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Preparation and Characterization of Biochar from Coconut Shell Biomass Activated Potassium Hydroxide (KOH)

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Abstract. Biochar made from coconut shell biomass contains constituent elements such as, Al, Si, P, S, Cl, K, Ca, Cr, Mn, Fe, Ni, Cu, Zn, Sr, Ag, Cd, Zr, Br, and Rb. Where the largest components in this biochar are Potassium (K) of 2.17% and Aluminum (Al) of 1.51% and the presence of C-H and C-O groups with the presence of carbon, and has an amorphous material structure. After activation, has a role in increasing the porosity and surface area of the activated carbon produced. During the activation process, KOH reacts with carbon, resulting in the formation of porous structures. This activation not only increases the surface area but also increases carbon reactivity, which is beneficial for supporting the metal catalyst and improving its catalytic performance

Key words: Biomass, Coconut Shells, Biochar, Potassium Hydroxide.

INTRODUCTION

Indonesia is the largest producer of coconuts in the world, where the majority of coconut products come from smallholder plantations. In 2020, coconut production in Indonesia reached 2,811,954 tons with an area of 3,396,776 ha [1] The high production of coconuts is also proportional to the amount of coconut shell waste produced, where usually coconut farmers throw away or burn coconut shells to be used as fertilizer, which produces CO and CH4 gases which have a negative impact on the environment [2] In addition, the coconut processing industry that produces oil, health products, beauty, energy and food also contributes to the increase in coconut shell waste. With the volume of coconut shell waste continuing to increase, effective management solutions are needed to prevent environmental pollution. One alternative that can be taken is to utilize this waste as an alternative energy source through the thermochemical process, so as to not only reduce the negative impact of the environment but also increase the economic value of waste [3]

One of the commonly used thermochemical conversion methods to convert biomass into an energy source is pyrolysis. Pyrolysis is a chemical process in which organic or inorganic matter is broken down into simpler compounds through heating at high temperatures in the absence of oxygen, or with a very limited amount of oxygen. Biomass processing through pyrolysis produces products such as biochar, bio-oil, and gas. Among these products, biogas and bio-oil are more in demand for energy production and power generation, while biochar is commonly used in gas adsorption [4], soil amendment [5], and wastewater purification [6].

Biochar is a porous carbon-dense material with a high degree of aromatization and strong resistance to decomposition, which is obtained through the thermal breakdown of biomass from plant or animal waste without oxygen or in the atmosphere with little oxygen. The biochar produced from this thermochemical process has high porosity, good thermal stability, and contains active functional groups [7]. The superior properties of biochar open up great opportunities for its use in various technological applications, especially its utilization as a catalyst buffer in various chemical processes.

In order for biochar to be used effectively as a catalyst buffer, an activation process is required first. This activation process aims to improve the physicochemical properties of biochar, such as porosity and number of active sites, so that it can support the catalyst performance optimally. One of the chemical activators used to significantly improve the physicochemical properties of biochar is KOH. Activation with KOH has a role in increasing the porosity and surface area of the activated carbon produced. During the activation process, KOH reacts with carbon, resulting in the formation of porous structures. This activation not only increases the surface area but also increases carbon reactivity, which is beneficial for supporting the metal catalyst and improving its catalytic performance [8].

MATERIALS AND METHODS

The materials used are coconut shells, nitrogen gas, aquadest, and KOH. The equipment used is beaker equipment, bamboo and pestle, yakan 100 mesh, spatula, analytical balance, oven, grinder, *Fourier Transform*

Infrared (FTIR) spectrophotometer, *X-Ray Diffractometer (XRD)*, and *X-Ray Fluorescene* (XRF).

Coconut Shell Biomass Preparation

The coconut shells taken from the jenang candy factory are cleaned of fibers attached to the surface of the shells. Then it is cleaned using running water and dried in the sun for 24 hours. The dried coconut shells are chopped and dried again using an oven with a temperature of 110^0 C for 12 hours.

Coconut Shell Pyrolysis

A total of 100 grams of coconut shells are put into the reactor and then pyrolyzed at a temperature of 500^0 C for 2 hours by being treated with nitrogen gas. The pyrolysis results in the form of biochar are then crushed using a gerander machine, then sifted using a 200 mesh sieve and characterized using FTIR, XRD, and XRF.

Activation Using KOH

A total of 10 grams of coconut shell biochar was activated with a base activator of Potassium Hydroxide (KOH) with a concentration of 2M with a ratio of 1:4 (w/v). Then it is neutralized using aquuades to pH 7 and dried using an oven with a temperature of 110^0 C for 2 hours. Followed by calcining at a temperature of 500^0 C for 2 hours.

