Production of Biosorbent from Sawdust and Isotherm Studies of its Sorption Capacity on Crude Oil

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Abstract- **The feasibility of employing Malina Sawdust as a biosorbent for the removal of oil from produce water was examined. Malina sawdust, a byproduct from sawmills, was transformed into a cost-effective biosorbent through various physical methods such as drying, crushing, and sieving. Its sorption capacity was assessed using isotherms, and the results indicated a 94% removal of oil, suggesting its efficacy as a viable biosorbent for oil removal in applicable scenarios. The data generated from the sorption experiments were employed in isotherms, revealing a higher regression in Freundlich plots, signifying that the adsorption process is best described by this particular isotherm. The high Freundlich regression coefficient (R^2=0.9632) suggests a physical nature of the adsorption process (Febrianto et al., 2009).**

Elemental analysis of the sorbent unveiled a composition primarily consisting mainly of carbon, calcium, iron and potassium. It also showed trace amounts of other elements. Surface morphology examination indicated the presence of small pores (binding sites) that serve as collection packets for contaminants. The Fourier Transform Infrared spectroscopy (FTIR) of the sawdust displayed peaks, affirming the availability of various functional groups.

Key Words: **biosorbent, adsorption, isotherms, characterization.**

1.0 Introduction

Legal regulations mandate the treatment of industrial wastewater to specific standards before its release into the environment (Banzhaf et al., 2016). This is crucial to safeguard the environment's biodiversity and uphold the equilibrium within the entire ecosystem. Crude oil emerges as a significant environmental pollutant, impacting aquatic life by impeding the supply of essential oxygen and carbon dioxide needed by aquatic organisms (Kirrolia et al., 2013). Additionally, it disrupts pH levels and increases the overall toxicity of both water and land. Consequently, wastewater generated in crude oil refineries, commonly referred to as produced water, must undergo thorough treatment to meet environmental standards before being discharged (Kumar et al., 2020).

To eliminate water pollutants and promote a safer environment, a variety of methods, including membrane filtration, precipitation, ion exchange, reverse osmosis, electrochemical treatments, evaporation, flotation, and oxidation processes, are widely applied (Sathya et al., 2022). Among these water treatment approaches; adsorption stands out as an effective technique for contaminant removal. Ongoing research continues to explore and enhance the understanding of this process.

Adsorption, a process where substances adhere to the surfaces of materials and are subsequently removed, is particularly efficient (Nel et al., 2009; Werber et al., 2016). When the adsorbent used originates from biological sources, the process is termed biosorption (Ahluwalia & Goyal, 2007). This method is both cost-effective and proficient, finding application in various areas such as the removal of metal ions from water, industrial catalytic processes, heterogeneous catalysis, the purification and drying of chemical substances, colour removal in sugar processing, vegetable oil refining, metal ore separation, and the adsorption of toxic gases in gas masks, among other uses.

2.0 Materials and Method

2.1 Biosorbent Preparation

The sawdust was acquired from a local sawmill in North Bank Makurdi, Benue State, Nigeria. After obtaining it, the sawdust underwent a drying process in an oven and was weighed until a consistent mass was achieved over an 8-hour period at a temperature of 60 degrees Celsius. This specific temperature was chosen to preserve the physical properties of the particles. Subsequently, the dried sawdust was sieved using a mesh with a size of 212µm to achieve a uniform particle size. Characterization processes included Fourier Transform Infrared spectroscopy, Scanning Electron Microscopy for analyzing surface morphology, and Electron Dispersion Spectroscopy for elemental composition analysis.

2.2 Batch Sorption Experiment

The potential of the Malina sawdust for the sorption of oil was studied at different dosages. The temperature (Room temperature), pH (6.5), stirring speed (450 rpm) and duration of stirring were kept constant throughout the experiment. The biosorbent particle size was 212 µm while the initial oil concentration of the produce water was at 51mg/L. After allowing contact of the biosorbent with the produce water, it was filtered off and 1,1,1-trichloroethane was added which separated the mixture into two layers of oil and water. The oil was tapped off from a separating funnel and analyzed using the DR-2000 spectroscopy machine and recorded at the end of the experiment. The procedure was repeated with different biosorbent dosages.

