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Making Biochar from Coffee Grounds and Powder Waste Through the Torrefaction Process and Adding $NaHCO_3$

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ABSTRACT

This research examines biochar manufacture from waste coffee grounds and wood dust using the dry torrefaction method with a temperature ratio of 250°C and 300°C. The adhesive used at 5% shows a calorific value of 6,786 cal, volatile matter 81.82%adb, water content 1.79%ar, and ash content 9.52%adb. Meanwhile, the adhesive at 7% obtained a calorific value of 6,264 cal, water content of 3.9%ar, volatile matter 81.82%ab, and ash content of 14.29%adb. The results of the functional group analysis with FT-IR of the two torrefaction biobriquettes showed the presence of CH and OH groups originating from cellulose compounds, indicating that the carbon quality in the torrefaction charcoal is still high. Activated charcoal products produced through torrefaction are briquettes using tapioca flour adhesive to be molded as bio briquettes, and the results are tough and not easily broken.

Keywords: *Aquades; Biobriquette; Coffee; Sawdust; Torrefaction*

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ABSTRAK

Penelitian ini mengkaji tentang pembuatan bioarang dari limbah ampas kopi dan serbuk kayu dengan menggunakan metode torefaksi kering dengan perbandingan suhu 250°C dan 300°C. Perekat yang digunakan pada 5% menunjukkan nilai kalor 6,786 kal, *volatile matter* 81,82%adb, kadar air 1,79%ar, dan kadar abu 9,52%adb. Sedangkan pada perekat 7% memperoleh nilai kalor yaitu 6,264 kal, kadar air 3,9%ar, *volatile matter* 81,82%ab, dan kadar abu 14,29%adb. Hasil analisis gugus fungsi dengan FT-IR kedua biobriket hasil torefaksi menunjukkan adanya gugus CH dan OH yang berasal dari senyawa selulosa. Hal ini menunjukkan masih tingginya kualitas karbon dalam arang hasil torefaksi. Produk arang aktif yang dihasilkan melalui torefaksi dibriketkan menggunakan perekat tepung tapioka untuk dicetak sebagai biobriket dan hasilnya sangat keras dan tidak mudah pecah.

Keywords: *Ampas kopi; Aquades; Biobriket; Serbuk kayu; Torefaksi*

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INTRODUCTION

Fossil fuels are currently the most frequently used energy sources to meet daily needs such as gas, oil and coal. Energy is produced through the combustion process of fossil fuels so that it can cause an increase in greenhouse gas (GHG) emissions so that it can cause an increase in global warming and environmental population at the same time [1]. Global energy consumption in 2018 had an impact of increasing up to two times the growth rate since the year 2010 [2]. The use of fossil energy also has an increase in the production of anthropogenic waste caused by increasing growth. The waste produced can provide a fairly large opportunity for use as bioenergy and biofuel production. In the last five years, many researchers have tried to develop renewable energy and alternative fuels that are environmentally friendly such as biofuel and bioenergy that have been studied [3].

Coffee grounds waste is the biggest contributor to environmental pollution, because the waste it contains has a very significant impact on environmental pollution and also has the risk of gas emissions [2]. This is caused when the release of toxic waste contained in coffee such as caffeine, tannins, and phenols that are still left in the coffee grounds. The release of leachate and greenhouse gas (GHG) emissions from decomposition in landfills makes it phytotoxic and harmful to the environment. Coffee grounds waste produced from coffee drinks each year has around six million tons. worldwide [4]. According to one of the International Coffee Organizations, global coffee production continues to increase to reach its highest figure of around 9.6 million tons recorded in 2017. Aceh is one of the largest coffee producing areas that plays an important role in economic development. Currently, coffee consumption is a global phenomenon among the community. Coffee grounds waste can be used as raw materials for bio-based products so that it can reduce material costs which generally reach more than 70% of the total production costs [5].

