Effect of Torefaction Temperature and Adhesive Amount on the Characteristics of Waste Briquettes Coffee Grounds as an Alternative Renewable Fuel

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EFFECT OF TOREFACTION TEMPERATURE AND ADHESIVE AMOUNT ON THE CHARACTERISTICS OF WASTE BRIQUETTES COFFEE GROUNDS AS AN ALTERNATIVE RENEWABLE FUEL

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Abstract

Waste coffee grounds is one of the biomass that has the potential to be used as a renewable alternative energy through the process of making briquette. This study was conducted to determine the process of making briquettes coffee grounds and assess the effect of torefaction temperature and the amount of adhesive to the characteristics of the product briquettes coffee grounds. The sample used in this study is waste coffee grounds obtained from coffee-based beverage cafe. This study was conducted using an independent variable in the form of variations in temperature torefaction 200℃, 250℃, and 300℃, and variations in the amount of adhesive that is tapioca flour with a concentration of 10% and 25%. This study includes 3 stages namely pretreatment stage, operation stage, and analysis stage. At the pretreatment stage, drying and sieving are carried out on coffee grounds waste as raw material for briquettes. At the stage of operations carried out, mixing raw materials with adhesives, briquetting, and torefaction process briquettes of coffee grounds. The resulting briquettes are then followed by a characteristic analysis stage. From the research that has been done obtained the results that the variation of torefaction temperature affects the characteristics of coffee grounds briquettes include proximate analysis, ultimate analysis, calorific value, compressive strength value and briquette burn test while the amount of adhesive has no significant effect on the characteristics that have been done. Based on krevelen diagram shows that briquettes have almost the same characteristics as bituminous coal and anthracite, thus showing that briquettes can be used as a substitute for coal to reduce CO2 emissions in steam power plants (PLTU), namely through the fulfillment of energy needs on a household scale.

Keywords: Briquettes, Coffee Grounds, Torefaction, Proximate, Ultimate

1. Introduction

The need for energy sources is increasing every year. As for 90% of the current national energy consumption, it comes from fossil fuels, including 37.2% from coal, 33.6% from petroleum and 20.1% from natural gas (strategic data for the ESDM sector, 2020). The fulfillment of energy needs at the household scale is still dominated by petroleum and LPG fuels. In 2020, the majority of people still depend on the use of LPG gas where the fulfillment the need for LPG of 79.74% is obtained through imports which certainly weighs heavily on the state budget (MEMR Performance Report,2020). For this reason, it is necessary to have alternative energy that can be used on a household scale that is safe for the environment and health. One of them is briquettes that can come from mixed coal briquettes or biomass briquettes. Biomass waste of coffee grounds in Indonesia is very abundant. This is evident through coffee consumption continues to increase every year without any effort to utilize waste coffee grounds. Based on data, Indonesia is the country with the fourth largest coffee production in the world, which is as much as 639 thousand tons/year (DJPEN, 2018). This much waste if not utilized will be decomposed into methane gas which has the highest destructive power in greenhouse gases and causes global warming. For this reason, the utilization of coffee grounds waste into briquettes is very necessary to support Indonesia's commitment to achieve the emission reduction target and Net Zero Emissio (carbon neutrality) which is targeted to be achieved in 2060 or earlier.

2. Methodology

2.1 Materials

Waste coffee grounds from cafes coffee-based drinks. The adhesive used is tapioca flour. The torefaction reactor used in the experiment was a modified stainless steel tube from the Tekmira Research Center with a diameter of 30 cm and a height of 50 cm. The reactor is equipped with a condenser connected to a water chiller that serves to cool.

