

## Adsorption of Lead (II) Ion onto Jackfruit Chaff Matrix

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**Abstract:** This study was carried out to investigate the adsorption of Pb (II) ion onto jack fruit chaff. The jackfruit chaff powder was characterized using Fourier Transform Infrared (FTIR) and Scanning Electron Microscopy (SEM). The adsorption process was investigated with respect to initial concentration, time and pH at 298 K. Adsorption of Pb (II) ion was found to be dependent on pH, initial concentration and time of the medium. Maximum adsorption capacity was achieved at pH of 6 and the optimum contact time for the adsorption of Pb (II) ion onto jackfruit was 30 mins. The effect of equilibrium concentration showed an optimum uptake of 0.97 mg/g. The process was characterized with Freundlich and Langmuir isotherm models. The result of the modeling showed that the adsorption process followed Langmuir adsorption model with a correlation coefficient ( $R^2$ ) of 0.974 and monolayer adsorption capacity ( $q_m$ ) of 0.63 mg/g. The result of the kinetic evaluation showed that adsorption of Pb (II) ion onto jackfruit chaff followed Pseudo-second-order kinetic model equation with a correlation coefficient ( $R^2$ ) of 0.99. Jackfruit chaff was found to be effective and efficient in the removal Pb (II) ion.

**Key words:** Jackfruit Chaff • Pollution • Adsorption • Modeling • Characterization • Applications

### INTRODUCTION

Industrial waste constitutes the major source of various kinds of metal pollution in natural waters. Rapid industrialization has led to increase in disposal of heavy metals into the ecosystem. According to Azevedo *et al.* [1] mining activities, agricultural run-off, industrial and domestic effluents are mainly responsible for the increase of metals released in the ecosystem. Metals released into the ecosystem tend to persist indefinitely accumulating in living tissues throughout the food chain and are posing threat to environment and public health. Heavy metal like lead is difficult to remove from water and once in the body there is no known metabolism or excretion of these heavy metals.

Literature has revealed many methods for removal and recovering of heavy metals from contaminated environment and many physicochemical methods have been proposed for removal and recovery of heavy metals from waste water [2]. These processes include adsorption, microbial degradation, chemical oxidation, precipitation, ion exchange, solvent extraction, etc. Above all, adsorption offers an effective approach for lead removal owing to easy recovery and insensitivity to toxic plants.

Most agricultural wastes are cheap and eco-friendly. Consequently, many researchers have focused on the feasibility of low-cost materials that are derived from agricultural wastes for the removal of various dyes, heavy metals, other pollutants, etc [3]. However, waste and some industrial by-products can be used directly or after modification as adsorbents.

An adsorbent is low cost if it requires little processing; it is provided in nature or is by-product of waste materials [4]. Generally, plant biomasses exist as cellulosic surfaces that have partially negative charges in water. They possess columbic interaction with cationic species in water [5]. Due to the sorption properties possessed by cellulosic materials, many agricultural wastes have been used for removal of various heavy metal ions, organic and inorganic compounds [6-8].

Complete removal or reduction of lead to acceptable concentration has become a major challenge in environmental protection. According to Inbaraj and Sulochana [9] it is difficult for lead to be biodegraded. Consequently, development of potentially low-cost adsorbents with high adsorption capacity is critical for heavy metal removal.

The jack fruit (*Artocarpus heterophyllus*) also known as jack tree, is a species of tree in the fig, mulberry and breadfruit family (Moraceae) native to South Eastern India [10, 11]. Previous studies have shown that parts of the jackfruits in unmodified and modified forms can effectively remove metal ions, organic and inorganic pollutants from both aqueous and real-life systems [12-16].

The availability of safe drinking water, or rivers, soils for planting is a major concern. The high level of pollution and inadequate treatment of waste water has increased crisis in our environment. Lead being persistent in the environment has contributed to water and soil contamination.

Therefore, there is urgent need to develop adsorbents for heavy metals and other pollutants to ensure safe drinking water and soil for planting. Agricultural solid waste like rice husk, sesame, sunflower, etc has been used to remove lead from waste water [17]. In order to totally exploit the potentials of all the components of jackfruit, this study focuses on the utilization of its chaff as an adsorbent for the removal of lead from aqueous system.

## MATERIALS AND METHODS

**Sample Collection:** The jackfruit chaff was collected from a Post-Graduate student of the Department of Pure and Industrial Chemistry, University of Port Harcourt.

**Preparation of Adsorbent:** The chaff was put on a foil and then taken to the oven for drying at 70°C. It was ground to powder form using a mechanical blender. After which the chaff was sieved using a sieve of 100 µm, then taken for weighing. The weighed chaff was put into sample bottles. A 5 g sample was used for Fourier Transform Infra-red Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) analysis.

