ORIGINAL PAPER

CHARACTERIZATION AND PROPERTY OF HIGHLY EFFICIENT TOXIC METAL ADSORBENT ACTIVATED AND NON-ACTIVATED CHARCOAL DERIVED FROM WASTE BY-PRODUCT OF JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS* LAM.) PEEL

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Abstract. *Preparation of charcoal from organic waste by-product of Jackfruit (Artocarpus heterophyllus Lam.) is one of the most efficient tool and advantage of waste management that have technological, economic, and environmental impact. The purpose of present study is to develop activated charcoal for the removal of toxic metals from aqueous solution. Batch adsorption experiments were carried out to investigate the suitability of activated and non-activated charcoal in removing Lead and Cadmium. Adsorption/Sorption processed to remove heavy metals accumulation from aqueous environment is primary concern due to health impact upon chronic exposure. Fourier-transform infrared spectroscopy (FTIR) and Scanning Electron Microscope (SEM) were used to characterize prepared activated and non-activated charcoal from Jackfruit peel. Rapid and Efficient adsorption/Sorption properties of prepared charcoal were tested against Cadmium (Cd) and Lead (Pb). FTIR and SEM characterization revealed functional groups ─OH, C─H, and C═C stretches in activated and non-activated charcoal with pore size of 2.86 - 10.0 µm and 2.96 - 14.7 µm, respectively. Rapid adsorption/sorption capacity demonstrated 87.39±3.5173% and 84.30±2.9166% efficiency for activated and non-activated charcoal, respectively. Statistical analyses showed significant difference ($p<0.05$) between activated and non-activated charcoal in absorbing Cd and Pb.*

Keywords: *organic waste, jackfruit (Artocarpus heterophyllus Lam.) peel, activated and non-activated charcoal, adsorption, heavy metals.*

1. INTRODUCTION

Reducing food waste disposal at limited landfill space is vital due to the undesirable environmental effect that requires further mitigation to deal with [1]. Aside from these, greenhouse gas emissions from organic waste create 45-75% methane (CH_4), 20-45% carbon dioxide (CO_2) which could accumulate as greenhouse gas [2]. In the Philippines local and national legislation were passed into law regarding waste management [3]. However, compliance to these laws remains a challenge nowadays [4]. In addition, water inorganic pollution (e.g. heavy metals as Cd and Pb) becomes a serious threat to the aquatic environment since they are nonbiodegradable and have the ability to accumulate in living organisms [5-10]. Heavy metal toxicity has proven to be a major threat and there is several health risks associated with it because they sometimes act as a pseudo element of the body while at certain times they may even interfere with metabolic processes [9-11].

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According to World Health Organization Pb is a widely detected poisonous heavy metal. It has no minimum exposure limit as it enters in the body [12]. Lead toxicity affects the renal, central nervous system, reproductive system and hematopoietic, mostly through increased oxidative process. In Pb toxicity affects nervous system, the peripheral nervous system mostly in adults while the central nervous system is more highly affects the children [13]. Cadmium is a nondegradable pollutant and a carcinogenic compound that affect primarily the human kidneys to lose their function as well as to remove acids from the blood in proximal renal tubular dysfunction [13]. Cadmium intake have linked to higher risk of cardiovascular disease, mortality in males, increased bone fragility, children's nephrotoxicity and decreased visual ability [14]. The removal of heavy metals is considered an important issue with respect to the environment and economical considerations. Many technologies like adsorption, precipitation, membrane filtration, and ion-exchange have been used to remove metal pollutants from water however, adsorption has proven to be economical and efficient for removing heavy metals, organic pollutants and dyes from polluted the effectiveness of activated carbons to act as adsorbents for a wide range of contaminants is well noted [15]. Biosorption processed is one of the emerging and attractive technologies to remove heavy metals from aqueous solution. Activated carbon is relatively cost effective in the comparison of other inorganic adsorbents. High surface area, micro porous character of activated carbons has made it good adsorbent for the removal of heavy metal from wastewater [16]. The objective of the present study is to characterize and determine the efficiency of cost-effective and environmental alternative water treatment that removed Pb and Cd. It used activated and non-activated charcoal derived from waste by-product jackfruit peel. The efficiency of adsorbent could be an environmental friendly method to removed metal contaminants from surface water.

