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Pb Adsorption of Coffee Peel Derived Activated Carbon by Varying KOH Concentration

Ni Made Dwidiani[a,*], I Nyoman Gede Wardana[b], Ngakan Gede Putu Suardana[c], I Gusti Ngurah Nitya Santhiarsa[d], Relius Zakaria Sibarani[e]

[a]Department of Mechanical Engineering, Faculty of Engineering, Udayana University. Email: madedwidiani@unud.ac.id
[b]Department of Mechanical Engineering, Faculty of Engineering, Udayana University. Email: wardana@ub.ac.id
[c]Department of Mechanical Engineering, Faculty of Engineering, Udayana University. Email: npgsuardana@unud.ac.id
[d]Department of Mechanical Engineering, Faculty of Engineering, Udayana University. Email: nityasanthiarsa@unud.ac.id
[e]Department of Mechanical Engineering, Faculty of Engineering, Udayana University. Email: reliuszakaria56@gmail.com

Abstract

Turning biomass waste into added value products is crucial as it is beneficial to the environment. Coffee peel is a waste that has excellent potential to produce activated carbon. Activated carbon is carbon that has gone through an activation process and has a large surface area and higher adsorption rate. The high need for activated carbon in overcoming waste problems makes it useful to reduce its environmental impact. Activated carbon is widely used in water filtration including heavy metal Pb and Cd. The aim of this research is to study the impact of KOH (Potassium Hydroxide) concentration on Pb adsorption of activated carbon derived from coffee peel. KOH activator could enhance the performance of the activated carbon. The KOH activator concentration is varied to obtain the best-surface structure in activated carbon. The KOH concentration is 2,3 and 4 molars. Each specimen will undergo the same carbon activation process by maintaining the carbonization and drying temperature. Then at the activation stage, variations of KOH concentration will be mixed with the activated carbon and soaked for 24 hours with a weight ratio of KOH to charcoal of 1,5 to 1. The result shown that fixed carbon of 2,3,4 molar KOH concentration is 45.99%, 58.22%, 42.99% respectively, while Pb adsorption are 96.56%, 98.34% and 96.45%. In addition, the adsorption rate of activated carbon is proportional to the concentration level of the KOH solution. However, there is a limit on adsorption concentration, so there is a significant decrease when KOH exceeds the saturation point. Based on this research, Pb adsorption of coffee peel derived activated carbon is quite significant even though the amount of fixed carbon relatively low.

Keywords: Activated carbon; coffee peel; KOH; Pb

1. Introduction

The public interest growth in coffee makes the industry multiply worldwide. The increasing market demand for coffee seeds creates a new problem in the waste form. The availability of abundant coffee peels without maximum utilization in the long term can damage the ecosystem.

Coffee peel is a waste that has excellent potential to produce activated carbon. Activated carbon is carbon that has gone through an activation process and has a large surface area and higher adsorption rate

Activated carbon has a high surface area and good adsorption performance to pollutant molecules such as methylene blue, Pb, and Cd. Coffee peel used as a material for manufacturing activated carbon because of its availability in the environment.

The need for activated carbon is vast. It showed by the increased world demand for activated carbon, growing more than 6% annually and is estimated to reach 1.9 million metric tons in 2020 with a breakdown in area 27% for North America, 14% for Western Europe, 39% for the Asia Pacific, 7% for Central and South America, 7% for Eastern Europe, 6% for Africa.

Coffee peel is waste generated the moment after the production of coffee seed; In Indonesia, there is a lot of unattainable coffee peel because of the immense production of coffee seeds. The coffee peel used in this research originates from Petang District, Badung Regency. Indonesia is the fourth coffee producer after Brazil, Vietnamese and Colombia. Coffee production in Indonesia reached 612,000 tons in 2018. This waste is massive because this coffee is well-known and used by multinational companies. Indonesian effort to re-use this coffee peel is still inadequate, even though the massive volume of this coffee peel (27% of coffee fruit volume).

Pb is a heavy metal with high toxicity [1], a low melting point, and a widely used chemical as a metal mixture [2]. Pb can be found in fuel as a boost to the octane rate and as an anti-detonation or anti-nock in internal combustion engines [3]. Furthermore, Pb can be founded in dyes or paints as a pigment that gives light color [4]. Pb also functions as an anti-corrosion agent to inhibit metals' rust [5].