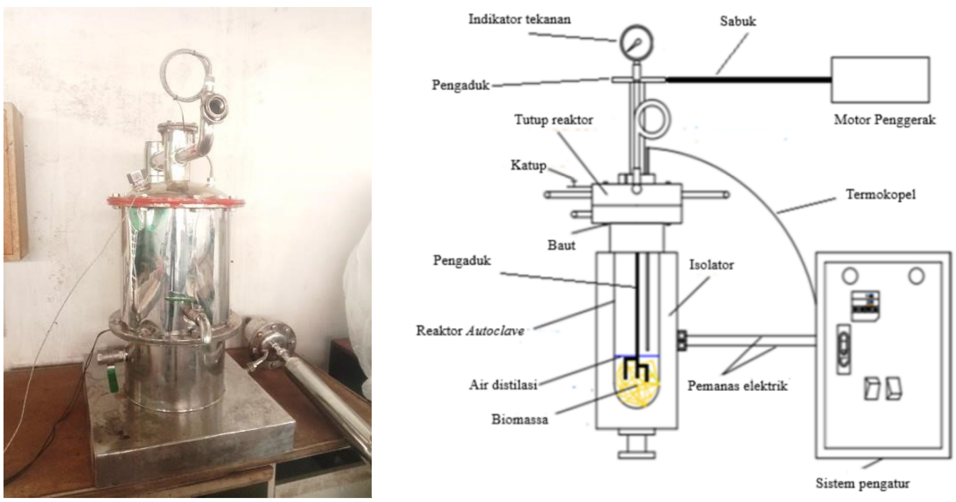


Fig. 1. a set of torefaction reactor

2.2 stages of the process

The stages of the process in making briquettes of coffee grounds can be seen in Figure 2. The process begins with the cleaning of waste coffee grounds that have been obtained from coffee-based beverage cafes and proceed to the drying process that can be done by using the sun for 2 days (depending on the weather) or using an oven with a temperature of ±60℃ for 2 hours. Furthermore, waste coffee grounds sifted using a sieve 60 mesh. Furthermore, the waste of coffee grounds (90% w and 75% w) and tapioca starch adhesive were weighed according to variations in the amount of adhesive used, namely 10% and 25%. Waste coffee grounds mixed with tapioca starch adhesive until evenly distributed. After that proceed to the stage of printing briquettes using hydraulic which can be seen in Figure 3. Furthermore, the briquettes that have been printed are dried by aerating for 8 hours and are ready to proceed to the torefaction stage with temperature variations (200℃, 250℃ and 300℃) and when the desired temperature is reached, they are held for 2 hours. After the torefaction stage, the coffee grounds briquettes proceed to testing the characteristics of the briquettes.