**Preparation of Lead Stock Solution:** A Pb(NO<sub>3</sub>)<sub>2</sub> solution of strength 1000 mg/L was prepared by dissolving 1.6 g of the lead nitrate in 1 L of distilled water. All other solutions of various concentrations were made by diluting this stock solution in distilled water.

**Adsorption Test:** The batch adsorption experiments were carried out for initial concentration with 0.5 g of jackfruit chaff and stirred in 10 ml of 10-70 mg/L of Pb (II) ion solution in a reaction container at 298 K for 1hr. The pH of the Pb (II) ion solution was varied from 2-12 at a constant concentration of 10 mg/L and time of 1hr. The contact time



Fig. 1: Jackfruit



Fig 2. Jackfruit chaff powder

was varied from 10-60 mins at 298 K using 10 mg/L of the Pb (II) ion solution. In each experiment apart from time analysis, the mixture was shaken for 1hr using rotary orbital shaker at 180 revolutions per minute (rpm). It was centrifuged and filtered. The supernatant solution was analyzed using Atomic Absorption Spectrophotometer. The metal uptake by the jackfruit chaff at equilibrium was evaluated using equation 1.

$$q_e = \frac{C_o - C_e}{M} \times V \quad (1)$$

where,  $q_e$  is the amount of Pb (II) ion absorbed in mg/g,  $C_o$  is the initial concentration of Pb (II) ion in mg/L,  $C_e$  is the equilibrium concentration of Pb (II) ion in mg/L,  $M$  is the mass of the jackfruit chaff in gram and  $V$  is the volume of the Pb (II) ion used in the adsorption process in liters.

## RESULTS AND DISCUSSION

The characterization of the jackfruit chaff using FTIR and SEM and the effects of contact time, initial concentration of metal ions, pH on adsorption of Pb (II) ion were presented and discussed below.

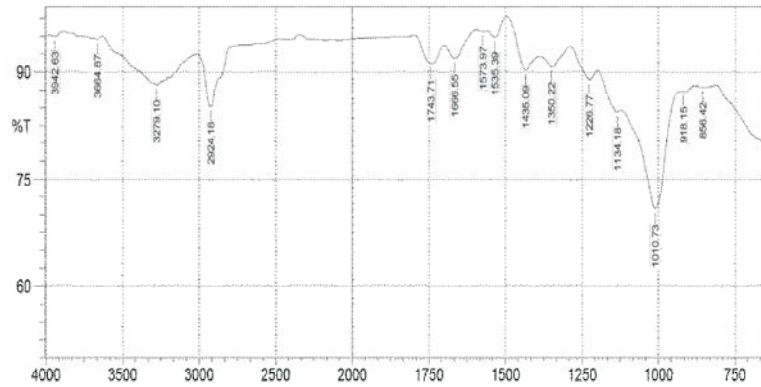


Fig. 3: FT-IR plot of jackfruit chaff

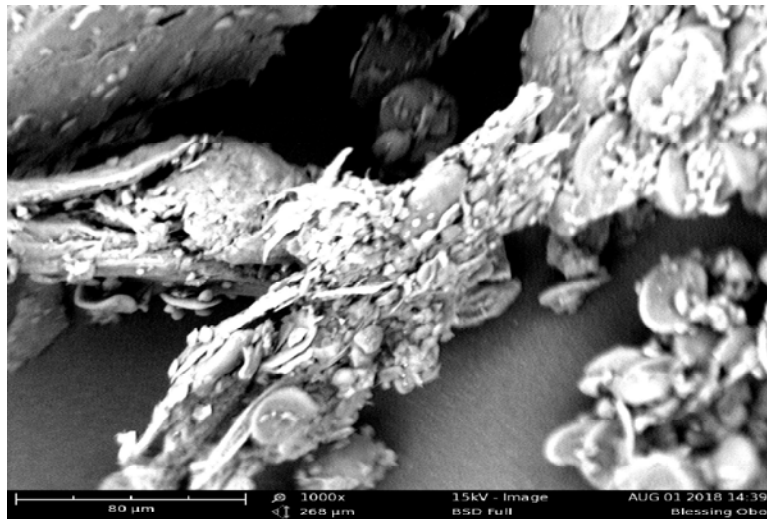


Fig. 4: SEM micrograph of Jackfruit chaff at 268 μm, EHT 15 Kv and magnitude of 1000x

