



Adsorption of Crude Oil in Aqueous Medium Using Different Cultivars of Cassava Peels as Biosorbent

^a Ademiluyi Falilat Taiwo, Nnewuihe Anagor ^b, and Onuoha Wopara ^b

^a Chemical/Petrochemical Engineering Department,

^b Petroleum Engineering Department, Rivers State University, Port Harcourt, Nigeria

Corresponding author Email: ademiluyi.taiwo@ust.edu.ng

ABSTRACT

Adsorption of crude oil in an aqueous medium using different cultivars of Cassava Peels was investigated. The effect of particle size, dosage, initial concentration, and contact time of dried Cassava Peels on the degradation of crude oil in an aqueous solution was studied. It was established that as the particle size of Cassava Peels increases, the adsorption increases, and vice versa. The result showed that Cassava Peels with a particle size of 800 μ m have the optimal amount of crude oil adsorbed thus implying that a bigger particle size is required for effective adsorption of crude oil in an aqueous solution. Adsorption of crude oil increased as the dosage of the biosorbent increased until equilibrium was achieved. Adsorption of crude oil in solution was established to increase with a decrease in initial crude concentration. The effect of contact time showed that crude oil adsorption increased rapidly within the first 10mins, thereafter, equilibrium was achieved in a contact time of 120mins. The experimental data fitted well into Freundlich and Temkin Isotherm. The maximum adsorption capacity obtained for the two optimal cultivars was 714mg/g and 2000mg/g respectively. The values of the adsorption intensity for Sample A ($n = 1.478$) and Sample C ($n = 1.125$) were greater than 1 indicating that the adsorption of crude oil using Sample A and C is more of chemisorption than only physical adsorption. The result from this study showed that there was the resultant regrowth in the population of hydrocarbon-degrading microbes after 24hrs which indicates that the crude oil environment was utilized by these microorganisms after adsorption of the crude oil using the sorbents from Cassava Peels. This study has shown that Cassava Peels (inactivated) can effectively be used to adsorb crude oil in polluted water.

KEYWORDS: Adsorption Isotherm, Aqueous Medium, Biosorbent, Cassava Peels, Crude Oil, Degradation.

Cite This Paper: Ademiluyi, F. T., Anagor, N., & Wopara, O. (2021). Adsorption of Crude Oil in Aqueous Medium Using Different Cultivars of Cassava Peels as Biosorbent. *Journal of Newviews in Engineering and Technology*. 3(2), 13 – 26.

1.0 INTRODUCTION

Accidental releases of petroleum products are of particular concern to the environment. Hydrocarbon components have been known to belong to the family of carcinogens and neurotoxic organic pollutants. According to Jain *et al.* (2011) in the bioremediation of petroleum oil contaminated soil and water, environmental pollution with petroleum and petrochemical products (a complex mixture of hydrocarbon) has been recognized as one of the most frequently experienced problems. Accidental leakages from petroleum-carrying ships lead to oily layers over the water surface, possessing a great threat to the existing flora and fauna. According to Vamsi (2012), although various conventional cleaning methods such as physical methods like the first response method have been used in the cleaning process, complete cleanup of oil spills was rarely achieved. According to the Office of Technology Assessment, current mechanical methods typically recover not more than 10-15 percent of the oil after a major spill. Chemical methods are faster in action but they are toxic to the biota present in the spill environment.

Several low-cost biosorbent/adsorbent has been reported for removal of crude oil from an aqueous environment. Zahra *et al.* (2014) used raw rice husk (RRH) as a low-cost adsorbent to remove three oil compounds with different viscosities (crude oil, engine oil, and spent engine oil) from an aqueous environment. The oil adsorption percentage was reduced for crude, spent, and engine oils from 50 to 30%, 65 to 20%, and 70 to 0.01%, as RRH particles size reduces respectively. The adsorption of crude and spent oils on rice husk followed the



Freundlich isotherm model, while the adsorption of engine oil was fitted by the Langmuir model. The maximum adsorption capacity (Q_{max}), calculated from the Langmuir model for the adsorption of engine oil on RRH, was 1,250 mg/g. The sorption process of crude oil, diesel, and kerosene onto rice husk and the standard conventional synthetic sorbent was studied (Kelle, 2018). Using Langmuir, Freundlich, Elovich, Temkin and Dubinin – Radushkevich adsorption models. The result of the study showed that the standard conventional synthetic sorbent material is a better sorbent for oil removal than rice husk. The sorption process for both sorbents was best described by Langmuir isotherm.