3.0 Results and Discussion

The FTIR analysis of sawdust revealed peaks in its spectrum, confirming the presence of diverse functional groups, as illustrated in Figure 1. The analysis of surface morphology revealed the existence of tiny pores that function as gathering sites for contaminants, as depicted in Figure 3. The elemental examination of the sorbent, illustrated in Figure 2, disclosed a composition primarily composed predominantly of carbon, calcium, iron, and potassium. Additionally, trace quantities of other elements were observed.

3.1 Saw Dust Characterization Result

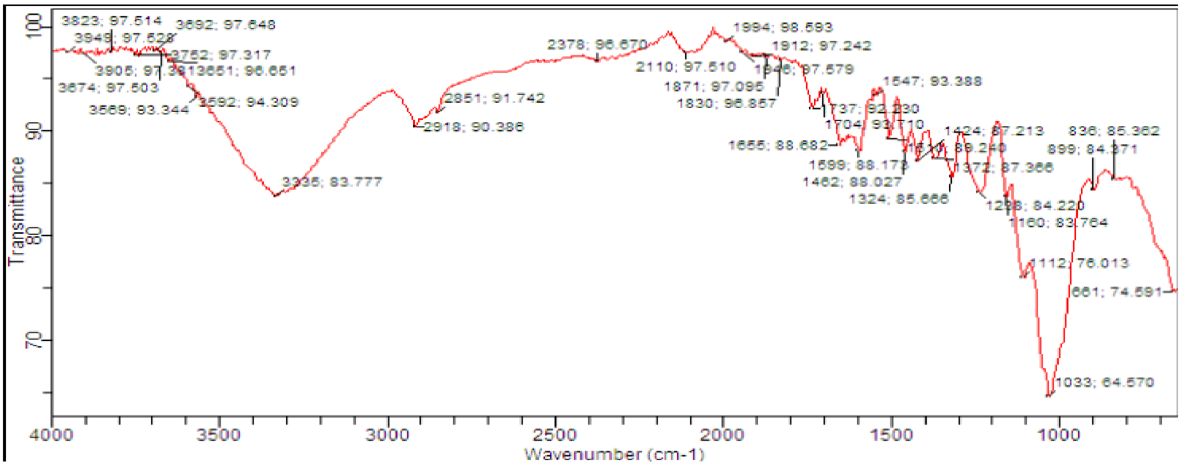

Fig 1: FTIR Analysis of Saw Dust

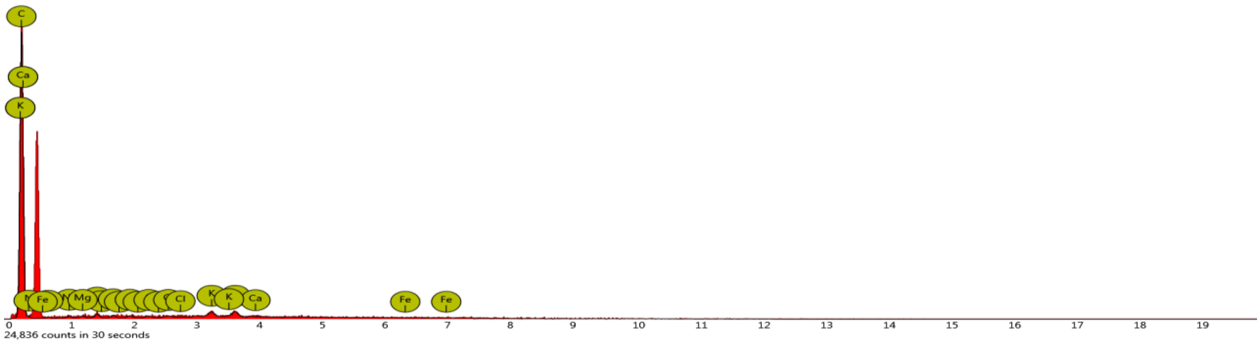

Fig 2: Elemental Analysis

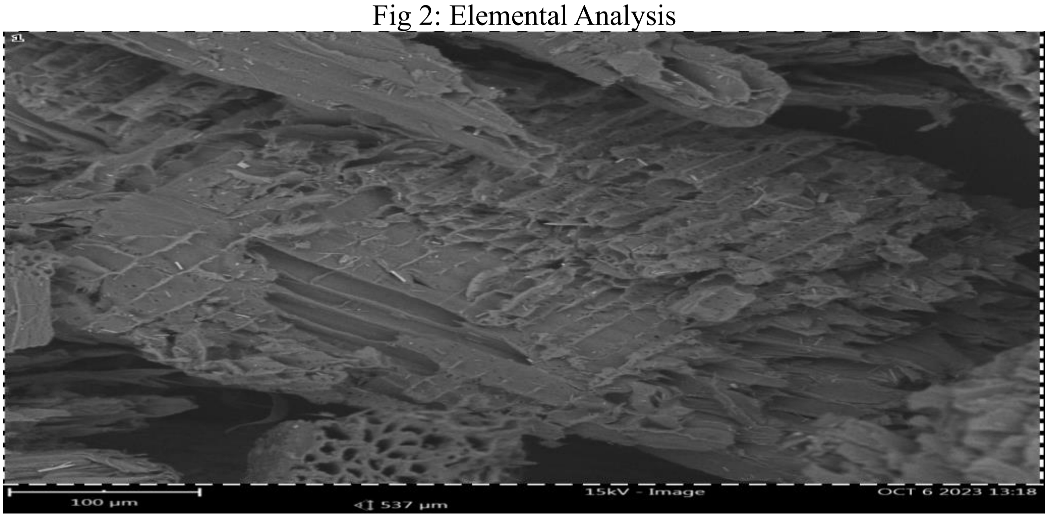

Fig 3: SEM of Saw Dust (FOV: 537 µm, Mode: 15kV - Image, Detector: BSD Full)

3.2 Batch Sorption Experiment Result

Table 1: Batch Sorption Experiment Result

DOSAGE (mg/L)	Ce	OIL REMOVAL	% OIL REMOVAL
0.00	51.00	0.00	0.00
309.69	13.00	38.00	74.50
465.10	9.96	41.04	80.47
618.20	6.50	44.50	87.25
930.10	3.30	47.70	94.00
1240.00	3.30	47.70	94.00

3.3 Isotherm Studies

3.3.1 Freundlich Isotherm

Equation 1 provides the Freundlich equation:

$$q_e = KC_e^{\frac{1}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\ln q_e = \ln K + \frac{1}{n}\ln C_e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where K represents a constant indicating the sorbent's relative adsorption capacity (mg/g). The parameter 1/n reflects the intensity of adsorption, and Ce denotes the equilibrium concentration of the solute in the solution (mg/l) (Schneider et al., 2010).

$$q_e = \frac{v(C_o - C_e)}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where v is the volume of the liquid in liter and C_o is the initial concentration of the solute in the solution (mg/l) and m is the mass of the sorbent (g) (Wu et al., 2010). The data was plotted using the linearized form of Freundlich equation (equation 2) and the plot in fig 4 was obtained.