2. MATERIALS AND METHODS

2.1. JACKFRUIT PEEL WASTE

The experiment was performed at the Chemistry Laboratory of the University of the Immaculate Conception, Davao City. The jackfruit peelings were purchased at Bankerohan Public Market, Davao City. Analytical grade of Pb and Cd reagents was provided by Science Resource Center (SRC), Davao City. The activation of jackfruit peelings carbon was performed at Philippine- Japan Activated Carbon Corporation (PJAC), Davao City.

2.2. RESEARCH INSTRUMENTS AND REAGENTS

The concentrations of Pb and Cd were determined using an Atomic Adsorption Spectrophotometer (AAS) Perkin Elmer PinAAcle 500. Characterization of the surface functional group of jackfruit peelings activated and non-activated charcoal was subjected to Fourier Transform Infrared Spectrophotometer (FTIR) and Scanning Electron Microscope (SEM) were done available at De La Salle University, Manila to determine the determine the pore size of the activated and non-activated charcoal. The samples were powdered to ensure efficient absorption of metals from the test samples. A muffle furnace was used to char the oven dried jackfruit peelings.

2.3. COLLECTION AND PYROLYSIS

Jackfruit peelings was collected from Bankerohan Public Market, Davao City and authenticated by an expert. These were washed thoroughly with tap water to remove physical impurities (e.g. dirt and dust). Distilled water was used for final washing. The jackfruit peelings were then sliced into small pieces with same sizes. It was then oven dried at 105 °C until stain is removed. The dried jackfruit peelings underwent pyrolis at 250 - 300°C for 1 hour in the muffle furnace. They were cooled then powderized using a grinder. The non-activated charcoal jackfruit peelings was then stored in dessicator for further experimental use.

2.4. CHARCOAL STEAM ACTIVATION

The non-activated charcoal jackfruit peelings were brought to Philippine - Japan Activated Carbon (PJAC), Davao City that underwent steam activation. After it was cooled, it was powderized using the grinder and stored in desiccator for further experimental use.

2.5. PREPARATION OF STOCK SOLUTION AND STANDARDS

The 1000ppm stock solution of Pb was prepared by dissolving 1.598 g $PbNO_3$ in 1 L deionized distilled water. From prepared 1000 ppm stock solution, 10 ppm intermediate solution was made to prepare 0.5, 1.0, 1.5, 2.0 and 2.5 ppm standard solutions. The 1000 ppm stock solution of Cd was prepared by dissolving 2.1032 g of $Cd(NO_3)_2$ in 1 L distilled water. From prepared 1000 ppm stock solution, 10 ppm intermediate solution was prepared to make 0.5, 1.0, 1.5, 2.0 and 2.5ppm standard solutions [17].

2.6. BATCH ADSORPTION STUDIES

From the prepared 1000 ppm Pb and Cd stock solution, 100 ppm intermediate solution was made to prepare 10 ppm and 15 ppm for batch adsorption studies. Effects of different parameters such as pH, initial lead and cadmium concentration and contact time was determined. The pH was varied from pH 4 and 6. Initial lead and cadmium concentration was varied from 10 ppm and 15 ppm. Contact time varied at 5, 15 and 30 minutes.

2.7. METAL UPTAKE

The amount that bounded on the adsorbent was assumed as the difference between the initial metal concentration and the final concentration after the jackfruit peelings activated and non-activated charcoal was applied.

$$\text{Removal Efficiency (\%)} = \frac{C_0 - C_e}{C_o} \times 100$$

Metal uptake of Pb and Cd:

$$q_e = \frac{(C_i \; - \; C_e)}{1000v}$$

where:

C_i = is the initial concentration in ppm,
C_e = is the metal uptake in ppm,
V = is the volume of the solution in mL,
w = is the mass of adsorbents in g, and
q_e = is the milligram of metal adsorbed per gram of adsorbent

2.8. FOURIER TRANSFORM INFRARED (FTIR) ANALYSIS

The Fourier Transform Infrared (FTIR) analysis of the samples was carried out by Fourier Transform Infrared Spectroscopy (FTIR) equipment of mark “spectrum one FTIR” incorporated with software (Perkin Elmer Instruments version 3.02.01) for the examination of the spectra. For sample analysis, 0.5 g of activated charcoal was mixed with about the same amount of potassium bromide (Merck, spectroscopy grade). The mixture obtained was crushed in a mortar to obtain a homogeneous powder which was then introduced into a mould to obtain very fine plates. The plate was then introduced into the spectrophotometer for analysis. The measurement was carried out over the range of 4000-400cm^{-1} [18].