Boleydei (2018) studied the efficiency of a biosorbent prepared from the green macroalgae *Enteromorpha intestinalis* biomass for decontamination of seawater and freshwater polluted by crude oil and engine spent oil. Based on the obtained results, the adsorption of spent oil with higher viscosity was better than crude oil. The algal biomasses which are abundantly available could be effectively used as a low-cost and environmentally friendly adsorbent for remediation of the oil spill in the marine environments. Mango shell (MS) and Mango shell activated carbon (MSAC) were used to adsorb crude oil from water at various experimental conditions (Olufemi & Otolorin, 2017). The MSAC was prepared by carbonization at 450°C and chemical activation using strong H_3PO_4 acid. The result demonstrated that MSAC was more effective for crude oil adsorption than raw Mango shells.

Ademiluyi *et al.* (2020) studied the adsorption of crude oil in aqueous media using dried Plantain (*Musa paradisiaca*) Peels (PP) and Plantain leaves (PL) was studied. Effect of particle size, dosage, contact time, initial crude oil concentration in terms of Total Organic Carbon (TOC), and effect of the microbial count was investigated. The Langmuir, Freundlich, and Temkin isotherm models were employed to analyze the experimental data. The Temkin adsorption model with a regression coefficient of 0.9919 provided the best fit to the experimental data compared to the Langmuir and

Freundlich models. Hence based on the results obtained, these biosorbents were found to have the potential of being an efficient tool for remediation in attempting to resolve the age-long challenge of crude oil spillage/pollution in an aqueous medium.

Several parts of Cassava had also been reported for bioremediation of soil and water. Cassava Peels is the rough brownish outer layer of Cassava. It can represent 5 to 15% of the root. Others use Cassava Peels. Cassava Peels are gotten by mechanically peeling the Cassava after it has been washed with water. The Peels may contain more proteins than the tuber parts as well as contain high amounts of cyanogenic glycoside (poisonous chemical) which can be removed by sun drying, cooking, and fermentation. Cassava Peels are a by-product of Cassava processing. The chemical composition of Cassava Peels is starch, sugar, amino acid cyanide, crude fiber, and crude protein (Aro *et al.*, 2010).

Others researchers also reported the use of Cassava Peel prepared as activated carbon to remove chromium (VI) from aqueous solution simulating industrial effluents (Acosta *et al.*, 2017). Batch adsorption operation was used and tests were performed by varying the initial concentration of chromium solution (30, 40, and 50 ppm) and temperature (25, 30, and 35 °C), keeping fixed the adsorbent dosage (3.33 g/l), the contact time of 40 minutes, and pH of 2, which was adjusted with sulfuric acid. It was observed that the higher the adsorbent dosage, the higher the percent removal of Cr(VI).

Kigho (2016) also carried out a comparative analysis of the efficiency of activated carbon produced from fermented Cassava Peels (CPB), unfermented Cassava Peels (CPA), and commercial-grade activated carbon (CAC) in the treatment of refinery wastewater was carried out. CPB was found to be a better adsorbent as it has the highest adsorptive capacity as evidenced from its better

Freundlich exponent. Ilaboya (2013) also studied the performance of Activated Carbon from Cassava Peels for the treatment of Effluent Wastewater.

Most of the studies activated the Cassava Peels before usage and the particular variety of Cassava used was not specified and still, there are limited researches on the use of Cassava Peels in the adsorption of crude oil in an aqueous solution in previous works, without activation of the Cassava Peels. Activation of the Peels increases the cost of adsorbent though studies showed it has a high adsorptive capacity,

Also, Nigeria is the world's largest producer of Cassava having almost 55 million tones out of 268 million tons of global production. Thailand, Brazil, and Indonesia are other major producers of Cassava. (UN Food and Agricultural Organization Corporate Statistical Database). Presently over 40 different Cassava cultivars are available and several studies have been carried out on them. (IITA 2017, Ademiluyi *et al.*, 2010). Hence, the objective of this research is to study the adsorption of crude oil in an aqueous medium using different cultivars of Cassava Peels (without activation) as a biosorbent.