Coffee grounds are considered as low quality raw materials that require special pre-treatment and have a high water content of more than 50%. Therefore, it takes a lot of energy to remove water from wet coffee grounds [6]. Products derived from cellulose, hemicellulose, and lignin open up great opportunities to be used as high-value products through chemical and biotechnological processes. In addition, coffee grounds also contain magnesium, sulfur, and calcium which are useful for plants. Waste produced from the wood cutting industry is currently still not optimally utilized. The wood cutting industry will certainly produce wood waste such as sawdust and wood cutting residue. Meanwhile, the handling of sawdust waste is only left to rot, piled up and burned so that it has a negative impact on the environment and the environment [7]. Sawdust contributes up to 10% of all waste dumped in landfills each year. For developing countries such as Bangladesh and Pakistan, this problem is considered serious because it can cause problems for the environment. Most developing countries also experience difficulties with pollution and environmental challenges if sawdust waste is not utilized optimally [8].

Coffee grounds produced in large quantities if not utilized will cause excessive environmental pollution. Biomass of coffee grounds and sawdust if charred through a dry torrefaction process can increase the calorific value of biobriquettes.

METHOD

The method used in this research went through several experimental stages, including:

1. Preparation of tools and materials for making biochar using the torrefaction process equipped with tools such as 12 kg gas, reactor units, pressure gauges, measuring cups, and thermometers. Collection of raw materials is carried out every day which has been collected from coffee drink and wood panglong business actors. The raw materials that have been collected then washed using water until clean and dried in the sun for 8 days when the sun is bright.
2. The chemical activation process is carried out by adding $NaHCO^3$ to 83% of coffee-grounds with a variation ratio of 5:6 and then stirring using a stirrer for 3 minutes constantly. The result of this stirring is that the coffee grounds become wetter so that they will be dried using an oven at a temperature of 105°C until dry.

3. The torrefaction process is carried out directly using a temperature of 250°C and 300°C without air for 1 hour at a constant temperature. At this stage, the raw material produces three products, namely biochar, biogasoline and sync gas. Several parameters that can affect the torrefaction process include temperature, time, and raw materials.
4. The products that have gone through the torrefaction process are then taken and varied with mixed raw materials from coffee grounds and sawdust using 5% and 7% tapioca flour adhesive which is expected to be printed strongly and not easily broken.
5. The printed product is then subjected to Proximate Analysis testing which aims to determine the basic composition of a material then FT-IR and XRD.

RESULTS AND DISCUSSION

The materials used to make biochar are variations between coffee grounds and sawdust obtained from coffee beverage and woodworking businesses. It can be seen from Table 1 to determine the composition of a material, a Proximate Analysis test was carried out to obtain the following results:

Proximate Analysis

Proximate analysis results of Biochar Torrefaction temperature Coffee grounds: Sawdust 250°C : 300°C (5%).

Table 1. Proximate test results of coffee grounds and sawdust using 5% adhesive.

No.	Ratio (gr) AK : SK ADHESIVE 5%	Mositure	Ash content	Volatile matter (%)	Fixed carbon (%)	Bombcalori meter (kal)
1	90 : 10	0.56	9.52	90.91	-0.99	5,945
2	80 : 20	0.77	9.52	81.82	6.87	6,070
3	70 : 30	6.22	13.64	81.82	-2.41	6,756
4	60 : 40	4.42	9.09	81.82	4.67	6,786

Proximate analysis results of Biochar Torrefaction temperature Coffee grounds: Sawdust 250°C : 300°C (7%).

Table 2. Proximate test results of coffee grounds and sawdust using 7% adhesive

No.	Ratio (gr) AK : SK (gr)	Mositure	Ash content	Volatile matter (%)	Fixed carbon (%)	Bombcalori meter (kal)
1	180 : 20	0.80	9.09	81.82	8.19	6,264
2	160 : 40	3.99	15.38	90.91	-10.28	5,910
3	140 : 60	1.96	9.52	83.33	5.19	5,954
4	120: 80	0.74	14.29	90.91	-5.94	6,104