2.9. SEM ANALYSIS

The pore size of the activated and non-activated charcoal jackfruit peelings was studied using Scanning Electron Microscope (SEM). The samples were coated with ultrathin coating gold to increase the signal and surface resolution of the samples. This analysis allows providing information about the topography, morphology and composition. In this study it was used to measure the pore size and assessed why Jackfruit peelings activated charcoal was high in adsorption capacity than non-activated charcoal.

2.10. STATISTICAL ANALYSIS

All data from different parameters of jackfruit peelings activated and non-activated charcoal in terms of different pH, initial concentration and contact time was subjected to Analysis of Variance (ANOVA).

3. RESULTS AND DISCUSSION

3.1. FTIR ANALYSIS

The results illustrated in Figs. 2 and 3 showed the FTIR spectra of the Jackfruit peelings activated and non-activated charcoal, respectively. These results represented the information about the functional groups on the surface cell wall of the jackfruit peelings activated and non-activated charcoal. From these data, it is clear that the biomasses have a strong broad peak at 3411.11cm^{-1} for jackfruit peelings activated charcoal and 3410.25 cm^{-1} for jackfruit peelings non-activated charcoal signifying a ─OH stretch of hydroxyl group originating primarily from cellulose and hemicelluloses components of jackfruit peelings. The presence of C─H stretch at 2924.38 cm^{-1} for activated and 2923.32 cm^{-1} and 2853.50 cm^{-1} for Non-activated is due to the methylene groups of carbohydrates. The medium sharp peaks at 1616.05 cm^{-1} for activated and 1612.48 cm^{-1} for non-activated may also indicate the presence of C═C stretch.