Heavy metals substances that enter the waters cause pollution in ground and surface waters. This groundwater

*Corresponding author. Tel.: +62-895-0869-6220
Jl. Raya Kampus UNUD Jimbaran, Kuta Selatan, Badung Bali, Indonesia, 80361

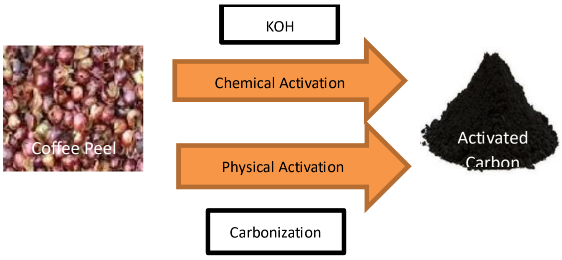

Figure 1. The production process of activated carbon using coffee peel

contamination makes the water undrinkable. Heavy metals also accumulate in living things [6]. Pb is a non-essential heavy metal where this heavy metal cannot be degraded in nature and have an unchanged form [7].

The ability of plankton to obtain heavy metals by eating is excellent [8]. Plankton, especially, Phytoplankton, are at the lowest trophic level [9]. If the plankton as the primary producer is exposed an accumulates the heavy metals, Pb can enter the food chain and reach the higher trophic level.

2. Basic Approach

2.1. *Activated carbon*

As Shown in Fig. 1, Activated carbon is charcoal that has gone through a process of chemical or physics. The activation definition is to open the charcoal pores from $2m^2/g$ to $300\text{-}3500m^2/g$. The composition of activated carbon consists of bonded atoms by covalent in side hexagons where the molecule-shaped plates are flat. Configuration plates stacked on top of each other with group hydrocarbons, by removing hydrogen and ingredient active (group hydrocarbons) makes the surface and center active becomes large [10].

There are several components of activated carbon parts: ash, fixed carbon, water (moisture), volatile, sulfur, and nitrogen. There are two ways to obtain activated carbon: a weak oxidation reaction using steam water at a relatively high temperature, which ranges between 900-1000°C or chemical dehydration. Many companies now produce activated carbon with the second method to produce specific large surfaces.

2.2. *Coffee's peel*

A coffee plant is a group of genus Coffea, family Rubiaceous. The genus Coffea has more than 100 species. Arabica Coffee, Robusta coffee and Liberica coffee are three species of coffee cultivated for commercials. Coffee fruit has two major parts: peel (cascara) and bean. Composition of a coffee peel listed below:

Table 1 displays the composition of the coffee peel. Data are expressed as the mean ± standard deviation.

Table 1. Coffee peel composition

Composition	Acidic Soluble Dietary Fiber (ASDF)
Moisture (g/100 g DW)	3.94 ± 0.02
Protein (g/100 g DW)	2.82 ± 0.05
Ash (g/100 g DW)	2.09 ± 0.01

Values in the same column with different letters are significantly different ($p < 0.05$)

Acidic soluble dietary fiber is chemical method to extract from soluble dietary fiber with process that contains washed, vacuum drying, and yielding [11].

2.3. *Chemical activation*

Activation is the process of making carbon become activated carbon. Activation aims to increase the surface area and rate of adsorption. Chemical and physics activation are two methods often used for the activation process. In this research, chemical activation was used because the research variable variated with the concentration activator. The chemical activation method is the process which uses chemicals to break chains of carbon from organic compounds. This method requires a chemical compound as an activator. An activator is a chemical compound to activate carbon to have a higher surface area and better adsorption. The activator's function is to release water molecules and other organic substances that are still attached to the carbon at the time of carbonization.

Furthermore, it will erode pores and form new pores on the surface. Activation could conduct by soaking carbon into alkaline solutions such as KOH or NaOH. Acids like H_3PO_4 or H_2SO_4 and salts like NaCl [12].

In this research, we used KOH as an activator with varying concentrations. KOH is elected as an activator based on its function as a dehydration agent. It has a high-water affinity, functioning as a desiccant, tar transformation inhibitor, and charcoal form agent at temperatures below 200°C [13]. The effect of variations of KOH concentration in the activators determines the specific surface area and the pore distribution on the activated carbon surfaces [14].

