
Preparation of Activated Carbons From Banana (*Musa acuminata* L.) peels for Carbon Monoxide Adsorption

BPAC for CO
Adsorption

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Abstract

Purpose – In this research, we have prepared activated carbon (AC) from the waste of banana peels (*Musa acuminata* L.) using potassium hydroxide (KOH) for carbon monoxide (CO) adsorption from motorcycle gas emission.

Design/Methodology/Approach – The activation was conducted using a chemical activator (KOH) at various concentrations of 1, 2, and 3 N for 1, 2, and 3 h, respectively. Characteristics of banana peels AC (BPAC) produced were analyzed using the *Fourier-transform infra-red spectroscopy* and *scanning electron microscopy*.

Findings – Results showed that KOH concentration and activation time strongly affected the CO adsorption and opening of the AC surface pore. There was an increase in the CO sorption when the KOH concentration was increased up to 3 N concentration. The highest CO adsorption from the emission occurred at 70.95% under KOH concentration of 3 N during the 3-h preparation.

Research Limitations/Implications – BPAC has been used as an adsorbent for only CO from motorcycle gas emission but not as an adsorbent for HC, NO, NO_x, or H₂S.

Practical Implications – BPAC can be used as the potential adsorbent for the removal of CO from motorcycle gas emission, and it is an environmental friendly, low cost, and easy to make adsorbent.

Originality/Value – In this study, the AC is made from biomass and is used in wastewater treatment, but limited studies are found on the removal of CO from motorcycle gas emission.

Keywords Banana peels activated carbon, KOH, adsorbent, Carbon monoxide

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1. Introduction

Activated carbon (AC) is a porous solid containing 85–95% carbon. Materials containing carbon can produce AC by heating them at high temperature. Pores could function as an adsorbent of carbon. AC with a bulky surface area has been used for various purposes, such as color remover, reliever, deodorizing agent, and purifying agent in the food industry. It is also commonly used in the water purification process—both in the production of drinking water and in the wastewater treatment (Wu, 2004). The advantages of AC prepared using agricultural by-products offered an effective, inexpensive replacement for non-renewable coal-based granular ACs, which has similar or better adsorption efficiency (Martin *et al.*, 2003).

The exploitation of alternative waste materials from industry and agriculture for AC production has been encouraged in the recent years (Kadirvelu and Namasivayam, 2003). Some studies showed that the banana peels contained polyphenols, carotenoids and other bioactive compounds that have many advantages for human health (Larrauri *et al.*, 1999). The potential applications of banana peels vary based on its chemical composition. It is composed of dietary fiber, proteins, essential amino acids, polyunsaturated fatty acids, and potassium (Emaga *et al.*, 2007).

Giraldo and Morena-Pirajan (2014) mentioned that in the past five decades, industrialization has deflated and polluted the planet because of the uncontrolled usage of fossil fuels as the main energy source; consequently, the average global temperature has increased, thereby altering the ecosystem. In particular, according to Castro *et al.* (2001), the internal combustion engine in the industry has become one of the major causes of environmental pollution with their excess gas emission, such as CO₂, CO, hydrocarbons, SO₂, and NO_x, generating volatile organic compounds (VOC) and particulate matter. This factor contributed to the greenhouse effect, acid rain, photochemical smog, stratospheric ozone depletion, and the global warming.

To reduce these emissions, some studies had suggested the usage of porous materials such as mesoporous materials, modified mesoporous materials, alumina, silicon compounds, compounds derived from coal as both chemically and physically activated powders, granular materials, and fabrics modified with TiO₂. Castro *et al.* (2011) identified functional groups of OH, -COO, and -NH in the banana peel and stated that these organic compounds serve as an adsorbent and had abundant potential to be made as one of the low-cost biomass ACs through physical and chemical activation. Mopoung *et al.* (2015) studied the removal of Fe from the aqueous solution by AC prepared from tamarind seeds by potassium hydroxide (KOH) activation. The percentage yield was highly affected by the activation temperature and KOH–seed ratio. The infra-red spectra characterized on the AC surface showed the following functional groups: O–H, C=O, C–O, -CO₃, C–H, and Si–H.

Sugumuran *et al.* (2012) also studied the chemical activation using H₃PO₄ and KOH in the preparation of ACs from the pyrolysis of banana empty fruit bunch waste and fruit pods of *Delonix regia* at 450°C and 400°C. The yields of the ACs produced using chemical activation were found to be more qualified than untreated carbon. The ACs produced had an improved adsorption characteristics such as surface area, chemical functional groups, and the ability to remove iodine and methylene blue when compared with the high-performance adsorbents.