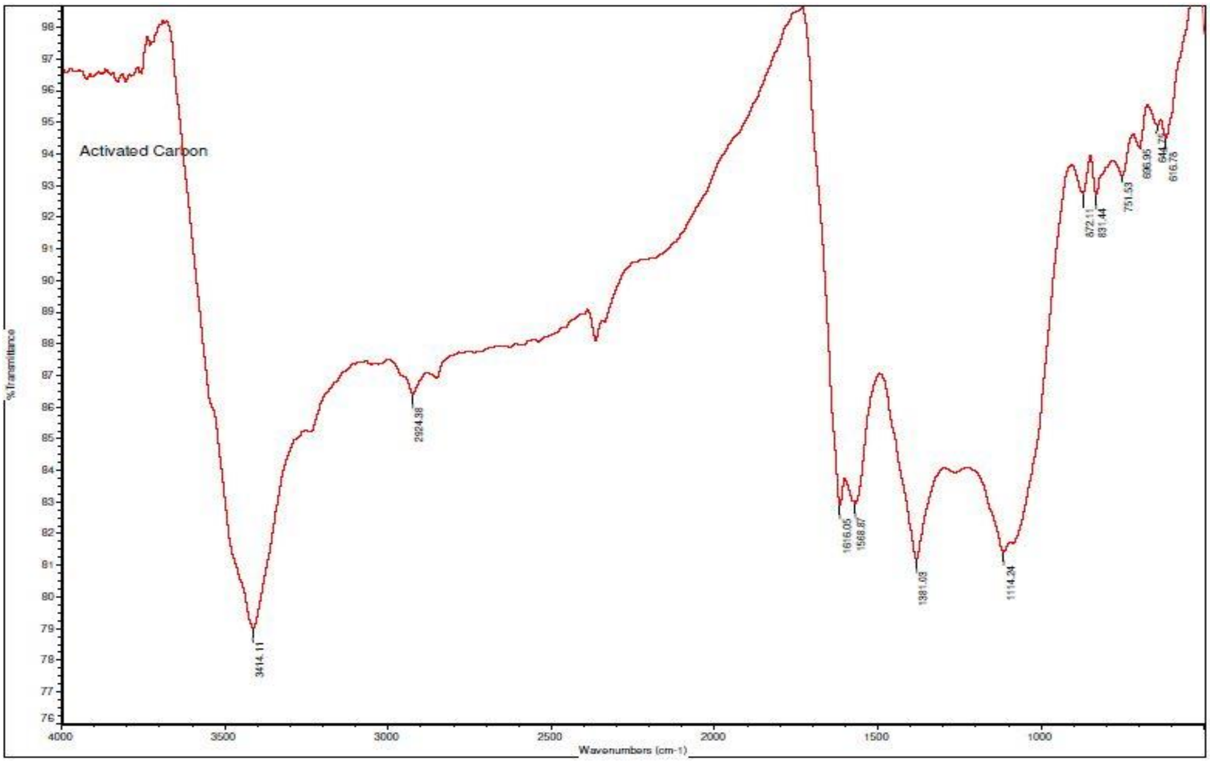

Figure 1. FTIR spectra of Jackfruit peelings activated charcoal.

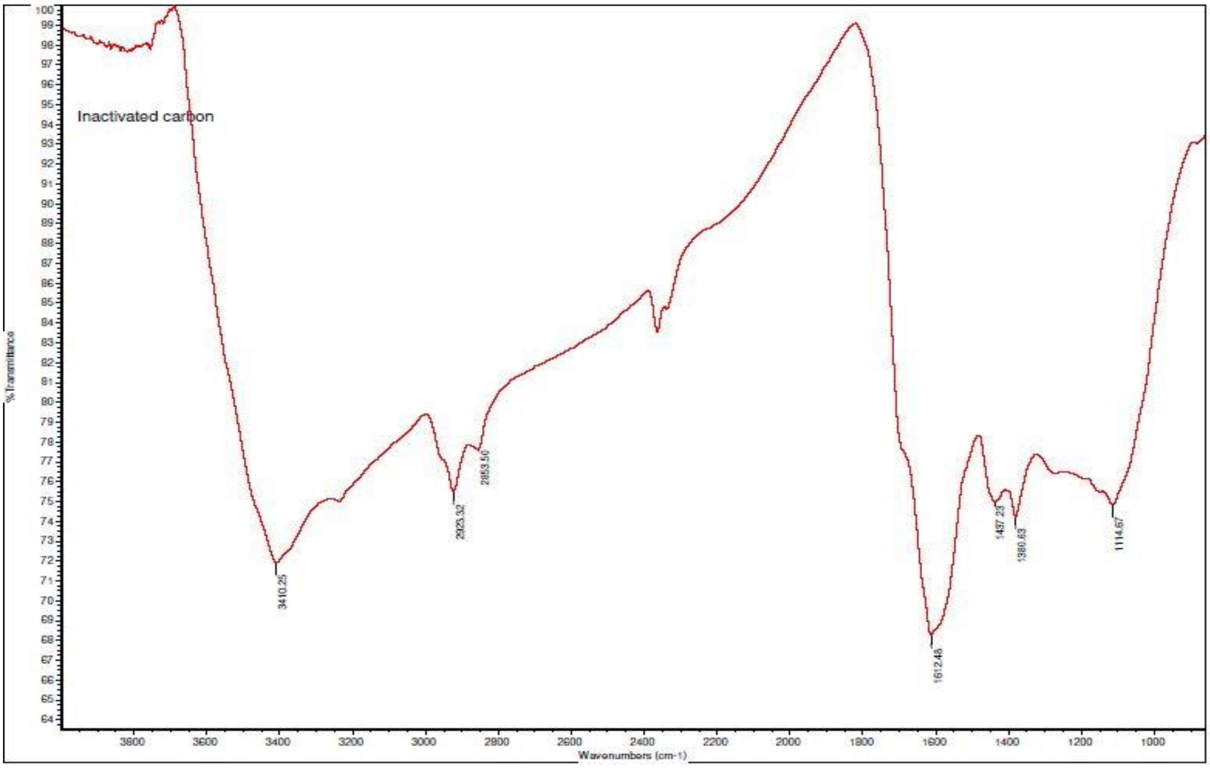

Figure 2. FTIR spectra of Jackfruit peelings non-activated charcoal.

