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THE EFFECT OF TEMPERATURE ON THE CALORIFIC VALUE OF BRIQUETTES FROM COFFEE GROUNDS WASTE AS AN ALTERNATIVE FUEL

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ABSTRACT
The making of coffee grounds briquettes was carried out at the Rena briquette house which was followed several tests then are done with the objectives of (i) to determining out the compressive strength and calorific value with the DSC (Differential Scanning Calorimetry) test. (ii) To find out if there are differences in the characteristics of the briquettes due to the influence of combustion temperature. (iii) To determine whether there are differences in briquette morphology due to the effect of temperature analyzed by SEM test. Briquette research made from coffee grounds waste with briquette combustion temperature using a furnace of 150˚C and 250˚C, tapioca adhesive at 10% for both different temperature variations. Molding using a hydraulic press with a pressure of 1900 psi. Drying temperature of coffee grounds and briquettes using sunlight. The heating value at 150˚C was highest at the third peak point at 154.52 cal/g, and lowest at the second point at 3.86 cal/g. At 250˚C, the highest was 12.86 cal/g at the second peak, and the lowest was 8.39 cal/g at the first peak. The compressive strength at 150˚C was 1.98 - 3.44 kg/cm^2, while at 250˚C it was 0.89 - 3.19 kg/cm^2. SEM analysis of the morphological structure of the briquettes at 150˚C showed carbon particles that were closer than other carbon particle structures with small pores. The distance between the particles is tenuous with other particles not yet perfectly bonded so that there is a void of space. Whereas at 250˚C seen from SEM analysis the morphological structure has a smooth surface and shows the distance between some carbon particles that are connected to tenuous carbon particles may be caused by cracks so that they are not bound together.

Keywords: Coffe Dregs, Charcoal Briquettes, DSC, Calorific Value.

INTRODUCTION

Indonesia is one of the developed countries with potential resources to develop renewable energy sources, but only a small portion has been utilized. Biomass is an organic material produced from photosynthesis, consisting of waste such as plants, trees, grass, sweet potatoes, agricultural waste, and animal manure. Biomass is classified as a renewable energy source with a high potential of 146.7 million tons per year. Meanwhile, the potential of biomass from waste reached 53.7 million tons in 2020 (Parinduri, 2020).

One type of waste utilized as biomass is coffee grounds. After brewing, it is usually discarded, which contributes to soil pollution. A small portion of coffee grounds is used to feed animals. However, in various regions, it is often burned in open land, leading to air and soil pollution, and it has become a major concern as biomass waste (Hachicha et al., 2012).

The amount of coffee grounds waste is increasing along with the growing popularity of coffee in Indonesia. Coffee grounds waste is solid biomass obtained during coffee production. Coffee grounds contain substances such as protein, carbohydrates, caffeine, tannins, pectin, fiber, and polyphenols (Aprita, 2016). Coffee grounds in the form of briquettes can be used as an alternative fuel to reduce the organic waste generated during coffee production (Jamilatun, 2008). Briquettes are solid fuels used as an alternative energy source, made from wood or plant biomass in powder form and mixed with a binding solution, which is then pressed into specific shapes, sizes, and densities (Silitonga, 2020).

The low utilization of coffee grounds opens opportunities to explore their potential as an alternative fuel. On the other hand, efforts are needed to address the waste problem in the community. Briquettes produced with alternative fuels reach high combustion temperatures, resulting in high calorific values (Jamilatun, 2008).

The moisture content of biomass is usually removed through drying. During pyrolysis, a vaporization process occurs that reduces volatile substances. However, the ash residue from combustion can reduce the carbon content bound in charcoal combustion.

Variations of alternative fuels based on their source and production process are produced sustainably and cleanly without carbon dioxide (CO2) emissions (Abolhosseini et al., 2021). Alternative energy is a substitute for conventional fuels aimed at reducing the use of hydrocarbon fuels that cause environmental damage due to high carbon dioxide emissions, which contribute to global warming (Gielen et al., 2019).