FT-IR Analysis

FT-IR analysis is one of the methods used to determine the functional groups of a material before analyzing the flammability and thermal properties. The results of this study indicate changes in functional groups that occur in coffee grounds waste biobriquettes. This shows changes in functional groups that occur in coffee grounds and sawdust waste biobriquettes. It can be seen from the wave number 2800–3000 cm^{-1} which is the vibration of the O – H and C – H groups that have changed. This indicates a change in functional groups so that most of the hemicellulose and cellulose compounds have been degraded or decomposed [9]. FTIR analysis studies of caffeinated beverages such as tea and coffee have reported the same peak area of 2882–2829 cm^{-1} related to the asymmetric stretching of the C – H bond of the methyl group (-CH3) in caffeine molecules and can be identified to develop a predictive model for quantitative analysis of caffeine [10].

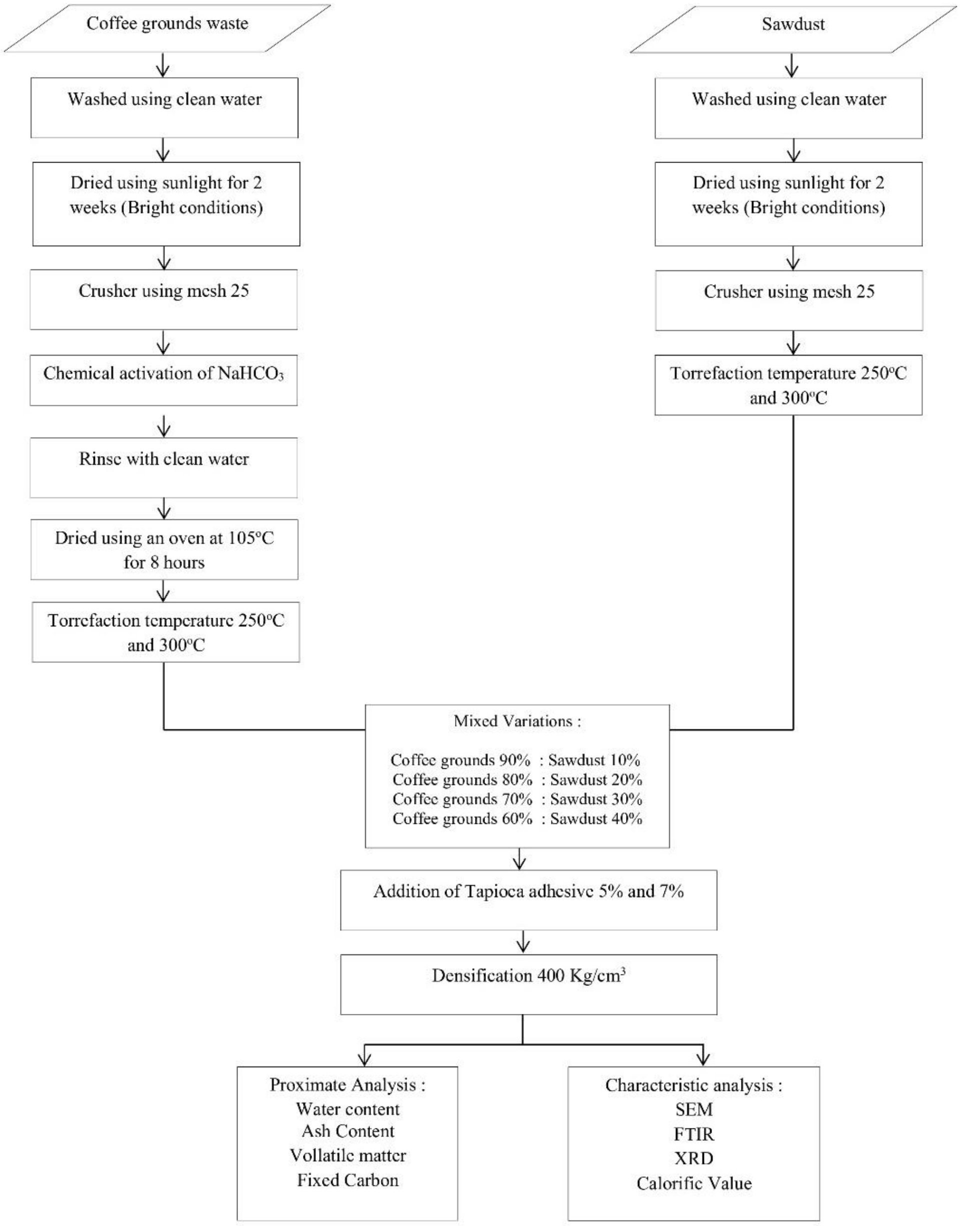

Figure 1. Research diagram.

Table 3. FT-IR spectrum correlation.

Functional Group	Wavenumber (cm^{-1})
C – H	2850–3300
C = O	1680–1750
C – O	1000–1300
O – H (alcohol)	3230–3550
O – H (acid)	2500–3300 (very bond)

The C = C group is a lignin structure that is in the wave range between 1500–1800 cm^{-1}. The significant increase in lignin levels in biomass is due to the accumulation of hemicellulose and cellulose compounds that are degraded at a temperature of 270–300°C. The absorption of infrared molecules 1 is based on its sensitive and selective vibration mode. Therefore, FTIR testing is used to study the degradation of polymers or biomass [11].