2.4. *Pb*

Pb is a heavy metal pollutant with high toxicity, which causes acute and chronic poisoning. The method to reduce the concentration of Pb is by adsorption. This test was carried out using atomic adsorption spectroscopy (AAS).

$$Pb\ Degrading\ (\%) = \frac{Ci-Cf}{Ci} x100\% \tag{1}$$

The following equation calculates the Pb adsorption capacity (Q_e):

$$Q_e = \frac{\text{Ci}-\text{Cf}}{\text{m}} \text{x}\, V \tag{2}$$

where:

Ci = Initial Concentration
Cf = Final concentration
Q_e = Rate of Pb adsorption
m = Mass of adsorbent
V = Volume of Pb solution

Description:

- Atomic Adsorption Spectrometer (AAS) measured the concentration
- m = 0.1 gr
- V = 20 ml

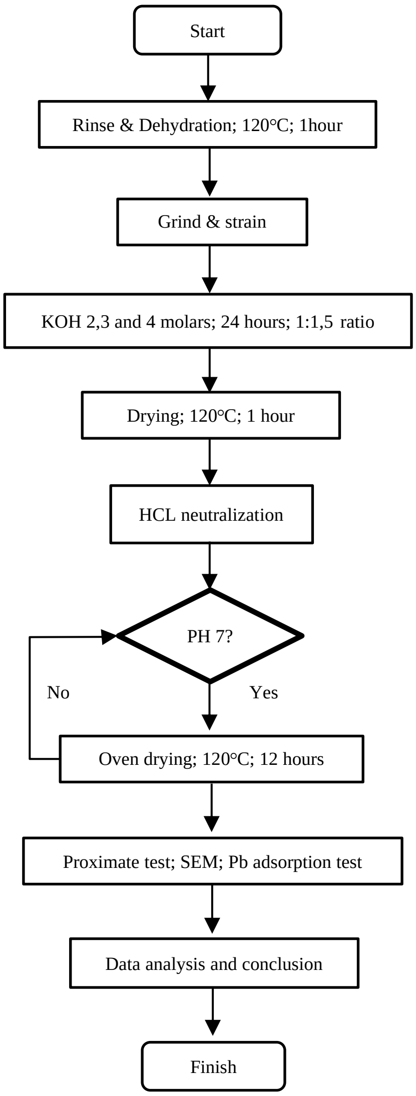

Figure 3. Research flow diagram

3. Research Method

3.1. Materials and tools

The materials and tools used in this research respectively were coffee peel waste, KOH, H_20, silicone dioxide, distilled water, aluminum foil, HCL, Pb solution and oven, jug, pan, furnace, thermocouple, mortal, filter with 100 mesh, proximate analyzer, Litmus paper, PH meter, Scanning Electron Microscope (SEM), AAS.

3.2. Research flow diagram

Reserch flow diagram is shown in Fig. 3.

4. Results and Discussion

4.1. Proximate test

The specimen labelled CSAC 2, 3 and 4 for KOH concentration of 2, 3 and 4 molar respectively. The proximate test determines the content of activated carbon such as moisture, ash, volatile, and fixed carbon.

As Shown in table 2, fixed carbon remains the highest content with the highest value of 58.22% in specimen CSAC 3. The ash, moisture and volatile content influenced

Table 2. Proximate test

Specimen	Moisture (%)	Volatile (%)	Ash (%)	Fixed Carbon (%)
CSAC 2	7.39	33.68	12.94	45.99
CSAC 3	6.13	33.90	1.75	58.22
CSAC 4	13.14	33.99	9.88	42.99

the carbon score. If those three values are getting lower, the carbon score will rise.

Figure 4 shown the lowest moisture content acquired in CSAC 3 is due to the nature of dehydrating agent owned by the activator. The CSAC 3 specimen achieves the optimum KOH concentration and effectively lowering the moisture [15].

Volatile levels of specimens with variations in concentration did not show a significant difference. However, there is an increasing trend of volatile along with the increase of KOH; Inadequate temperature carbonization causes this phenomenon and makes the gasses unraveled/trapped, thus making the specimen more volatile.

Ash is a waste that could influence carbon quality. Based on SNI-06-3730-1995, an excellent activated carbon has a maximum ash content of 10%. The lowest ash content value at CSAC 3 with the value of 1.75% which is good and follows the regulation.