RESEARCH METHOD

In this study, coffee grounds waste from a café were used and sun-dried for approximately 7 days. The combustion synthesis temperatures varied at 150°C and 250°C using a combustion furnace for 60 minutes. The mixture was then sieved through a 50 mesh screen until it was fine. Charcoal was mixed with 10% tapioca binder. It was molded using a hydraulic press and dried under sunlight. Calorific value testing was conducted using a DSC device, compressive strength testing was performed with a Universal Testing Machine, and Scanning Electron Microscope (SEM) testing was used to examine the surface morphology of the briquettes to ensure they meet the Indonesian National Standard (SNI).

Here is the research diagram

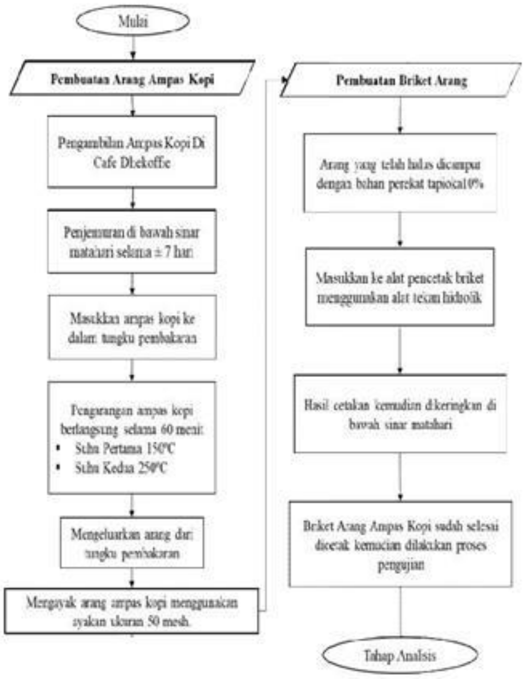

Figure 1. Research flow diagram

RESULT AND DISCUSSION

Result

1. **Formation of Coffee Grounds Waste Briquettes with Variations of 150°C and 250°C**

Coffee with Variations of 150°C and 250°C: The results of the briquette research are shown as follows: At a temperature of 150°C, the charcoal particles from the briquettes with 10% tapioca binder appeared to be not mixed with a coarse texture, making the briquettes more prone to breaking, as shown in Figure 2, which is light brown in color.

Figure 2. Briquettes at 150°C with 10% Binder

Meanwhile, at a temperature of 250°C, the charcoal particles obtained from the briquettes with 10% tapioca binder appeared to be unevenly mixed, exhibiting a smooth texture with slight cracks, making the briquettes prone to breaking and resulting in a dark brown color, as shown in Figure 3.

Figure 3. Briquettes at 250°C with 10% Binder

2. Calorific Value of Coffee Grounds Briquettes Using DSC

Based on the research conducted using a DSC device for testing the calorific value of coffee grounds briquettes, as shown in Figure 4, the DSC test results for briquettes at the thermopressing temperature variation of 150°C exhibited an exothermic reaction (releasing heat) with three peaks: (1) at a temperature of 350.27°C with a calorific value of 29.17 cal/g, (2) at a temperature of 465.28°C with a calorific value of 154.52 cal/g, while the lowest value at the second peak was 3.86 cal/g, and (3) at a temperature of 538.47°C with a calorific value of 154.52 cal/g. The highest peak is at the third peak, measuring 154.52 cal/g, while the lowest value is at the second peak, measuring 3.86 cal/g

Meanwhile, in Figure 5, the thermopressing temperature of 250°C exhibited an exothermic reaction (releasing heat) with two peaks: (1) at a temperature of 482.70°C with a calorific value of 8.39 cal/g, and (2) at a temperature of 557.36°C with a calorific value of 12.86 cal/g. The highest point is at the second peak, measuring 12.86 cal/g, while the first peak is the lowest at 8.39 cal/g.