Until now, there is a limited literature on the utilization of KOH AC for the adsorption of carbon monoxide (CO) from gas emission. Ultimately, the carbon produced is used for the removal of heavy metal from the wastewater or for water purification. In this research, the

AC was prepared from the waste of banana peels (*Musa acuminata L.*) for CO adsorption from motorcycle gas emission. Characteristics of banana peels AC (BPAC) produced were compared with the Indonesian National Standard Quality (SNI no. 06-3730-1995). Characterization was conducted using an approximate method, whereas surface analysis of the AC was performed using the Fourier-transform infra-red (FTIR) spectroscopy and scanning electron microscopy (SEM) to examine the CO adsorption capacity from motorcycle gas emission.

2. Materials and method

2.1. Materials

Banana peel waste was collected from Banda Aceh traditional market. Chemicals such as KOH, iodine, sodium thiosulfate, and amilum powder were purchased from Merck, p.a. grade.

2.2. Research procedure

2.2.1. Preparation of BPAC Banana peel was cut into pieces of ± 3 cm and dried in the oven. The dried peels were carbonized in the furnace (Line Thermocline FB1410M-33) at a temperature of 400°C for 1.5 h. Carbon was mashed and sifted using 100-mesh sieves. Carbon was activated chemically using KOH at various concentrations of 1, 2, and 3 N for 1, 2, and 3 h, respectively. Carbon was filtered and washed thoroughly with aquadest until neutral pH was reached and then heated at 200°C for 2 h. The BPAC produced was then mixed with adhesive and molded to attain a size of 1 cm in length, 1 cm in width, and 1 cm in height. After hardening, the BPAC was heated in an oven for 3 h at 120°C.

2.2.2. Characteristic Analysis of BPAC The characteristics of BPAC were analyzed using the proximate analysis that consisted of water content, ash content, volatile matter, fixed carbon, and iodine adsorption capacity. The functional group analysis on the surface of BPAC was performed using the FTIR spectroscopy (FTIR Shimadzu Prestige-6400). The BPAC characteristics were compared with the Indonesian National Standard Quality (SNI no. 06-3730-1995). The surface and the pores of the BPAC were observed using the SEM. The motorcycle gas emission analysis was performed using the Emissions Analyzer (Sensonic-6000) for recording CO from the gas emission.

2.2.3. CO Adsorption Treatment using BPAC Measurement of CO from the motorcycle gas emission was conducted by mounting the tested vehicle in a flat position. Engine acceleration was conducted at an idle condition with an engine rotation of 800 rpm as manufacturer's recommendation. The adsorption tube containing BPAC was connected to the vehicle's exhaust, and the CO from the gas emission was analyzed by the Emissions Analyzer (Sensonic-6000).

3. Results and discussion

3.1. Characteristics of BPAC

Table 1 presents the characteristics of BPAC before and after the activation using KOH. The characteristics were measured by the proximate analysis that consisted of moisture content, volatile matter, ash, fixed carbon, and iodine adsorption.

3.2. FTIR Spectroscopy Results of AC

Figure 1 shows the FTIR spectrum of raw banana peel carbon (BPC). Bands in the region of 3,612 and 3,124 cm^{-1} were assigned to O-H stretching, and those at 2,892 and 2,920 cm^{-1} were assigned to C-H stretching. The FTIR analysis results indicate only a slight difference

Table 1.
Characteristics of AC

No.	Activation Concentration	Activation Time (hours)	Moisture Content (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	Iodine Adsorption (mg/g)
1	No activation	-	9,360	9,360	7,700	73,580	659,880
2	KOH 1 N	1	8,361	8,361	7,000	76,278	761,400
3	KOH 1 N	2	6,020	6,020	7,100	80,860	789,318
4	KOH 1 N	3	5,017	5,017	7,500	82,467	819,774
5	KOH 2 N	1	5,686	5,686	8,300	80,329	789,318
6	KOH 2 N	2	10,033	10,033	8,900	71,033	818,505
7	KOH 2 N	3	9,365	9,365	9,700	71,571	845,154
8	KOH 3 N	1	3,679	3,679	10,400	82,242	817,236
9	KOH 3 N	2	2,007	2,007	10,110	85,877	837,540
10	KOH 3 N	3	12,375	12,375	11,120	64,131	862,920
	Indonesian National Standard		Max 15	Max 25	Max 10	Min 65	Min 750

between samples that could be established. However, the shift in bands and the changes in the number of wavelengths and adsorbance between the unactivated and activated samples indicate that chemical transformation has occurred during chemical treatment or pyrolysis.