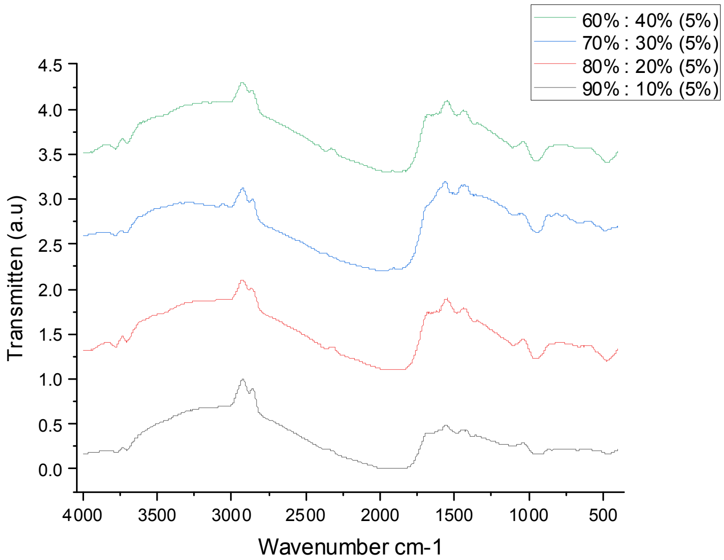

Figure 2. FT-IR test results for coffee grounds and sawdust.

XRD Analysis

This increase in diffraction peaks indicates that the degree of crystallinity in the charcoal powder sample is similar to that of the graphite sample, which is the main element forming carbon. The XRD intensity value is influenced by the level of crystallinity in the raw materials, namely coffee grounds and sawdust. Where the higher the intensity, the higher the crystallinity of the material. When a material has a crystalline structure, the arrangement of its atoms will be more orderly and tidy. Further evidenced by the broad peak at 29.39° which corresponds to the diffraction of graphitic carbon. Figure 4.24 shows several well-known peaks in the 2θ range from 20° to 80°. In particular, characteristic peaks appear at values 22°, 30°, and 40° respectively. The broad diffraction peaks observed between 20° and 30° indicate amorphous carbon along with remaining organic matter [12]. When a light beam interacts with a material, there are three possibilities that can occur, namely absorption, diffraction (scattering), or fluorescence (emission) of returning X-rays with lower energy. When this phenomenon occurs, it becomes the basis for analysis using X-ray techniques [13]