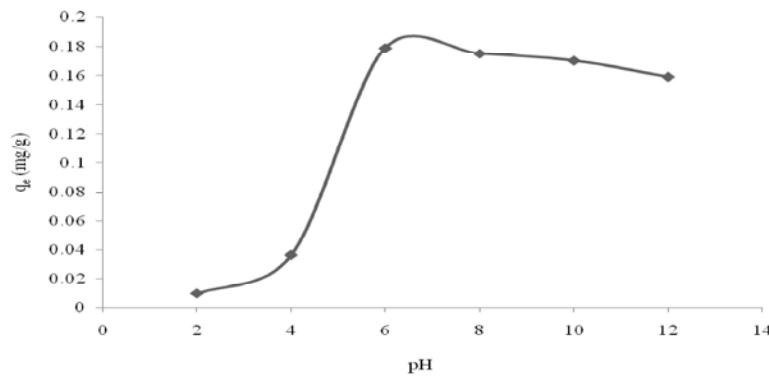


Fig. 5: A plot of  $q_e$  against pH at 298K

The broad band at  $1010.73\text{ cm}^{-1}$  may be due to the C-O stretching of alcohols and carboxylic acids. The O-H stretching of carboxylic acids ( $2500\text{-}3000\text{ cm}^{-1}$ ) could be responsible for the broad peak at  $2924.13\text{ cm}^{-1}$ .

The micrograph above showed that the chaff of jackfruit is micro-porous.

**Effect of pH:** The result shows that maximum amount of lead (II) ion adsorbed was achieved at pH of 6; close to neutral value [18]. It was observed that at higher pH values, the Pb (II) ion uptake decreased significantly. This could be as a result saturation of the surface of the jackfruit chaff [19]. This result is similar to the research

