment adhesive at 97% (Fengmin and Mingquan, 2011) and eucalyptus briquettes using starch adhesive at 88.19% (Araújo *et al.*, 2016). However, this volatile matter content is higher than nimba wood briquettes using arabic gum and starch at 11% (Sotannde *et al.*, 2010).

3.5. Effects of Adhesive Concentration on EFB Briquette to Fixed Carbon

Figure 5 shows that higher adhesive concentration results in higher fixed carbon content, meaning that there is more material to burn. The value of fixed carbon depends on water content, ash content and volatile matter. Lower moisture content, ash content and volatile matter lead to higher fixed carbon value, and vice versa. Briquettes with longer burning time and low flash point require high fixed carbon (Araújo *et al.*,

2016). The highest fixed carbon content (9.1%) in an EFB briquette was found at 7.5% adhesive concentration, while the lowest (8.7%) was found at 2.5% adhesive concentration. A deviation was found at 10% adhesive concentration, where the fixed carbon content decreased (8.9%) as the adhesive addition increased. This is due to changes in water content, ash content and volatile matter values.

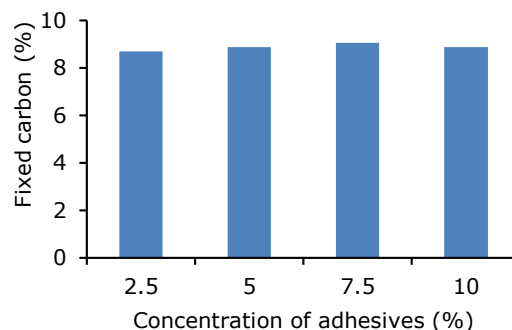


Figure 5. Effects of adding brown algae adhesive concentrate to fixed carbon at room temperature

Overall, the resulting fixed carbon was in line with that of previous research: fixed carbon proximate analysis showed that 2.5% adhesive concentration resulted in 8.38% fixed carbon, 5% adhesive concentration resulted in 8.40% fixed carbon, 7.5% adhesive concentration resulted in 8.42% fixed carbon and 10% adhesive concentration resulted in 8.44% fixed carbon, with a total concentration of EFB charcoal powder and brown algae adhesive of 100%. The fixed carbon content of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000 (BSN, 2000). In addition, it is 8.7–10.5% lower than briquettes made of oil palm shells with tapioca adhesive at 10.12% (Husain *et al.*, 2002), nimba wood briquettes using arabic gum and starch at 84% (Sotannde *et al.*, 2010), macrophyte briquettes using lake sand sediment adhesive at 11% (Fengmin and Mingquan, 2011) and eucalyptus briquettes using starch adhesive at 11% (Araújo *et al.*, 2016).

3.6. Effects of Adhesive Concentration on EFB Briquette to Density

Figure 6 shows 0.96 g/cm³ density at 2.5% adhesive concentrate and 1.05 g/cm³ density at 10% adhesive concentrate due to the size and uniformity of briquette particles. The higher adhesive concentrate increases density. Density is closely related to the

applied pressure during briquette moulding. Higher density results in higher quality because it increases calorific value. Density also affects the burning speed; higher density slows burning and increases calorific value (Jamilatun, 2008). The density found here has met the world standard of 0.4–1.2 g/cm³ (BPPK, 2000).

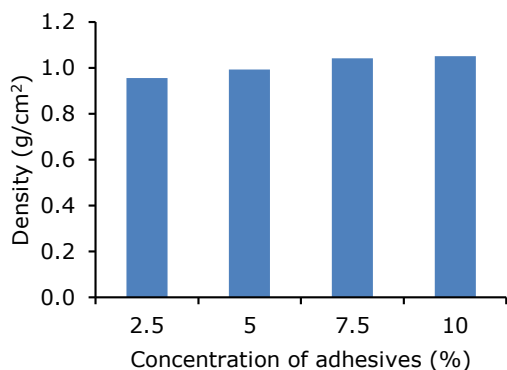


Figure 6. Effects of adding brown algae adhesive concentrate to the density at room temperature

The density of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000. In addition, it is 0.96-1.05 g/cm³ lower than briquettes made of oil palm shells with tapioca adhesive at 1.1–1.2 g/cm³ (Husain *et al.*, 2002), nimba wood briquettes using arabic gum and starch at 1.2–1.4 g/cm³ (Sotannde *et al.*, 2010), macrophyte briquettes using lake sand sediment adhesive at 1.2 g/cm³ (Fengmin and Mingquan, 2011) and eucalyptus briquettes using starch adhesive at 1.14 g/cm³ (Araújo *et al.*, 2016).