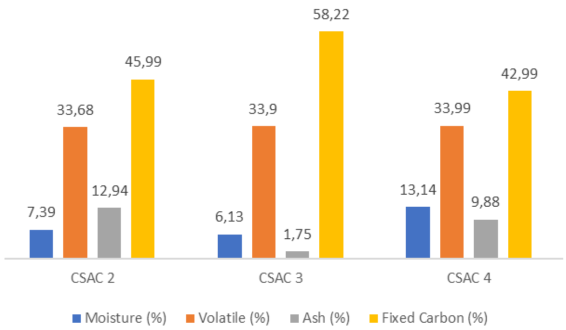

Figure 4. Proximate analysis graph

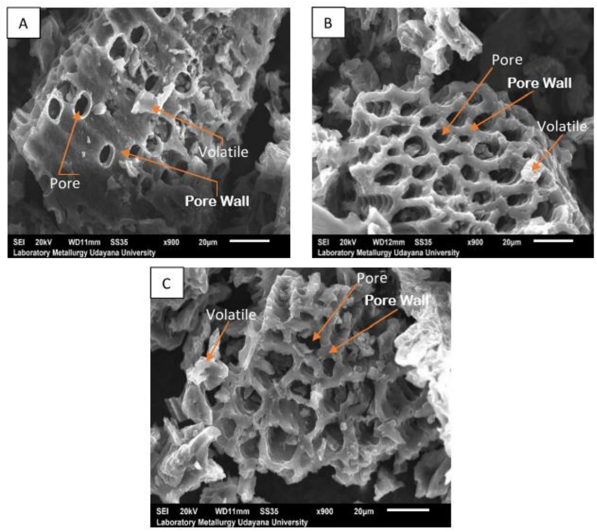

Figure 5. SEM; Activated carbon morphology with 900x magnifying; (a) CSAC 2, (b) CSAC (3), (c) CSAC (4)

Table 3. Pb adsorption test

Specimen	Ci (ppm)	Cf-Ci (ppm)	Qe (mg/g)	Pb Degrading (%)
CSAC2	0.34	9.66	193.2	96.56%
CSAC3	0.16	9.84	196.8	98.34%
CSAC4	0.35	9.65	193	96.45%

4.2. SEM

Figure 4(a) shows the morphology of the pore shape from specimen CSAC 2. few pores formed, and there is no sign of regular shapes. For specimen (b) CSAC 3, there are more pores, and it has a regular form of pore structure. In specimen (c) CSAC 4, pores are formed like the CSAC 3, but it is visible that the pore wall is damaged/collapsed; because of this, the specimen does not have a regular pore structure.

Based on the pore shape of each specimen, the concentration of KOH affects the pore shape of activated carbon. The concentration of CSAC 3 is optimum because it has a lot of pores and regular shapes of pore structure.

The SEM image shows that activated carbon has three main parts: the section of pores, wall pores and volatile (fly substances/dirt). Based on the picture, each specimen still has volatile/substance impurity caused by the washing process, which is still deficient.

Result of adsorption test shown in Table 3 indicate the ability of activated carbon to absorb Pb. The mixture of 0.1 activated carbon and ten ppm 20 ml in aluminum foil lid elementary that had been stirred for 15 minutes with a magnetic stirrer and filtered with "Whatman paper" shows that Pb adsorption is still effective even though the amount of fixed carbon relatively small and the best performance achieved by the CSAC3 specimen.

The atomic adsorption spectrometer shows that the Pb concentration in the CSAC 3 specimen has a value of 196.8 mg/g. The lowest adsorption rate occurred in CSAC 4 specimen with only 193 mg/g. CSAC 2 performance is not entirely different from CSAC 4, with a value of 193.2 mg/g. There is a considerable increase in adsorption rate between CSAC 2 and CSAC 3, but at CSAC 4 specimen with a concentration of 4 molars, the adsorption rate massively decreases to the lowest rate, which indicates the concentration value has passed the optimum limit. It shows that three molar concentration is the optimum concentration for the adsorption rate of Pb; a larger surface with a consistent adsorbent structure makes a higher adsorption rate.

Based on this research, even though the activated carbon has carbon content lower than SNI standard of 65%, it is still effective in Pb adsorption.

5. Conclusion

1. carbon content and surface morphology of the activated carbon. With an increase in concentration, 2, 3 and 4 molars, respectively, the fixed carbon content increase from 45.99% to 58.22%, then decreases to 42.99%. It concludes that the optimum concentration is in 3 molars.
2. KOH activator concentration affects Pb adsorption performance. With increasing concentrations of 2, 3 and 4 molars, respectively, the rate of Pb adsorption increased from 96.56% to 98.34%, then decreased to 96.45%. It concludes that the optimum adsorption rate is in 3 molars. In addition, even though carbon content produced less than SNI standard of 65%, The Pb adsorption is high.

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