Data analysis

The data to be obtained are in the form of components that make up coconut shell biochar, the crystallinity of coconut shell biochar before and after activation.

RESULTS AND DISCUSSION

Coconut shells are one of the potential sources of biomass to be used as raw materials in the manufacture of biochar catalysts. Coconut shells are used as the basic material for making charcoal, because coconut shells have good thermal diffusion properties resulting from the high content of cellulose and lignin contained in the shells (Bledzki et al., 2010).

Biochar is made through pyrolysis, which is the heating of biomass (in this case coconut shells) at high temperatures without oxygen. This process produces biochar with a large pore structure and a wide surface. The selection of KOH as an activator is because KOH is able to control the acidity of coconut shell carbon powder so that it is able to open pores, after being activated using KOH is expected to be able to multiply the micropore structure and mesopores in the carbon electrode.

Analysis Using XRF

Table 1. Components of Coconut Shell Biochar

BC	
Element	Mass%
Al	1.51
Si	0.236
P	0.159
S	0.0740
Cl	0.0805
K	2.17
Ca	0.0606
Cr	0.0038
Mn	0.0013
Fe	0.0634
Ni	0.0004
Cu	0.0034
Zn	0.0012
Sr	0.0012
Ag	0.0001
Cd	0.0012
Zr	0.0001
Br	0.0002
Rb	0.0026

X-Ray Fluorescence (XRF) analysis is used to determine the chemical composition of the sample and will also obtain a spectrum that shows the relationship between intensity and energy. The spectrum produced by XRF comes from firing a beam of electrons at a target. This will cause the atoms of the material to undergo ionization. This process will cause the atoms of the material to be in a stable state with the same number of protons as the electrons, the electrons in the material will undergo excitation. Electrons that have a higher energy level will undergo a transition to a lower energy level. When a transition occurs, a certain amount of energy will be released, including X-rays that will be captured by the detector and displayed in the form of a spectrum.

In the characterization results, the constituent components in coconut shell biochar can be seen in table 1 which shows that coconut shell biochar contains constituent elements such as, Al, Si, P, S, Cl, K, Ca, Cr, Mn, Fe, Ni, Cu, Zn, Sr, Ag, Cd, Zr, Br, and Rb. Where the largest components in this biochar are Potassium (K) of 2.17% and Aluminum (Al) of 1.51%.

Table 2. Components of KOH Activated Coconut Shell Biochar

BC - CAL	
Element	Mass%
Al	1.57
Si	0.124
P	0.158
S	0.120
Cl	0.0723
K	2.00

Ca	0.0596
Cr	0.0091
Mn	0.0024
Fe	0.0781
Ni	0.0040
Cu	0.0038
Zn	0.0016
Sr	0.0007
Mo	0.0002
Ag	0.0001
Zr	0.0001
Rb	0.0001

In table 2 after activation, the elemental components in biochar experienced a decrease in mass such as Potassium (K) which decreased to 1.69% and Aluminum (Al) to 1.41%. However, after calcining, the mass increases to 2.00% and 1.57% which can be seen in table 4.3. This shows that after activation, the biochar must be calcined to ensure that the activator using the activator enters perfectly.

Analysis Using FTIR

Fourier Transformed Infrared (FTIR) is one of the instrument units that can be used to detect functional groups, identify compounds and analyze mixtures from the analyzed sample without damaging the sample. In the infrared region on the electromagnetic wave spectrum it starts from wavelengths of 14000 cm-^{1} to 10^{-1}. FTIR can also be used to detect functional clusters [9].

From the research of [9] revealed that the FTIR detector showed a band that widened in the region of 1200–1500 $^{cm-1}$ which identified the presence of C-H and C-O groups. The appearance of the absorption peak at the wave number of 2510.46 cm^{-1} which forms the O-H functional group.