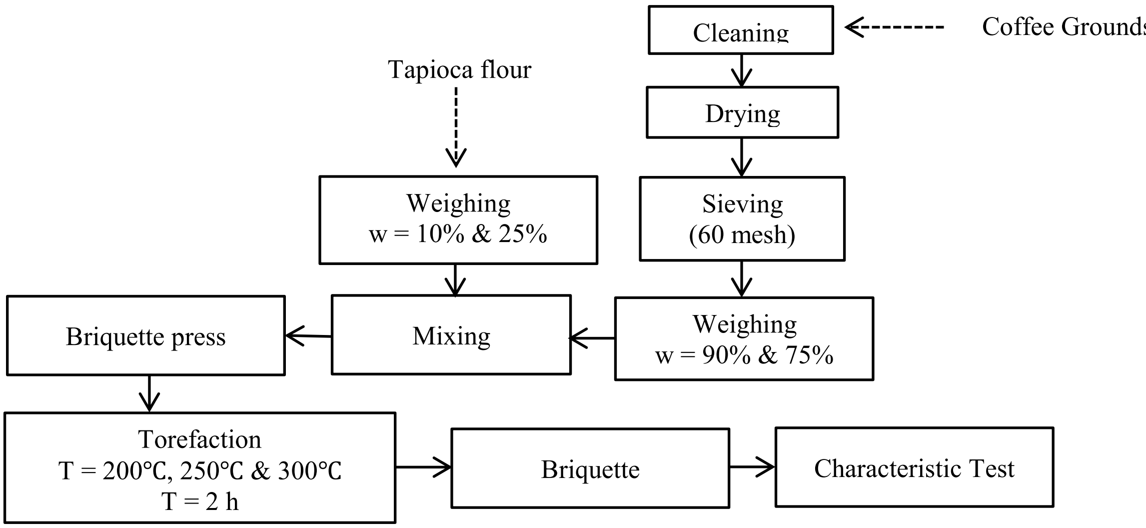


Fig. 2. Stages Of The Process Of Making Briquettes Of Coffee Grounds

Fig. 3. hydraulic presses and briquette molds

3. Results And Discussion

3.1 Compressive Strength

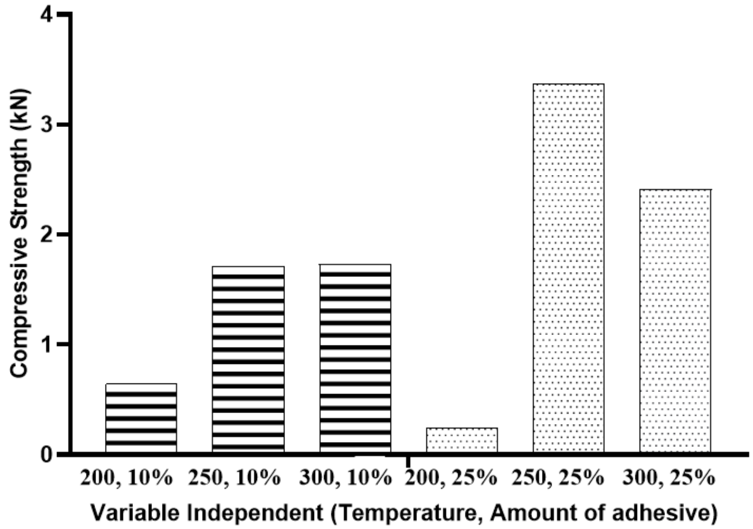


Fig. 4. Analysis Of The Compressive Strength Of Briquettes

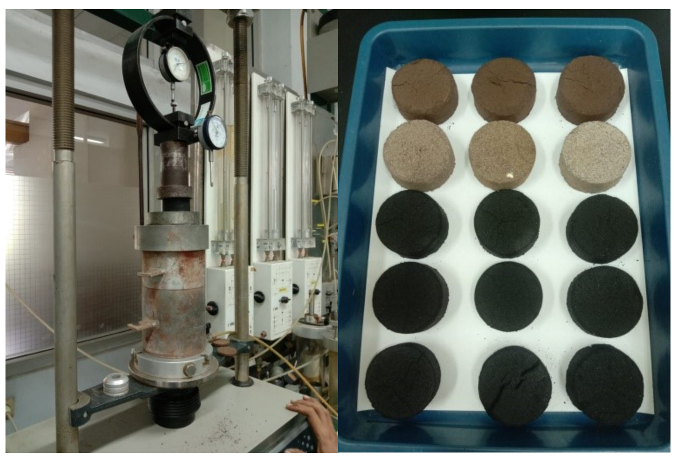


Fig. 5. Visualization Of Briquette Compressive Strength Analysis

Based on the research that has been done, it is known that variations in torefaction temperature and the amount of adhesive affect the compressive strength value of briquettes that have been produced. The increase in the strength of briquettes with torefaction heating results from the presence of high extractive substances in their structure. Enrichment of lignin components in the briquette structure as a result of hemicellulose degradation and extractive materials can increase the strength of briquettes (Haykiri-Acma & Yemen, 2022). As based on the amount of adhesive in accordance with previous research where the increase in adhesive concentration tends to increase the value of the compressive strength of briquettes (Purwanto et al., 2015; Idris et al., 2021).