2.0 MATERIALS AND METHODS

2.1 Materials

The following materials and apparatus were used for this work: Waste Nigerian based Cassava Peels, Crude Oil sample, Desiccators, Crucibles, Funnels, Filter papers, pH Meter, Redwood Viscometer, Two electronic weighing balance, Ohaus top loading balance (+0.01), and a more sensitive electronic analytical weighing balance (+0.001, Adams AFP 360L), Retort stand, Thermocouple with temperature sensor, Spatula.

2.2 Preparation of Adsorbents

The waste Cassava Peels that were used for this research work were collected from The International Institute of Tropical Agriculture (IITA), Onne, Rivers State. The Cassava Peels that were used are; (TMS 419), (TMS 92/0326), (TMS 01/1368), (TMS 98/0510) & (TMS 2205). (TMS =

Tropical Mosaic Specie). The Peels were oven-dried at 105°C for 24hrs. They were later ground with a manual grinding machine and sieved, (Plate 1) to obtain particle sizes of 75µm, 150µm, 300µm, 600µm, and 800µm.

2.3 Characterization of Crude Oil

The Crude oil sample used for this study was from a well from the Niger Delta region. Its properties such as Density, Viscosity, Hydrogen Concentration, Total Organic Carbon (TOC). Total Coliform, Specific Gravity, pH, and Conductivity were determined.



Plate 1: (a) Manioc Tubers (Cassava) (b) Dried Cassava Peels and (c) Blended dried Cassava Peels

2.3.1 Determination of Total Organic Carbon (TOC)

Crude oil concentration in mg/L was measured in terms of Total Organic Carbon. 0.2ml of the sample was measured into a 500ml flask. 10ml of 0.5M potassium dichromate solution ($K_2Cr_2O_7$) was added and swirled gently. 20ml of H_2SO_4 was added rapidly and swirl gently to mix the reagents while avoiding splash. Flask was allowed to stand for 30minutes. 200ml of Distilled water was added, then 10ml of Ortho Phosphoric Acid (H_3PO_4). three drops of



Ferriin indicator were added. The solution was titrated against the FAS (Ferriin Ammonium Sulphate) Solution.

Total Organic Carbon (TOC) was determined from Equation 1.

% TOC = (Vb-Vs) X M X 1.38 / Volume of Sample (1)

Where:

Vb = ml of FAS used for blank

Vs = ml of FAS used for sample

M = Molarity of FAS (0.25M)

Volume of sample = 0.2ml

FAS = Ferriin Ammonium Sulphate (FAS)

2.4 Characterization of Cassava Peels

The dried Cassava Peels were characterized to determine the bulk density, moisture content, ash content, iodine value, and volatile matters of the Biosorbent.

2.5 Degradation and Adsorption Analysis of Crude Oil using Dried Cassava Peels

2.5.1 Effect of Particle Sizes of Dried Cassava Peels

The Cassava Peels were grounded and sorted into different particle sizes of 75µm, 150µm, 300µm, 600µm, and 800µm. Then 250ml of distilled water and a known amount of crude oil were mixed with 0.5g of each particle size. Each mixture was poured into a conical flask and was shaken vigorously.

2.5.2 Effect of Dosage of Cassava Peels on Degradation of Crude Oil

The dried and grounded Cassava Peels of different dosages (0.25g, 0.5g, 0.75g, 1g, 1.5g, 2g, and 2.5g) were mixed with 18131mg/L of crude oil and 250ml of distilled water in seven different glass containment according to the different weights. The mixture was then shaken vigorously for 2 hours and then filtered with a filter paper. The TOC of the filtrates were determined and recorded accordingly.

2.5.3 Effect of Initial Concentration on the Degradation of Crude Oil using Dried Cassava Peels

2.5g of 800µm of different Cassava Peels were poured into five different flasks containing crude oil

of varying concentrations between 5208mg/L to 18131mg/L. The mixtures were stirred and shaken vigorously. After stirring, each of the mixtures in the flask was filtered and the TOC of the filtrate was determined.