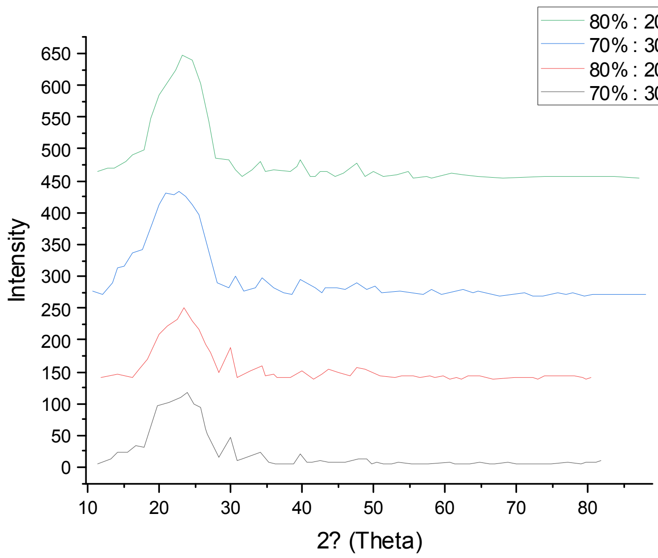

Figure 3. XRD result analysis

SEM (Scanning Electron Morphology)

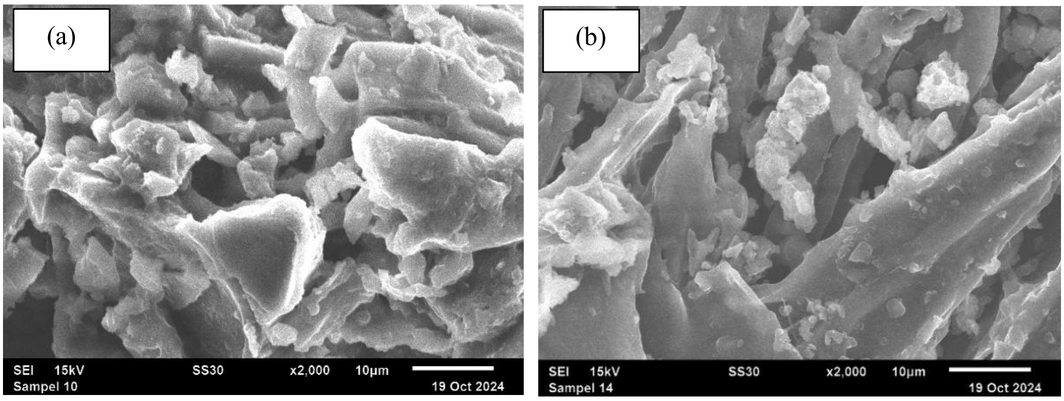

Figure 4. SEM Test Results of Biobriquettes of Coffee Grounds and Sawdust Waste
(a) AK 70% : SK 30% adhesive 5%, (c) AK 80% and SK 20% adhesive 5%.

It can be seen from the test results in image a that the variation of AK 70% : SK 30% using 5% adhesive has a rough structure as well as irregularly shaped particles and has varying sizes. This structure shows a material that has porous properties, this occurs because refraction or the condition of incoming light cannot be focused clearly. In image c with a magnification of up to 2,000×, the variation of AK 80% : SK 20% using 7% adhesive shows a rough material structure and has small particles and has an irregular shape. By adding $NaHCO_3$, more hydrocarbons or impurities are removed, thereby increasing the pore volume of the biochar obtained. This increase in pore volume is due to the dissolution of impurities that fill the pores in the material during the carbonization process. In addition, the process of adding activators functions to dissolve impurities that arise during the carbonization process that are closed in the pores [14].

CONCLUSION

The torrefaction process consistently yields a uniform and high-quality biochar product when performed in an oxygen-free environment. Notably, a 70%:30% blend of coffee grounds and sawdust produced biochar with the highest volatile matter content at 6.22%, indicating an incomplete carbonization process. The optimal calorific value of 6,786 cal was achieved with a 60%:40% coffee grounds to sawdust ratio, using torrefaction temperatures of 250°C and 300°C. Furthermore, qualitative analysis of the material’s surface morphology revealed that cavities or holes in the biobriquette structure of coffee grounds and sawdust enhance flammability and contribute to a higher calorific value.

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