3.2 Proksimate Analysis

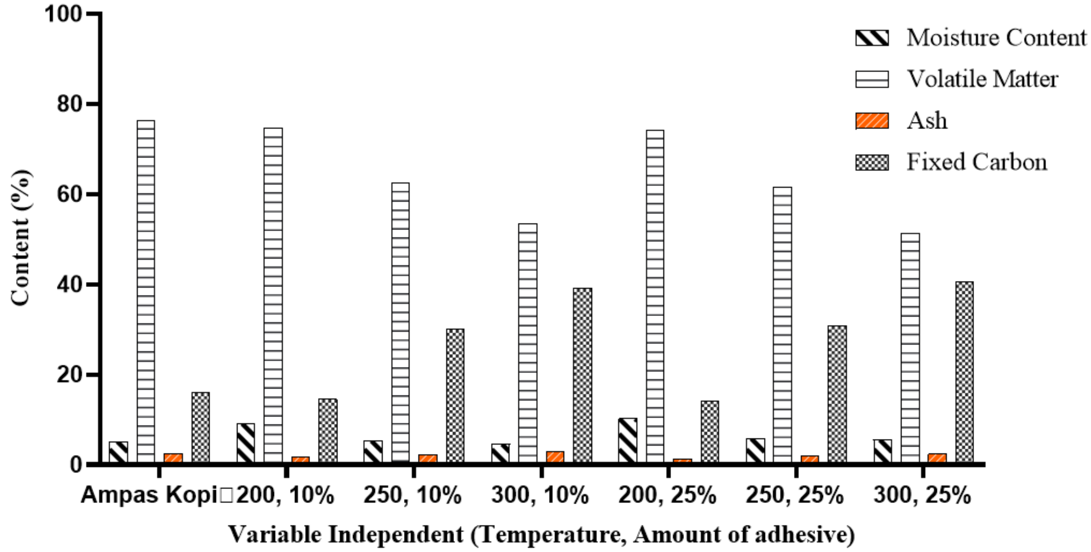


Fig. 6. Results Of Proximate Analysis Of Briquettes

Based on the results of the study, it is known that the temperature of torefaction affects the results of proximate analysis on briquettes, namely by increasing the temperature of torefaction will increase the value of ash content and tethered carbon content and reduce the value of water content and levels of flying substances. While increasing the amount of adhesive will affect the value of the higher water content. Increased torefaction temperature causes evaporation of water and extractive materials, and hemicellulose degradation is maximized so that the moisture content of the fuel decreases (Sulistio et al., 2020). The amount of adhesive affects the value of the higher water content in accordance with previous studies where the increase in adhesive concentration tends to increase the value of briquette water content (Deglas & Fransiska, 2020; Dewi, 2019; Ulva & Romadhoni, 2020; Adhiguna & Rejo, 2021). As for the levels of flying substances, they will decrease with increasing authoring temperature (Sugiharto & Firdaus, 2021; Norhikmah et al., 2021). With an increase in torefaction temperature, more volatile substances are released so that a lower fuel mass result is obtained (Apriyanto, 2020). According to Maryenti et al. (2017) in Rubiyanti et al. (2019), the increase in ash content in briquette products from torefaction due to mass reduction during torefaction is not followed by degradation of ash-forming inorganic components. The high ash content is caused by the trapping of difficult-to-burn components in the fuel (Apriyanto & Tohirin, 2022). Broadly speaking, the value of tethered carbon content of briquettes increases with increasing torefaction temperature. During the torefaction process, the process of thermal decomposition of hemicellulose into volatile substances occurs. With the formation of volatile substances, there is a reduction in O/C and H/C levels so that the levels of tethered carbon increase (Suastika et al., 2019; Ayuningtiyas et al., 2020).