2.5.4 Effect of Contact Time on Adsorption of Crude Oil using Dried Cassava Peels

2.5g of 800µm of different Cassava Peels were poured into five different flasks containing crude oil of varying concentrations between 5208mg/L to 18131mg/L. The mixture was stirred and shaken vigorously. After stirring, each of the mixtures in the flask was withdrawn at various contact times (10mins, 30mins, 60mins, 120mins, etc) were filtered. The TOC of the filtrate was determined was then filtered with a filter paper.

2.5.5 Determination of the amount of Crude Oil adsorbed by the Cassava Peels

The amount of Crude oil adsorbed at equilibrium, Qe (mg/g) was determined using equation (2).

Qe = (Co - Ce)V / m (2)

The percentage adsorption (%) of crude oil adsorbed was computed as follows: Percent adsorption (%)

= (Co - C) / Co * 100 (3)

Where Co and Ce are the initial and equilibrium concentration (mg/L), V, the volume of solution (L), m the mass of the dried Cassava Peels (g), and C the solution concentration at any time t after adsorption.

2.5.6 Determination of the Total Microbial Count in the Crude Oil Sample

Petri dish and test tube were sterilized first in an autoclave for some time and removed from it. 2g of crude oil-polluted water was measured into a beaker and nutrient agar into a conical



flask and mixed with 75ml of distilled water. The sample was poured into a Petri dish and 9ml of nutrient agar also into them respectively. Filter paper soaked with crude oil was placed inside the Petri dish containing the sample respectively. It was covered with foil paper and incubated for 24 hours in an incubator. After 24 hours, the sample was brought out and counted to know the number of hydrocarbons utilizing bacteria. The count was obtained by multiplying with a dilution factor.

$$\text{Total count} = \frac{\text{Colony count}}{\text{Volume inoculated}} \times \text{Dilution factor} \quad (4)$$

2.6 Isotherms Modeling

The most commonly used adsorption isotherms in adsorption studies to fit the experimental adsorption data were used, namely: Langmuir, Freundlich, and Temkin.

a) Langmuir isotherms are used for determining the isothermal behaviour of the adsorption processes. The Langmuir isotherm is expressed as equation (5)

$$\frac{C_e}{Q_e} = \frac{1}{K_L} + \frac{a_L C_e}{K_L} \quad (5)$$

where:

Q_e = the amount of crude oil adsorbed per unit mass of adsorbent (mg/g) at equilibrium.

C_e = the equilibrium concentration of the adsorbate (mg/L).

K_L = a constant related to the affinity between the adsorbent and the adsorbate.

$\frac{K_L}{a_L}$ = theoretical monolayer saturation capacity

Q_o .

The values of Q_o and K_L were determined by plotting C_e/Q_e versus C_e . One of the most important parameters of the Langmuir isotherm model was the separation factor R_L which is a dimensionless factor (Ademiluyi & Ujile, 2013).

$$R_L = \frac{1}{1 + a_L C_o} \quad (6)$$

where:

C_o = the initial adsorbate concentration and a_L is the Langmuir constant related to the energy of adsorption. The values of R_L shows the shape of the isotherm to be either unfavorable ($R_L > 1$), favorable ($0 < R_L < 1$), linear ($R_L = 1$), or irreversible ($R_L = 0$).

b) The linear form of the Freundlich isotherm was the earliest known relationship describing the adsorption equation and is often expressed as

$$\text{Log } Q_e = \text{Log } K_f + \frac{1}{n} \text{Log } C_e \quad (7)$$

K_f = The Freundlich constant related to the adsorption capacity.

$1/n$ = The Freundlich constant related to the adsorption intensity.

When employing this model in adsorption study, the assumption that should be taken into cognizance is that the removal of crude takes place on a heterogeneous sorbent surface and can also be applied to multilayer sorption

c.) The Temkin isotherm is also often used to represent the equilibrium adsorptive behavior between two phases composing the adsorption system. The Temkin isotherm is expressed as;

$$Q_e = a + b \ln C_e \quad (8)$$

where:

a, b = Constant related to energy and capacity of adsorption.