3.2. SCANNING ELECTRON MICROSCROPE (SEM)

The jackfruit peelings activated and non-activated charcoal was subjected to SEM analysis for pore size determination. Table 2 showed the pore size of the activated and non-activated charcoal. By referring to the adsorption capacity obtained, the Jackfruit peelings activated charcoal depict higher percentage removal of metal (Pb and Cd) compared to Jackfruit peelings non-activated charcoal. Based on the morphology analysis, it is clearly shown the surface morphology of Jackfruit peelings activated charcoal is more porous and structures were more developed [19-25]. Besides the activated charcoal has a pore size ranges from 2.86 - 10.0 µm while non-activated charcoal has a relatively high pore size ranges from 2.96 - 14.7 µm which may have influence the low adsorption capacity.

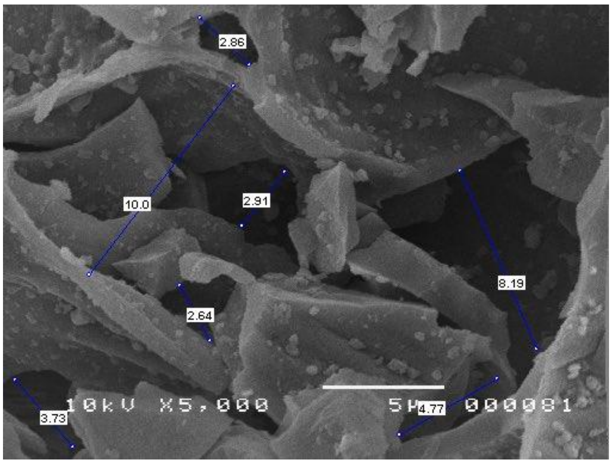

Figure 3. SEM analysis of Jackfruit peelings activated charcoal.

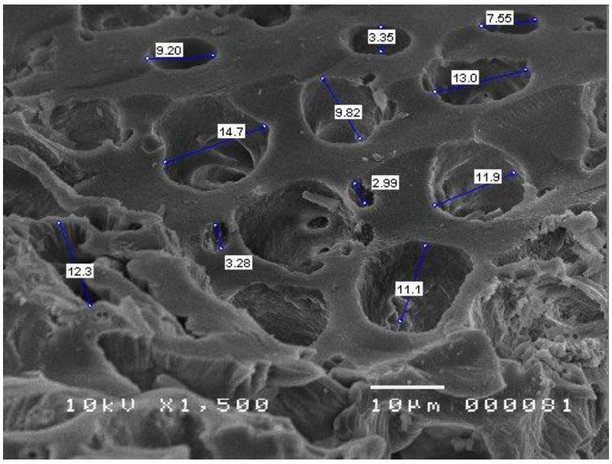

Figure 4. SEM analysis of Jackfruit peelings non-activated charcoal.

3.3. ADSORPTION EFFICIENCY

Rapid adsorption/sorption capacity demonstrated 87.39±3.5173% and 84.30±2.9166% efficiency when tested against activated and non-activated charcoal, respectively. Statistical analyses showed significant difference ($p<0.05$) between activated and non-activated charcoal in absorbing Cd and Pb. Varying Contact time did not significant influence ($p>0.05$) the adsorption activated and non-activated charcoal towards Pb and Cd but non-activated charcoal adsorption of Cd were significantly influenced with pH. Adsorption of Cd by activated charcoal was found significantly higher at pH 6.0 compared to pH 4.0 of the test solution. The findings clearly demonstrated potential of prepared Charcoal from organic waste by-product of Jackfruit (*Artocarpus heterophyllus Lam.)* Peel to remove toxic heavy metals. Rapid and Efficient adsorption/sorption properties of prepared charcoal can attributed to electrostatic attraction with surrounding ions and functional groups concurrent with smaller pore size of adsorbent.

Table 1. Adsorption efficiency of activated and non-activated charcoal derived from Jackfruit peelings.

Test Variable	**Conditions**		**Mean**	**P value**
Pb	pH	4.0	89.94	**0.165**
		6.0	87.85	
	Contact Time [minutes]	15	86.60	**0.823**
		15	87.29	
		30	88.29	
Cd	pH	4.0	86.14	**0.0001***
		6.0	93.26	
	Contact Time [minutes]	15	88.40	**0.655**
		15	89.33	
		30	91.37	

**Calculation was performed at the 0.05 level of significance*

4. CONCLUSION

Activated charcoal prepared from an organic waste significantly reduced Pb and Cd from aqueous solutions. The adsorption data suggest that the pH of the solution is most important parameter for adsorption of metal ion on activated charcoal. The efficiency of adsorption increases with the amount of adsorbent.

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