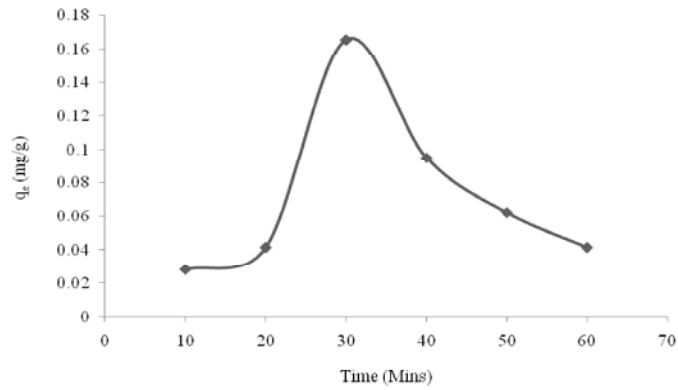


Fig. 5: A plot of  $q_e$  against contact time at 298K

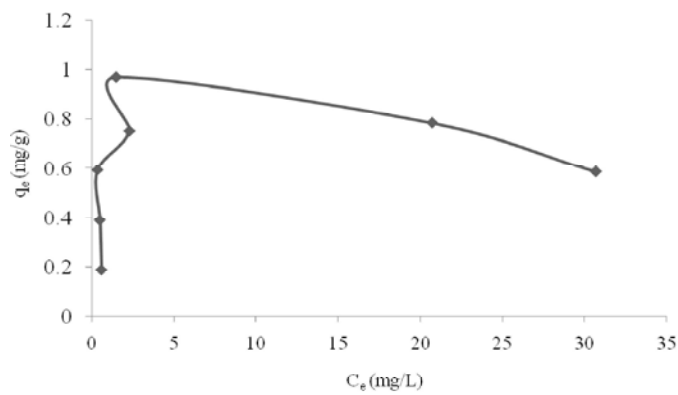


Fig. 6: A plot  $q_e$  against initial concentration at 298K

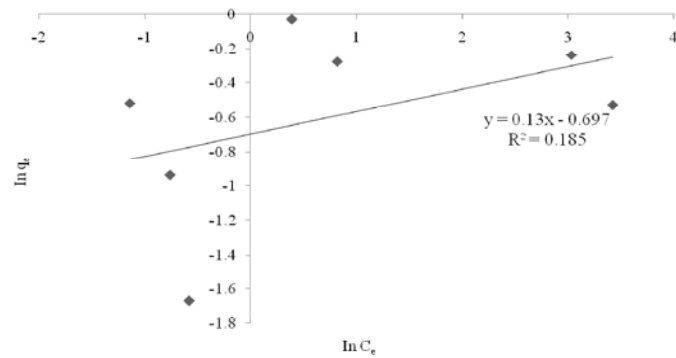


Fig. 7: Freundlich plot for Pb (II) in adsorption

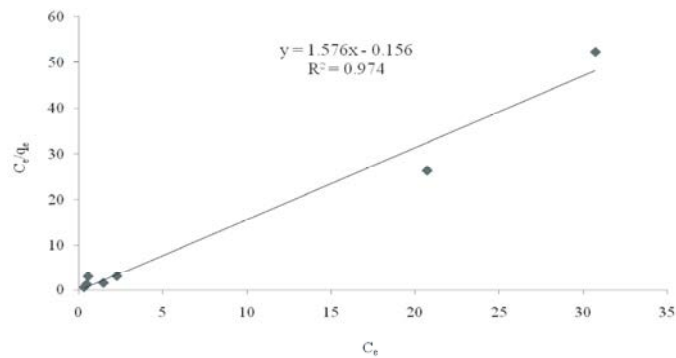


Fig. 8: Langmuir plot for Pb (II) ion adsorption

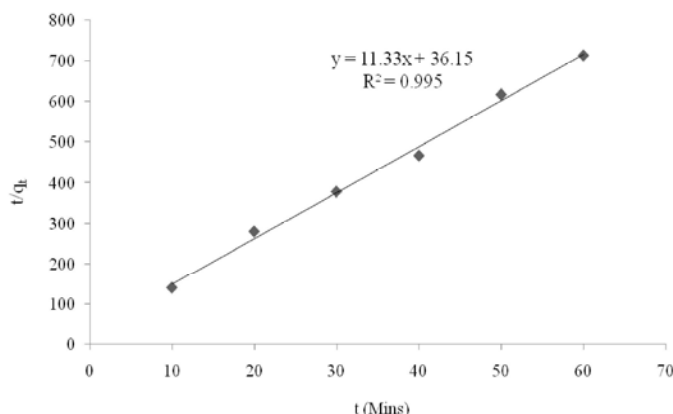


Fig. 9: Pseudo second-order plot for Pb (II) ion adsorption

carried out by Wasewar [20] on the removal of Cd (II) and Pb (II) ions using unmodified Bambara groundnut husk (*Vigna subterranean*).

**Effect of Contact Time:** The effect of contact time on the adsorption of Pb (II) ion onto jackfruit chaff as presented in Figure 5 showed that there was a gradual increase in Pb (II) ion uptake from 10 mins to 20 mins. It further shows a drastic increase from 20 mins to 30 mins. Thereafter, the Pb (II) ion decreased from 40 mins to 60 mins.

The reduction in the adsorption of Pb (II) ion could also be as a result of the saturation of the active sites of the adsorbent [21]. The optimum contact time for the adsorption of Pb (II) ion onto Jackfruit chaff was 30 mins.

**Effect of Equilibrium Concentration:** The result of equilibrium concentration on the adsorption of Pb (II) ion onto jackfruit chaff as represented in Figure 6 showed a two-step process. Firstly, there was an increase in Pb (II) ion uptake onto jackfruit from 0.19-0.97 mg/g. Secondly, there was a significant decrease in the Pb (II) ion uptake from 0.79-0.59 mg/g. The result shows an optimum uptake of 0.97 mg/g.

Subsequently, the equilibrium data generated was subjected to Freundlich and Langmuir adsorption isotherm equation models. The plots for these model equations as presented in Figures 7 and 8 showed that the adsorption process followed Langmuir adsorption isotherm equation with a correlation coefficient ( $R^2$ ) of 0.974. The monolayer adsorption capacity ( $q_m$ ) was found to be 0.63 mg/g.

**Kinetic Analysis:** The plot of the kinetic evaluation with respect to time is presented in Figure 9.

Table 1: Langmuir and Freundlich parameters

Model	Parameter	Pb (II) ion
Langmuir	$q_m$ (mg/g)	0.63
	$K_L$ (L/mg)	- 10.2
	$R_L$	- 0.01
	$R^2$	0.974
Freundlich	$K_F$ (L/mg)	4.98
	$n$	7.69
	$R^2$	0.185

Table 2: Pseudo-second-order parameters

Parameter	Pb (II) ion
$q_e$ (mg/g)	0.09
$K_2$ (Mins <sup>-1</sup> )	3.41
$R^2$	0.995

The result showed that the adsorption of Pb (II) ion onto Jackfruit chaff followed pseudo-second-order kinetic model equation with a correlation coefficient ( $R^2$ ) of 0.995 [7].

## CONCLUSION

From the results obtained it was concluded that jack fruit (*Artocarpus heterophyllus*) chaff can be used as a precursor for the development of adsorption technology for the removal of lead ions in aqueous system. However, efficiency of adsorbents to remove lead ion from aqueous system was affected by contact time, initial metal concentration and pH.

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