This indicates that the higher the calorific value, the better the quality of the produced briquettes. The calorific value of the briquettes depends on their moisture content.

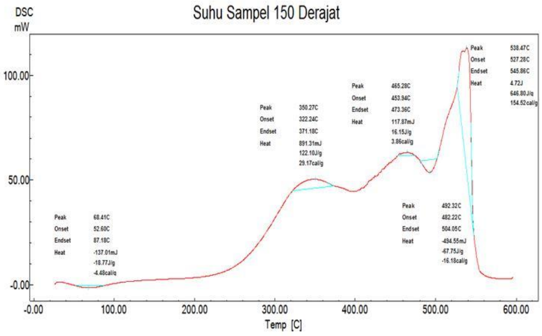

Figure 4. Graph of calorific value of briquettes at 150˚C

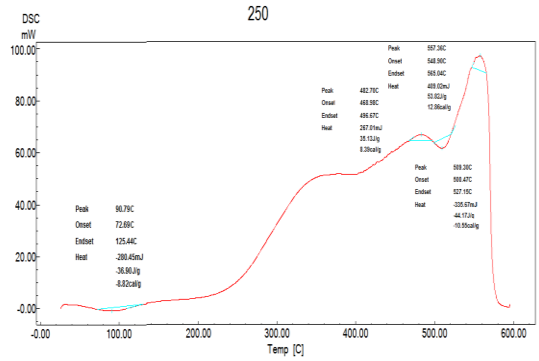

Figure 5. Graph of calorific value of briquettes at 250˚C

3. Compressive Strength of Coffee Grounds Briquettes

Compressive strength indicates the resistance of briquettes to pressure that causes them to crack or break. In this study, compressive strength tests were conducted using 10% tapioca adhesive, with two different temperature variations: at 150˚C, as shown in Table 1, and at 250˚C, as shown in Table 1.

Table 1. Data Results of Compressive Strength Analysis of Briquettes at 150˚C

Suhu 150˚C	Tinggi (mm)	Diameter (mm)	Jari-Jari (mm)	Fmax (kgf)	Luas Penampang (cm^2)	Kuat Tekan (kg/cm^2)
A_1	54,10	33	16,5	17	8,54	1,98
A_2	53,20	33,80	16,9	18	8,96	2,00
A_3	54,20	34,80	17,4	32	9,50	3,36
A_4	55,10	34,80	17,4	24	9,50	2,52
A_5	52,90	33,30	16,6	30	8,70	3,44

Table 1. Data Results of Compressive Strength Analysis of Briquettes at 250˚C

Suhu 250˚C	Tinggi (mm)	Diameter (mm)	Jari-Jari (mm)	Fmax (kgf)	Luas Penampang (cm²)	Kuat Tekan (kg/cm²)
A_1	50,75	33,8	16,9	24	8,96	2,67
A_2	49,2	34	17	20	9,07	2,20
A_3	50,7	33,4	16,7	28	8,75	3,19
A_4	51	33,8	16,9	8	8,96	0,89
A_5	52,8	34,2	17,1	28	9,18	3,04

The two tables above show that the compressive strength of briquettes at 150˚C ranges from 1.98 to 3.44 kg/cm². Sample A5 has the highest compressive strength, while sample A1 has the lowest. For the compressive strength of briquettes produced at 250˚C, it ranges from 0.89 to 3.19 kg/cm². Sample A3 has the highest compressive strength, while sample A4 has the lowest.