3.0 RESULTS AND DISCUSSION

3.1 Characteristics of the Crude Oil

The experimental analysis result for the crude oil used for this adsorption study is represented in Table 1. The bulk density of the crude oil was 0.96g/cm^3 . The specific gravity value (like other petroleum products) was close to density values and ranges from about



0.80 – 0.88 for light crude oils to about 0.94 - 0.98 for heavy oils and about 1.00 – 1.03 for Bitumen (Speight, 2001). The moisture content was just 0.029%. The API gravity of the crude was 16, which falls under the group of heavy oil (Table 1). the results showed that this crude oil was heavy because of its high resistance to flow as well as its high density/specific gravity which is more than that of light crude oil due to the presence of asphaltenes and resins. The Total Coliform was determined to ascertain the number of bacteria initially present in the crude oil before adsorption.

The crude oil was strongly acidic as its pH value is 3.64. This work was in line with other studies on the characteristics of Niger Delta crude done by other researchers. API gravity of 16° implies that the

Table 1 Characteristics of the Niger Delta Crude Oil Used

S/NO.	Parameter	Unit	Result
1	Appearance/colour	-	Dark brownish liquid
2	Bulk Density @15°C	g/cm ³	0.9592
3	Specific gravity@60F	-	0.9601
4	API gravity	-	16.0°
5	Kinematic viscosity	cSt	91.8
6	Dynamic viscosity	cP	88.05
7	pH @ 27.2°C	-	3.64
8	Electrical Conductivity	µs	1.58
9	Total Coliform	cfu/ml	21x10⁵
10	Moisture Content	%	0.029
11	TOC	mg/l	3.04570 x 10 ⁶

crude oil sample used for this experimental analysis is heavy crude.

3.1.2 Characterization of dried cassava Peels from different cassava cultivars

Table 2 shows the characterization of dried cassava Peels from different cassava cultivars. It showed that samples A & C has the highest bulk density while others have lower. Moisture content, volatile matter, ash content, and fixed carbon differ slightly among the cassava cultivate Peels characterized. The rate of adsorption decreases with lower ash content. The iodine number from Table 2 varies significantly with sample C having the highest value followed by samples A & B. Higher iodine value indicates high porosity and hence high adsorption, (Ademiluyi & David-West, 2012).

3.2 Effect of Particle Size of Dried Cassava Peels on the Adsorption of Crude Oil in Aqueous Solution

Figure 1 shows the effect of particle sizes of the different species of dried Cassava Peels on the adsorption of crude oil. It was observed that the rate of adsorption increases as the particle size increases and vice versa. The implication is that the rate of adsorption is dependent on the particle size. A similar trend was observed using Plantain Peels and leaves to adsorb crude oil in an aqueous solution. (Ademiluyi *et al.*, 2020). In this case, the particle size of 800µm has the highest amount of

crude oil adsorbed. Hence a greater particle size, for instance, $\geq 800\mu\text{m}$, is required for the effective adsorption of crude oil in an aqueous solution. Adsorption of crude oil with Cassava Peels of particle size of 800µm, Samples A, B, C, D & E gave percentage adsorption of 55.4%, 52.33%, 60.0%, 49.78% & 47.91 respectively.

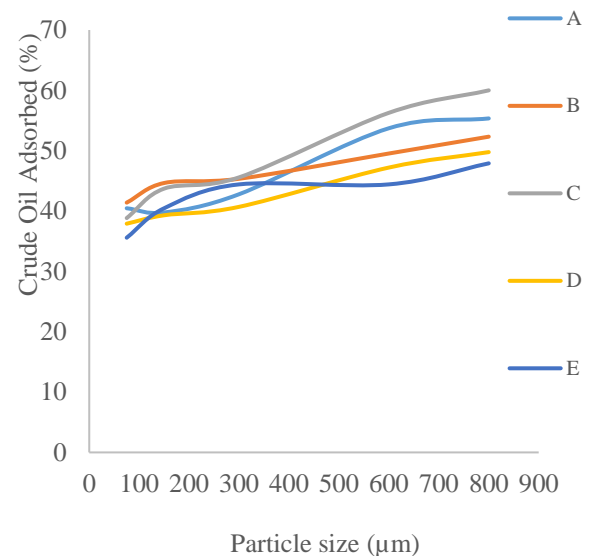


Figure 1 Effect of Particle Sizes of Samples A-E on the Adsorption of Crude Oil in Aqueous Solution.