3.3. Results of the SEM Analysis

Figure 2 shows the SEM images of raw BPC and treatment variations of BPAC with KOH. BPC showed a more uniform opening pore when compared with the KOH AC (Figure 2B–D). The increase in the KOH concentration closed the surface of the active carbon pore. In addition, the release of potassium at the time of activation process also played a role in covering the part of the pore of AC, so that iodine uptake in KOH AC was lower with an increase in concentration of KOH. In Figure 2C and D, the formation of small crystals of potassium is shown, which also can indirectly inhibit the adsorption process. The SEM image revealed that the pore of KOH AC was not fully open, and, hence, the ability of CO emission adsorption was low. These results suggested that KOH concentration and activation time strongly affected the CO adsorption.

3.4. The effect of KOH AC onto the CO Emission Adsorption

The effect of KOH AC onto CO emission adsorption was studied using different KOH concentration from 1 to 3 N. The sorption of CO increased by increasing KOH, as an activator, concentration up to 3 N. The adsorption of CO from the emission occurred to a

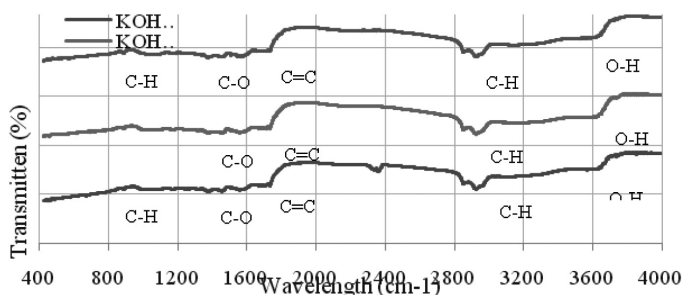


Figure 1.
Wavelength of the
FTIR Spectra for the
BPAC Adsorbent

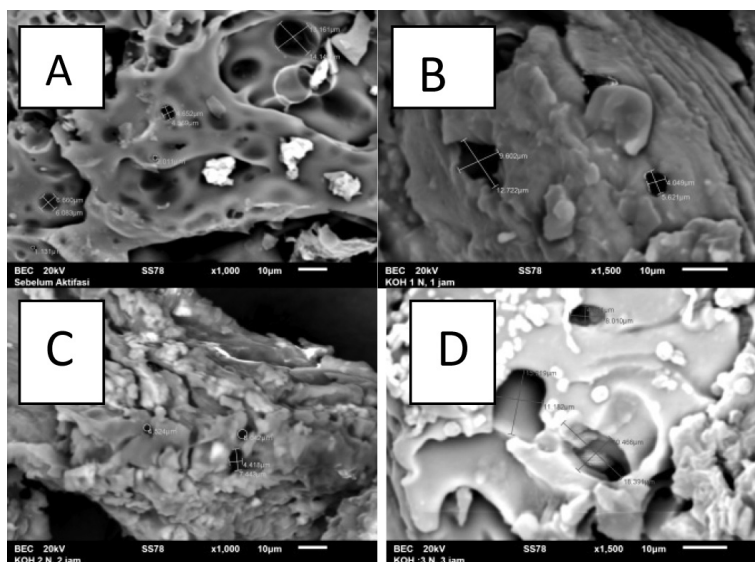


Figure 2.
The SEM of KOH AC.
(A) No activation,
BPC; (B) KOH 1 N for
1 h; (C) KOH 2 N for
2 h; and (D) KOH 3 N
for 3 h

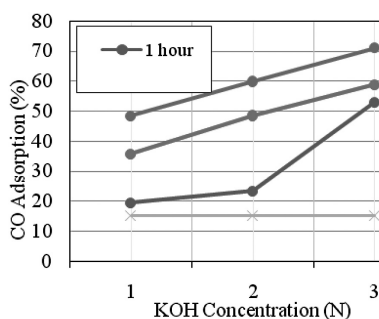


Figure 3.
The effect of KOH AC
onto the CO Emission
Adsorption

maximum of 70.95% under KOH concentration 3 N during the 3-h preparation. This result is indicates that the concentration of activator increases the surface area. The research by Sugumaran *et al.* (2012) added that activation time will affect the amount of CO adsorption from the emission. The adsorption of CO gas was increased by increasing the activation time to 3 h. It was revealed that the concentration of KOH of 3 N for 3-h activation as activator would be suitable for preparing the BPAC as an adsorbent. These results proved that BPAC was able to adsorp CO emissions, and it is the potential alternative adsorbent for removing air pollutants from motorcycle gas emission in the future (Figure 3).

4. Conclusions

BPAC has the potential to be used as an adsorbent for the removal of CO from motorcycle gas emission. The SEM images suggested that KOH concentration and activation time

strongly affected the CO adsorption and opening of AC surface pore. The sorption of CO increased when the KOH concentration increased up to 3 N. The highest CO adsorption from the emission occurred at 70.95% under the KOH concentration of 3 N during 3-h preparation.

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