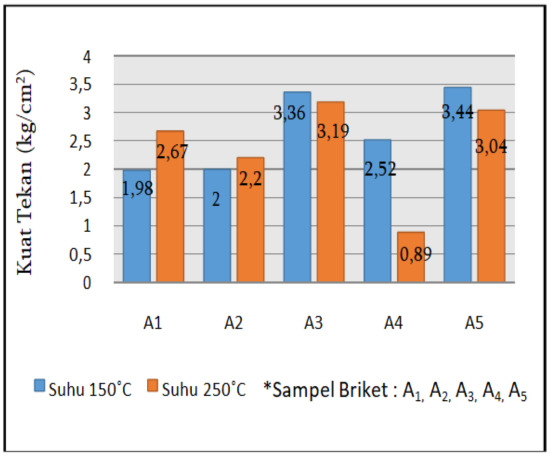

Figure 6. Compressive Strength Test at Temperature Variations of 150˚C and 250˚C

It can be seen from Figure 6 that the compressive strength graph is higher and increases along with the testing of the 150˚C sample, where the adhesive used bonds well even though the moisture content in the particles is still high. According to previous research by Nugraha (2017), increasing the pressure of the briquettes during combustion involves shortening the flame duration, extending the time, and raising the combustion temperature of the briquettes.

4. SEM analysis results of coffee grounds briquettes.

Based on the research conducted in the tests, the morphology of the coffee grounds briquettes was examined using an SEM device.

4.1. SEM Analysis Results of Coffee Grounds Briquettes at 150˚C

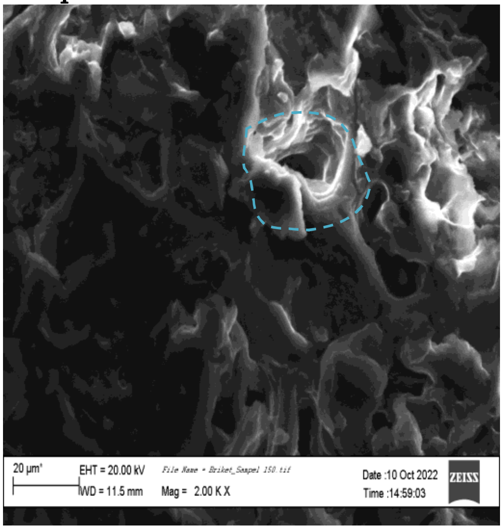

Figure 7(a). Temperature 150˚C (mag 2.00 kx)

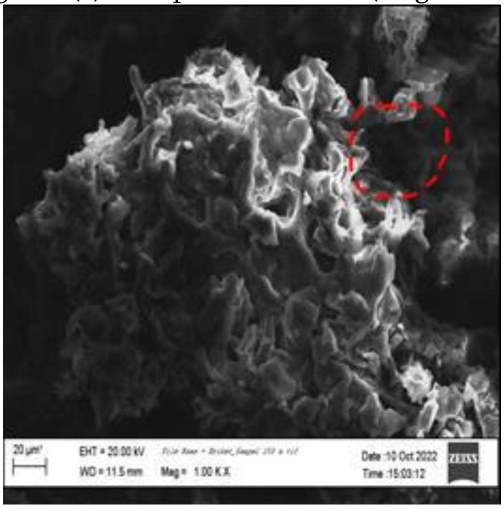

Figure 7(b). Temperature 150˚C (mag 1.00 kx)

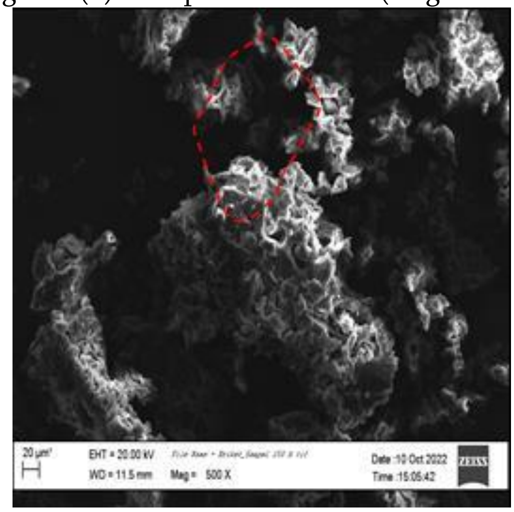

Figure 7(c). Temperature 150˚C (mag 500 kx)

From Figure 7 above, the SEM results show that the morphological structure of the briquette forms pores with greater depth. (a) shows a carbon particle closer to the carbon particle structure with small pores. In (b), the distance between particles is loose, creating empty spaces. (c) shows the distance between several carbon particles and other bonded carbon particles, but the distance between particles is large, resulting in an increase in calorific value.