Table 2 Characterization of Dry Cassava Peels from Different Cassava Cultivars

S/NO	Parameter	Sample A	Sample B
	Sample C	Sample D	Sample E
1	Bulk Density (g/cm ³)	0.433	0.356
		0.413	0.326
		0.293	
2	Moisture Content (%)	4.815	5.238
		4.760	5.251
3	Iodine Value (mg/g)	1,104.58	1,104.5
		1,280.8	705.05
		846.066	
4	Volatile Matter (%)	22.8	21.8
		22.0	23.6
		25.0	
5	Ash Content	11.2	12.4
		11.0	9.8
		10.4	

6	Fixed Carbon (%)	61.185	60.56	62.24
		58.769	61.35	

3.3 Effect of Dosage of Dried Cassava Peels (Sample A and Sample C) Adsorption of Crude Oil in Aqueous Solution

Cassava dosages ranging from 0.25 – 2.5g were introduced into Crude Oil in an aqueous solution for adsorption to take place. Based on the results obtained from this study. The adsorption of crude oil increased with an increase in biosorbent dosage until equilibrium or optimal adsorption is achieved in this case at optimum dosage values as shown in Figure 2.

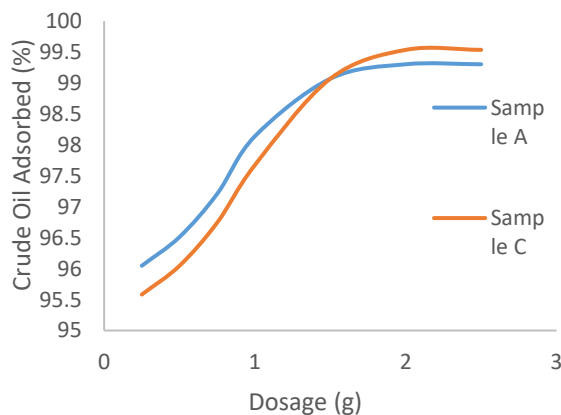


Figure 2 Effect of Dosage of Samples A & C on the Adsorption of Crude Oil in Aqueous Solution

In this study, the percentage (%) crude oil adsorbed was more for Sample A & Sample C, compared to other Cassava Peels, this may be because Sample A & Sample C had the highest iodine number hence more porous than other samples.

3.4 Effect of Initial Concentration on the Adsorption of Crude Oil using Dried Cassava Peels

Figures 3 and 4 show the effect of the initial concentration of crude oil on the adsorption of crude oil using dried Cassava Peels. According to the result of the experiment, the reduction in the initial concentration of crude oil in solution leads to the increase in the adsorption of crude oil in an

aqueous solution. In this study, there was variation in the concentration of the adsorbate from 5207.744mg/L - 18131mg/L.

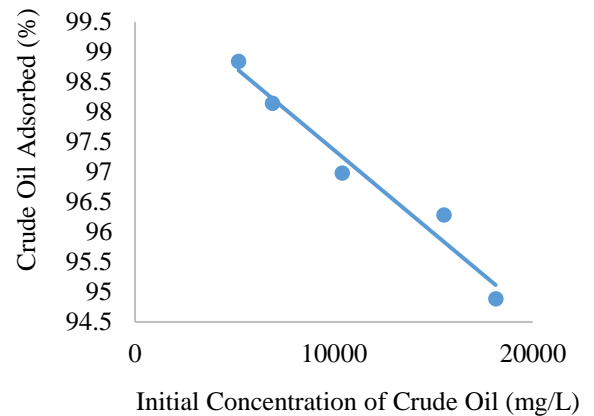


Figure 3 Effect of Initial Concentration on the Adsorption of Crude Oil Using Cassava Peels (Sample A)

The rate of adsorption increased from 97% to 99% in Sample A and 96% to 99% in Sample C, as the concentration of crude oil decreased from 18130.96mg/L to 5207.744mg/L within 120mins of adsorption for the different Cassava Peels.