3.3 Ultimate Analysis

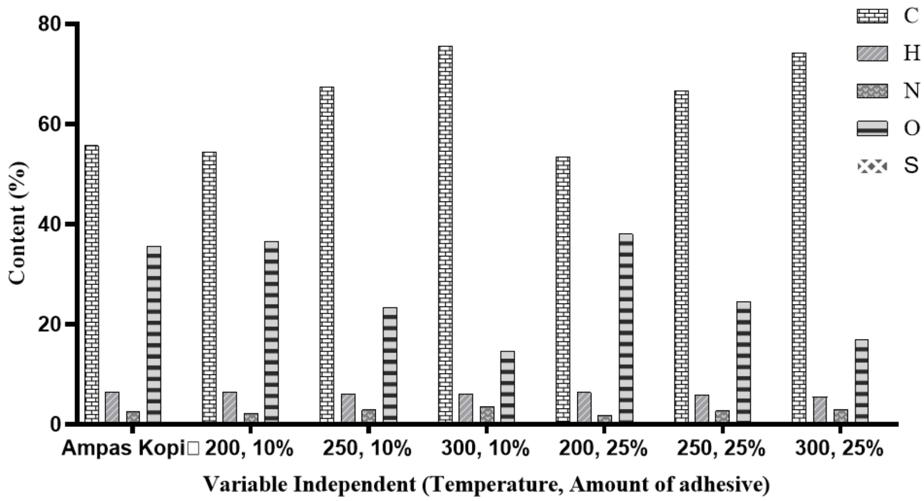


Fig. 7. Ultimate Briquette Analysis Results

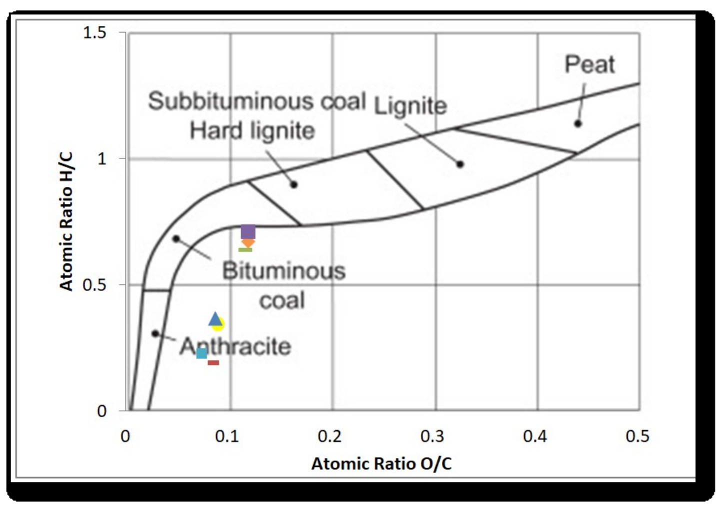


Fig. 8. Krevelen Briquette Product Diagram

Based on the results it is known that the torefaction temperature affects the results of ultimate analysis on briquettes, while the amount of adhesive does not affect. Based on Figure 7 shows that the concentration of successive atoms in the briquettes of coffee grounds is C > O > H > N > S. Element C is found in fixed carbon and volatile matter, while elements H and O come from hydrocarbon and water content contained in torefaction products (Apriyanto & Tohirin, 2022). Based on Figure 8, van krevelen diagram of the relationship between the ratio of H/C and O/C atoms in the briquettes of coffee grounds can be seen that the resulting briquettes are in the area of bituminous coal and anthracite so that they can be utilized in meeting energy needs on a household scale.

3.4 Calorific Value

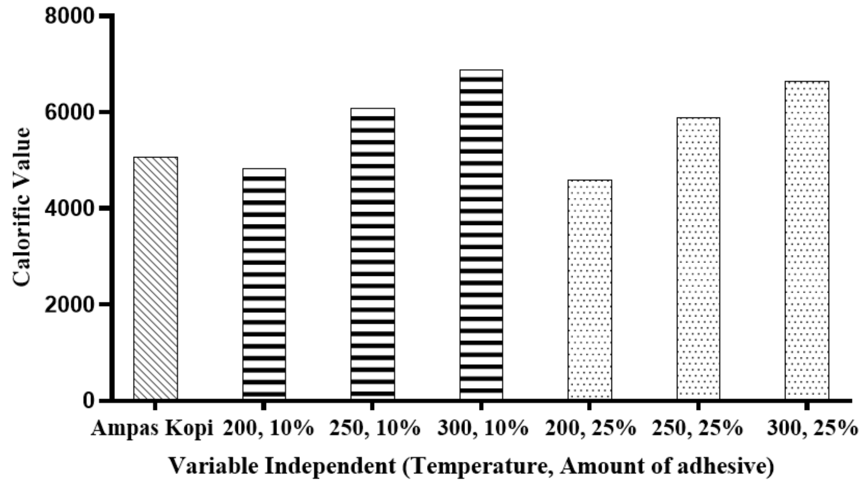


Fig. 9. Briquette calorific value Analysis Results

Based on the results it is known that the torefaction temperature and the amount of adhesive affect the results of heat analysis on briquettes. The increase in the calorific value of briquettes with increasing torefaction temperature is caused by a decrease in hydrogen and oxygen compounds that are converted into gas, which then leaves the carbon content tethered (Ismail et al., 2022). The addition of adhesive will increase the water content of briquettes, which is a lot of heat needed to evaporate the water content of briquettes so that the calorific value will decrease (Deglas & Fransiska, 2020; Arbi & Irsad, 2018).