4.2. SEM Analysis Results of Coffee Grounds Briquettes at 250˚C

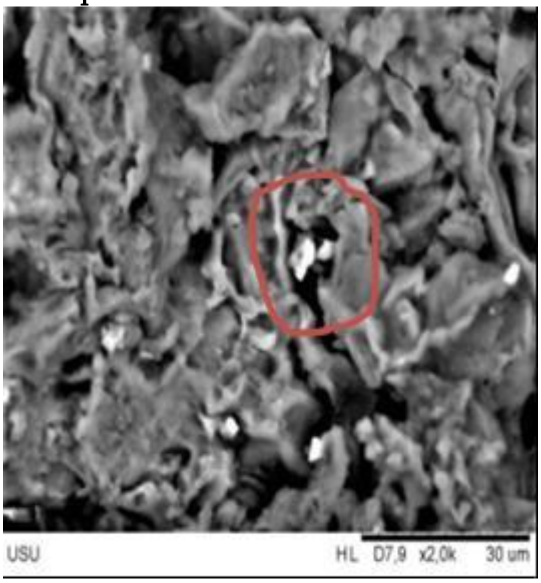

Figure 8(a). Temperature 250˚C (mag 2.00 kx)

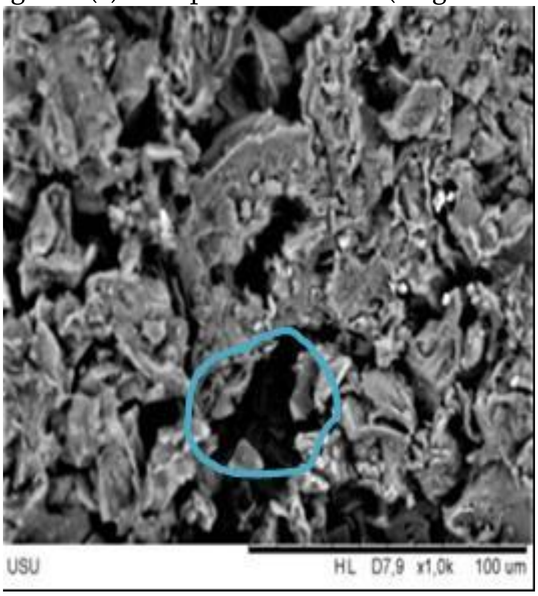

Figure 8(b). Temperature 250˚C (mag 1.00 kx)

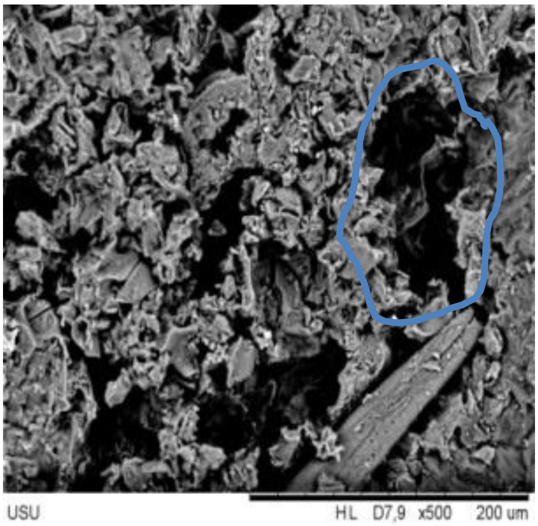

Figure 8(c). Temperature 250˚C (mag 500 kx)

From Figure 8 above, the SEM results show that the morphological structure of the briquette forms pores with smaller depth compared to the 150˚C sample. (a) shows the distance between a carbon particle and the nearest other carbon particle. (b) shows that some carbon particles are close to others, while some appear loosely spaced. (c) shows the distance between several carbon particles connected to other particles, but the loose spacing may be caused by cracks. As a result, the calorific value obtained will remain stable with each temperature increase.