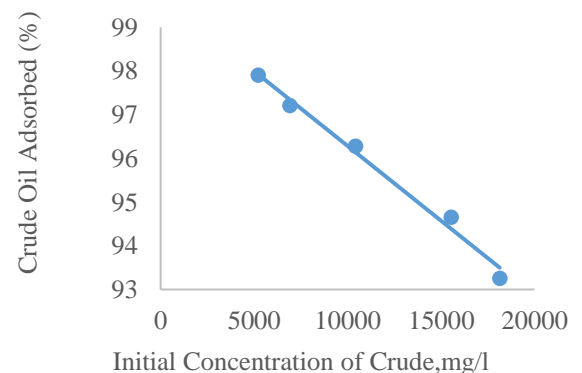


Figure 4 Effect of Initial Concentration on the Adsorption of Crude Oil using Cassava Peels (Sample C)

3.5 Effect of Contact Time on Adsorption of Crude Oil in Aqueous Solution

Figures 5 and 6 show the effect of contact time on the adsorption of crude oil in an aqueous solution using dry Cassava Peels (Samples A & C). There was variation in the concentrations of crude oil in aqueous solution from 5207.744mg/L - 18131mg/L within the time range of 10mins -24hrs for the adsorption process using Cassava Peels. The percentage of crude oil adsorbed increased with time until equilibrium was reached for each concentration. Figures 6 and 7 show that the surface of the sorption materials as well as the penetration into the inner microscopic voids gave rise to the initial sharp increase of adsorption. The percent adsorption increases with low concentration and more surface areas are covered at higher concentrations of crude oil in solution but as soon as there are no more active surface sites, the percent adsorption decreases thus leading to a decrease in the percentage of adsorbate adsorbed at higher concentration. At 120 minutes of contact for 5207.744mg/L concentration, the percentage adsorption of crude oil reached an equilibrium according to the result obtained.

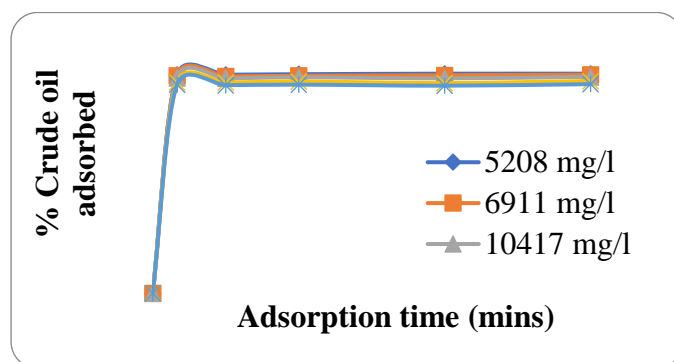


Figure 5 Effect of Contact Time on the Adsorption of Crude Oil in Aqueous Solution Using Dry Cassava Peels (Sample A)

The percentage then increased to more than 90% showing the effectiveness of the adsorption process at the concentration of 5207.744mg/L.

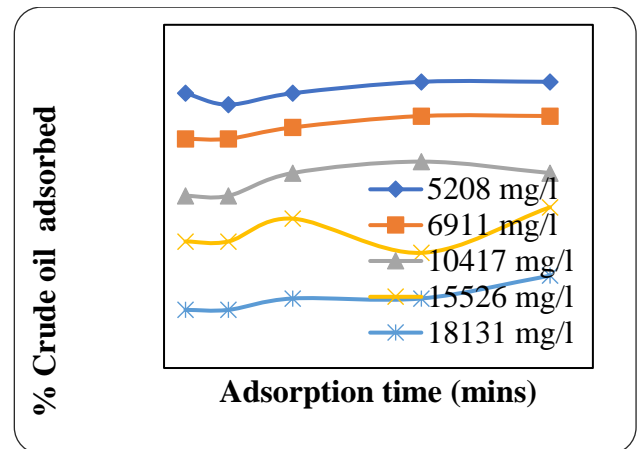


Figure 6 Effect of Contact Time on the Adsorption of Crude Oil in Aqueous Solution Using Dry Cassava Peels (Sample C)

3.6 Microbes Count Analysis before and after adsorption of Different Concentration of Crude Oil in Aqueous Medium

Table 3 shows microbes count analysis before and after adsorption of different concentrations of crude oil in an aqueous medium using Cassava Peel. A lower concentration of crude oil had a higher percentage (%) of microbes' regrowth. The results of this experiment correspond to the reality of microbial degradation of the crude oil hydrocarbons. The result from this study showed that there was the resultant regrowth in the population of hydrocarbon-degrading microbes after 24hrs of adsorbing the crude oil on the Cassava Peels, which indicates that the crude oil environment was utilized by these microorganisms after adsorption and that the adsorption of crude oil in solution occurred using the sorbents from Cassava Peels.