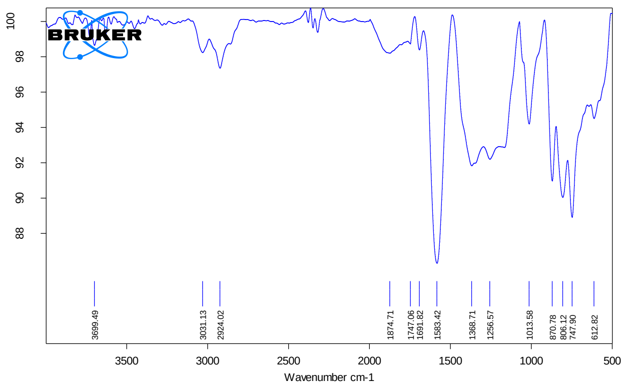

Figure 1. Spectral Pattern of FTIR Biochar Coconut Shell

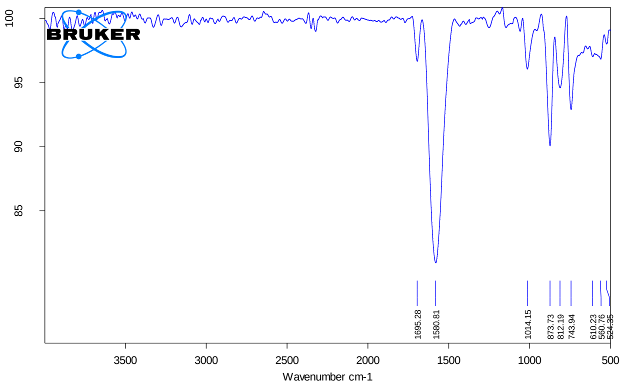

Figure 2. FTIR Biochar Spectral Pattern of KOH Activated Coconut Shell

In this FTIR, a wavelength of 500-4000 cm-1 is used, which the results of the FTIR biochar spectrum show a peak in the area of 1583.45 cm^{-1} in coconut shell biochar. Likewise, after being activated with KOH it shows a peak at 1584.34 cm^{-1} and after calcining it shows a peak at 1580.81 cm^{-1} which shows the presence of C-H and C-O groups with the presence of carbon.

Analysis Using XRD

X-ray diffraction (XRD) is to distinguish between crystalline and amorphous materials. The principle of X-ray diffraction is the diffraction of X-ray waves that undergo scattering after colliding with crystal atoms. The resulting diffraction pattern displays a crystalline structure. Diffraction pattern analysis can determine the parameters of the lattice, crystal size, and crystal phase identification. The type of material can be determined by comparing the results of X-ray diffraction with a catalog of diffraction results of various materials [10].

The degree of crystallinity is obtained from the measurement of X-ray Diffraction, which is used to determine the crystallinity properties (crystalline or amorphous) of a material, the lattice parameters and the distance between atoms in the crystal plane. The degree of crystallinity is the level of regularity of the structure of a material.

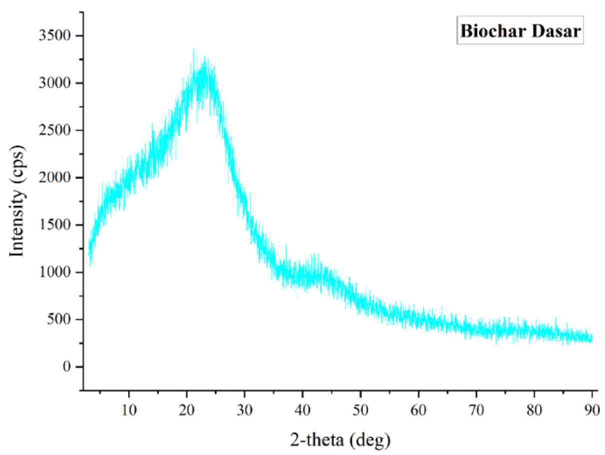

Figure 3. XRD Diffraction Pattern of Coconut Shell Biochar

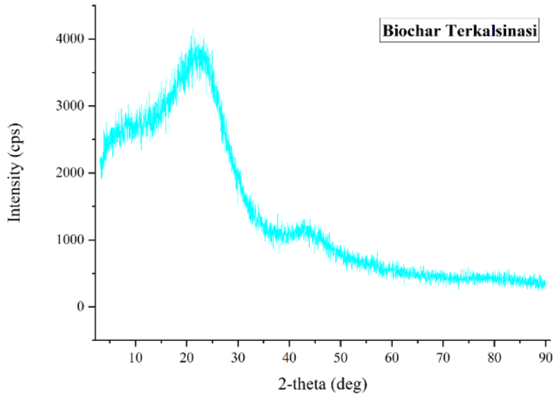

Figure 4. XRD Diffraction Pattern of KOH Activated Coconut Shell Biochar

Based on the results of characterization with 2-theta (deg) with a peak width of 25°, which is a characteristic of amorphous or semi-crystalline materials. It shows a partially organized structure of amorphous or carbon graphite. This indicates the existence of small domains with a low level of aromatic regularity. The absence of sharp peaks indicates that the biochar does not contain significant amounts of crystalline minerals, or that the minerals have been decomposed during the pyrolysis process. Likewise, even after being activated and calcined, the structure of bichar still shows an amorphous structure.

CONCLUSION

Biochar made from coconut shells produces biochar with a large pore structure and a wide surface. Chemical activation using KOH is carried out to improve the catalytic properties of biochar. KOH helps to open pores and increase the surface area of biochar, thereby increasing its adsorption and reactivity capacity. KOH activated biochar has an amorphous structure.

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