According to previous research by Haryanti (2020), particle structure is crucial in determining the bonding quality of materials. The lower the particle binder, the better the bonding quality, as the surface contact between particles is greater. Particle structure influences the distribution of particles; the more even the distribution, the smaller the particles, resulting in a homogeneous distribution during the mixing process.

Discussion

Based on the research results, the comparison of briquette tests shows that the coffee grounds charcoal briquettes did not meet the SNI (Indonesian National Standard) criteria for calorific value (> 5000 cal/g). However, the compressive strength test met the SNI requirements, as there is no specific standard for compressive strength in the SNI.

The test results of the coffee grounds briquettes indicate that the calorific value of this study does not meet the SNI (Indonesian National Standard). This is due to the high moisture content in the briquettes, which affects the quality determination, making it difficult for them to ignite and resulting in a short storage life that does not last long. The burning duration of the coffee grounds during the production process should be further increased, as briquettes produced from a 1-hour burning period do not meet the standards. According to research by Widyawati (2006), the efficiency of briquette combustion affects the calorific value. The higher the calorific value, the better the quality of the briquettes with more effective combustion.

Based on the investigation, the measuring instrument used in the SNI is unknown. So far, the equipment that researchers can use is DSC, which yields values below the SNI. If possible, it would be better to use a bomb calorimeter to determine the comparative results of both instruments.

The compressive strength test results obtained from the coffee grounds briquettes show that the compressive strength values at temperature variations of 150˚C and 250˚C, with a tapioca adhesive content of 10%, meet the SNI (Indonesian National Standard). According to Japanese standards (minimum 60–65 kg/cm²), British standards (minimum 12.7 kg/cm²), and American standards (minimum 62 kg/cm²), the compressive strength does not meet the standards. This is due to the factor of rapid burning duration, where the coffee grounds have not yet turned into charcoal and retain high moisture content. The addition of adhesive to coffee grounds that have already been burned makes it difficult to bind, resulting in brittle briquette formations. The greater the amount of tapioca adhesive, the better the charcoal particles adhere to each other, resulting in longer shelf life and higher compressive strength.

The results of the SEM analysis indicate that the surface morphology of the coffee grounds briquettes differs. The morphology at 150˚C forms pores with greater depth. The characteristics of the briquettes show that some carbon particles are closer within the carbon particle structure, with small pores present. The distance between loosely spaced particles creates empty spaces, and some carbon particles are connected to others, but the large gaps between them lead to an increase in calorific value.

Meanwhile, at 250˚C, the morphological structure of the briquettes shows that they form pores with shallower depth. The characteristics of the briquettes indicate that some carbon particles are connected to other particles, but the loose spacing occurs due to cracks, resulting in a calorific value that remains stable with each temperature increase.

CONCLUSION AND SUGGESTION

Coffee grounds charcoal briquettes with 10% tapioca adhesive produced the highest calorific value measurement at 150˚C, reaching a peak of 154.52 cal/g at the third peak, and the lowest at the second peak, which was 3.86 cal/g. Meanwhile, the calorific value measurement at 250˚C had the highest at the second peak, which was 12.86 cal/g, and the lowest at the first peak, which was 8.39 cal/g.

The results of the compressive strength measurements at 150˚C were 1.98 – 3.44 kg/cm², with the highest value in sample A5 and the lowest in sample A1. At 250˚C, the measurements were 0.89 – 3.19 kg/cm², with the highest value in sample A3 and the lowest in sample A4. From the data obtained, the calorific value does not meet the SNI (Indonesian National Standard), while the compressive strength values do meet the SNI.

The results of the SEM analysis indicate that the surface morphology of the coffee grounds briquettes differs. The morphology at 150˚C forms pores with greater depth. Meanwhile, at 250˚C, the morphological structure of the briquettes shows that they form pores with shallower depth.

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