3.5 Burn Test

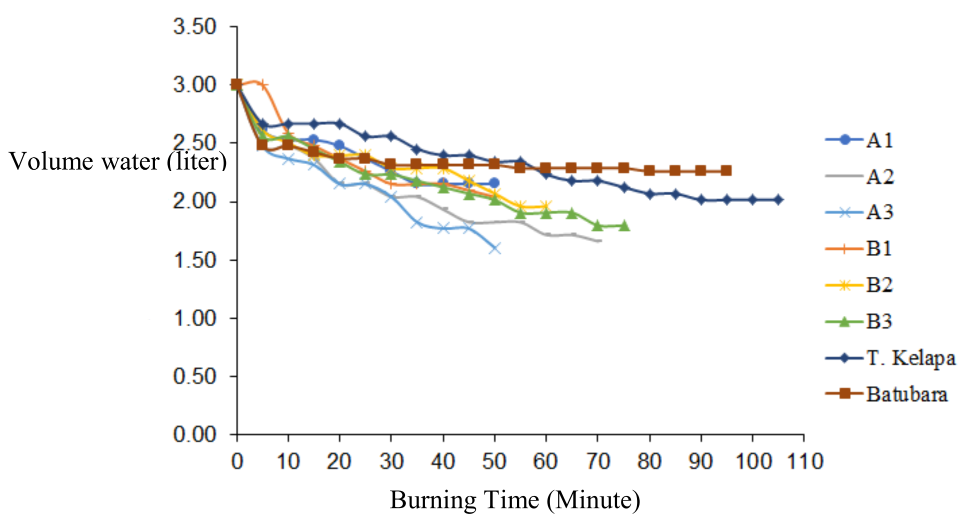
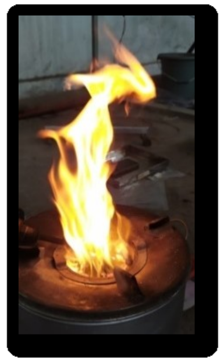


Fig. 10. Briquette Burning Test Results

Briquettes with torefaction temperature treatment of 300℃ and 250 ℃ produce better water shrinkage than 200℃. Briquettes A2, A3, B3 produce better water shrinkage because it has a high enough calorific value > 6000 cal/g. Briquettes of coffee grounds ignite more easily due to the high level of flying substances. The burning time of coconut shell briquettes and coal is longer because it has much higher tethered carbon. The content of flying substances and tethered carbon greatly affects the combustion of briquettes. The greater the content of flying substances, the faster the combustion of fuel and the longer the flame will be shorter (Nurhalim et al., 2018).

3.6 Performance Test

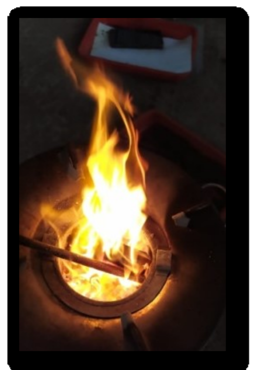
A1



A2

A3

B1



B2

B3

Coconut shell

Coal Briquette

Description:

A1 = Torefaction Temperature 200°C, Amount of adhesive 10%

A2 = Torefaction Temperature 250°C, Amount of adhesive 10%

A3 = Torefaction Temperature 300°C, Amount of adhesive 10%

B1 = Torefaction Temperature 200°C, Amount of adhesive 25%

B2 = Torefaction Temperature 250℃, Amount of adhesive 25%

B3 = Torefaction Temperature 300℃, Amount of adhesive 25%

The best flame color is produced by the briquette sample with sample code (A2, A3, B2, B3) which is bright orange which has the highest combustion temperature of 933℃. While the worst flame color is produced by coal briquette samples with sample code (BB), which is faded orange which has the lowest combustion temperature of 703℃.

4. Conclusion

Based on the research that has been done, it can be concluded that the torefaction temperature affects the results of the analysis of compressive strength, proximate, ultimate, calorific value, Combustion Test and performance test on the resulting coffee grounds briquettes. While the amount of adhesive does not significantly affect the testing characteristics of briquettes. As for the fuel test obtained briquettes A2, A3, B3 produce better water shrinkage because it has a high calorific value > 6000 cal/g so that the resulting coffee grounds briquettes feasible and potentially as household fuel.

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