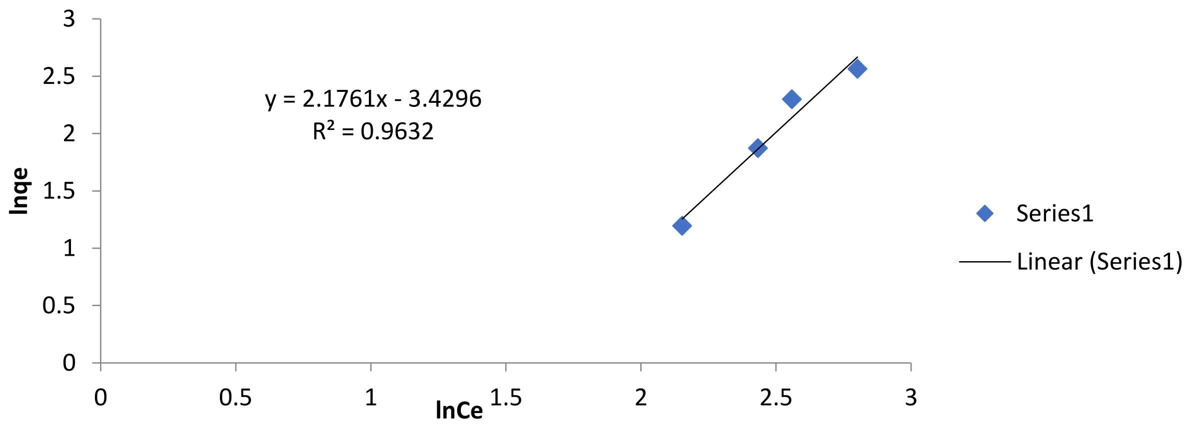

Fig. 4: Freundlich Isotherm Model for Sawdust

From the graph, the following values were deduced as shown in table 2:

Table 2: Values Deduced from Freundlich Plot

Isotherm Model	Correlation coefficient	Slope=$\frac{1}{n}$	Intercept=lnK	Freundlich constant (K)	Degree of non- linearity
Freundlich	0.9632	2.1761	-3.4296	0.0324	0.4595

3.3.3 Langmuir Isotherm

The Langmuir equation is given as shown in equation 4 below:

$$q_e = \frac{k_L b C_e}{1 + k_L C_e} \quad \ldots\ldots\ldots\ldots\ldots\ldots 4$$

The equation can be linearized to obtain the following equation:

$$\frac{C_e}{q_e} = \frac{1}{bk_L} + \frac{1}{b} C_e \quad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

Comparing with y=mx + c where $\frac{C_e}{q_e}$ is y and C_e is x

The slope= $\frac{1}{b}$ and the intercept = $\frac{1}{bk_L}$

The constants can be determined using the slope and the intercept values from the graph.

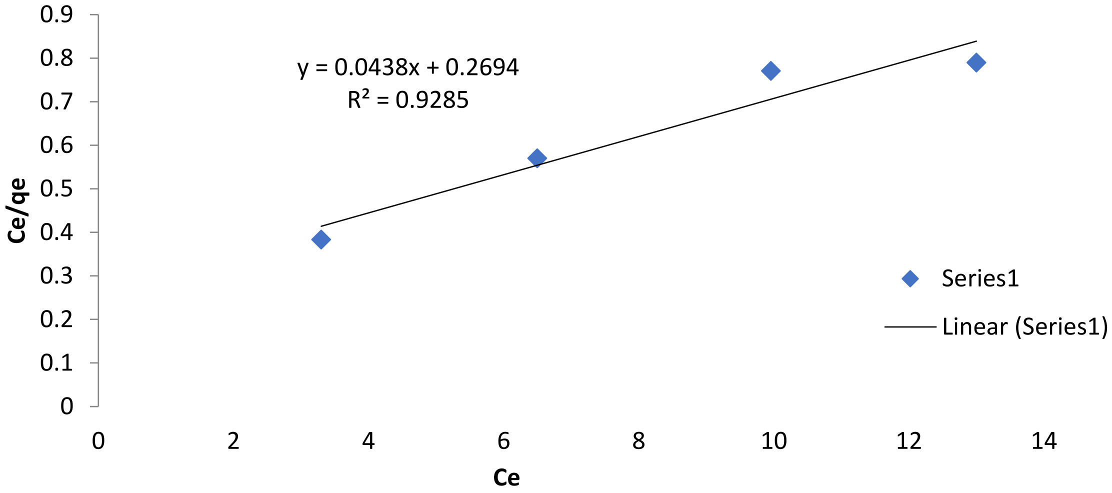

Fig. 5: Langmuir Isotherm for Sawdust

Table 3: Values Deduced from Langmuir plot

Isotherm Model	Correlation coefficient	Slope	Intercept	Isotherm Constant (k_L)	b	Separation factor
Langmuir	0.9285	0.0438	0.2694	0.1626	22.8311	0.0009