3.7. Effects of Adhesive Concentration on EFB Briquette to Flash Point

Figure 7 shows the fastest flash point (5.1 seconds) at 2.5% adhesive concentrate and the slowest flash point (8 seconds) at 10% adhesive concentrate. A better flash point is attributed to low moisture content and high carbon content, and vice versa. Therefore, drying must be performed well without damaging the material's structure. In addition, the flash point is determined by structure, fixed carbon, density and combustion characteristics. These characteristics are, among others, easy ignition, long burning time, less ash, less and easily dissipated smoke, and high calorific value (Jamilatun, 2008).

Briquettes have a fast flash point, burn longer with a constant flame, produce less

smoke and have high calorific values, which signify briquettes with good combustion quality (Faisal *et al.*, 2019). The flash point of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000. In addition, it is 5.1–8 seconds slower than briquettes made of oil palm shells with tapioca adhesive at 50 seconds (Husain *et al.*, 2002).

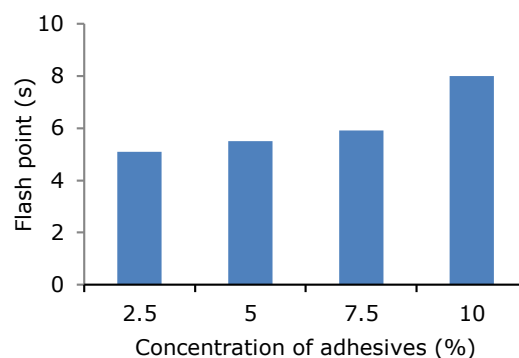


Figure 7. Effects of adding brown algae adhesive concentrate to flash point at room temperature

3.8. Effects of Adhesive Concentration on EFB Briquette to Burning Time

Figure 8 shows a burning time of 300 minutes at 2.5% adhesive concentrate and 376 minutes at 10% adhesive concentrate. During the burning, the amount of resulting smoke is close to none, putting EFB briquettes in the category of smokeless. The higher adhesive concentrates resulted in a longer burning time.

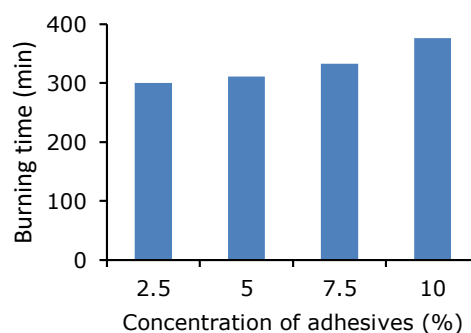


Figure 8. Effects of adding brown algae adhesive concentrate on burning time at room temperature

Higher adhesive concentrate increases burning time, which is calculated from ignition to complete burning resulting in ash. This duration affects briquette quality and combustion efficiency: A longer burning time with a constant flame produces better

quality briquettes (Faisal et al., 2019). The volatile matter content also affects this duration (Zhang et al., 2018). The burning time of EFB briquettes with brown algae adhesive has met the requirements set in SNI No. 01-6235-2000. It is 300–376 minutes lower than briquettes made of oil palm shells with tapioca adhesive at 500 minutes (Husain et al., 2002).

4. Conclusion

This research shows that adhesive concentration is a factor that influences briquette quality. The best quality was obtained by adding brown algae adhesive at a low concentration of 2.5%. Excessive adhesive concentration will reduce calorific values. The highest calorific value was obtained at a 2.5% concentration (21,405 J/g) with a 5.1 second flash point and a 300-minute burning duration. Its water content and ash content values were low at 7.4% and 4.9%, respectively. Additionally, the density, volatile matter and fixed carbon values were found at 0.96 g/cm³, 79% and 8.7%, respectively. These values and combustion characteristics are, therefore, in compliance with briquette quality standards (Standar Nasional Indonesia, or SNI).

Acknowledgment

We would like to appreciate the Ministry of Research, Technology, and Higher Education of Indonesia for the research grant (No. 215/SP2H/LT/DPRM/2019).

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