3.3.2 Temkin-pycher Isotherm

The Temkin-pycher equation is given below:

$$q_e = \frac{RT}{b_T} \ln (A_T C_e) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where R is the universal gas constant (J/mol K), T is the temperature (K), A_T is the Temkin isotherm constant and b_T is the Temkin-pycher isotherm constant.

Equation 6 can be linearized to obtain the equation below:

$$q_e = \frac{RT}{b_T} \ln A_T + \frac{RT}{b_T} \ln C_e \qquad \ldots\ldots\ldots\ldots\ldots 7$$

$$q_e = B_T \ln A_T + B_T \ln C_e \qquad \ldots\ldots\ldots\ldots\ldots 8$$

Comparing with y=mx+c, a plot of q_e on the y-axis and $\ln C_e$ on the x-axis can be obtained with slope=$\frac{RT}{b_T}$ and intercept=$\frac{RT}{b_T}\ln A_T$, Hence the constants can be obtained.

$$A_T = \exp(\frac{intercept}{B_T})$$

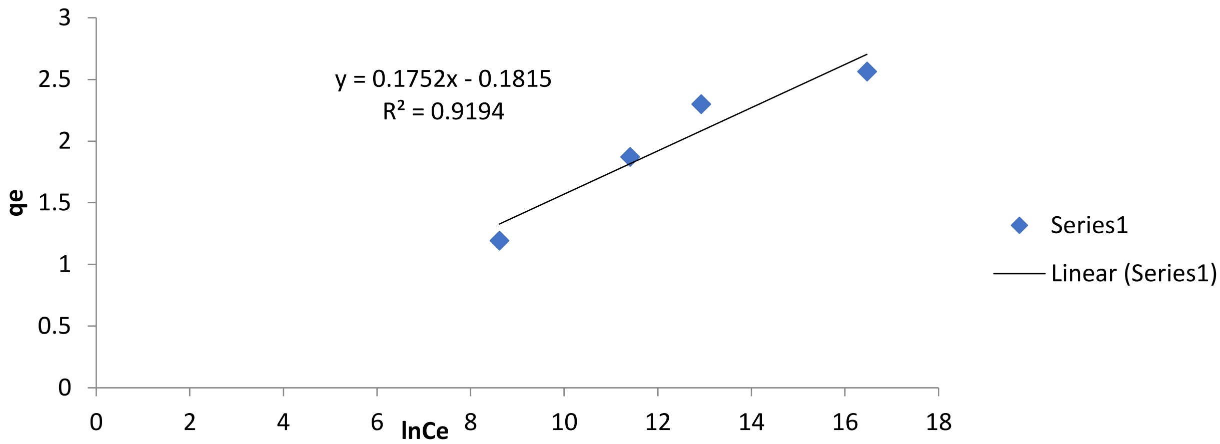

Fig 6:Temkin-Pycher Isotherm Model for Sawdust

Table 4: Values Deduced from Temkin-Pycher Plot

Isotherm Model	Correlation coefficient	Slope	Intercept	b_T	A_T
Temkin-pycher	0.9194	0.1752	-0.1815	0.8913	0.0211

4.0 Conclusion

Sawdust was utilized as a biosorbent and was employed for the extraction of oil contaminants from water. It demonstrated an impressive 94% removal rate. This suggests its efficacy as a reliable biosorbent for oil. The experimental data was subjected to isotherm analysis and it revealed that the most suitable isotherm model was Freundlich with a regression coefficient of (0.9632). This outcome, in line with Freundlich's theory dating back to 1906, indicates heterogeneous adsorption and implies a predominantly physical nature of the adsorption process.

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