Table 3 Microbes Count Analysis before and after adsorption of Different Concentration of Crude Oil in Aqueous Medium Using Cassava Peel.

Crude Oil Conc. (mg/L)	TBC cfu/mL Initial value
------------------------	--------------------------

5207.744	2.4×10^6
6910.804	1.4×10^7
10417.100	4.6×10^6
15526.000	2.7×10^6
TBC cfu/mL (24hrs After Adsorption)	% Microbes growth
18130.960	2.6×10^6

3.7 Adsorption Isotherm Equilibria

3.7.1 Langmuir Adsorption Isotherm for Crude Oil adsorption using dried Cassava Peels

Fig 7 & Fig 8 represents the Langmuir adsorption isotherms for the adsorption of crude oil on Sample A and Sample C. The ratio of the equilibrium concentration to the ratio of the amount of crude oil adsorbed (C_e/Q_e) was plotted against the equilibrium concentration of crude oil (C_e). Langmuir isotherm model can be used to predict the sorption of crude oil on Cassava Peels. The Langmuir plots in this study showed that there is an increase in the rate of adsorption as the concentrations are varied. The implication is that the rate of the adsorption in crude oil by the adsorbents increases with a lower concentration of crude oil.

The Langmuir model plots as shown in Fig 7 & 8 for Sample A and Sample C show that the correlation coefficient R^2 of 0.8966 and 0.9438 respectively were obtained. R^2 was greater than 0.89 for each of the adsorbents, which shows that the isotherm is consistent with the Langmuir model. The values of the separation factor (R_L) from equation 5, obtained for sample A was within the range of 0.132 - 0.0417 and that of sample C between 0.205 - 0.472 for adsorbate concentrations between 18130.96mg/L to 5207.74mg/L. The adsorption process was favorable since the value of R_L is less than 1 for all the concentrations.

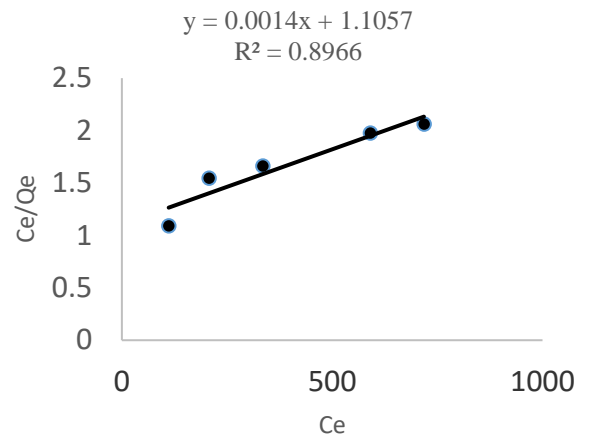


Figure 7 Langmuir Adsorption Isotherm for Batch Adsorption of Crude Oil on Sample A

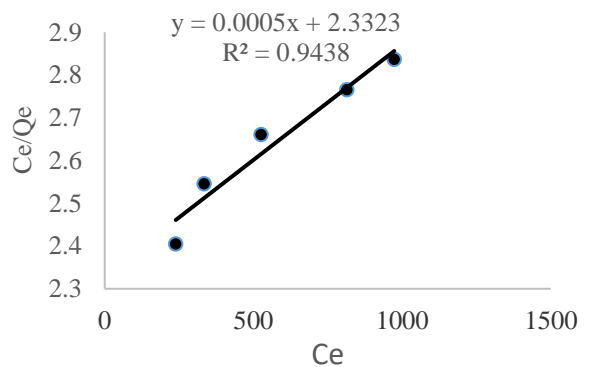


Figure 8 Langmuir Adsorption Isotherm for Batch Adsorption of Crude Oil on Sample C

3.7.2 Temkin Adsorption Isotherm for Crude Oil adsorption using dried Cassava Peels

The plot of the amount of crude oil adsorbed (Q_e) at equilibrium against the natural logarithm of the equilibrium concentration of crude oil ($\ln C_e$) was a linear graph in Figs 9 and

10. The correlation coefficient R^2 for Sample A and Sample C obtained was (0.997) and (0.999) respectively. Fig 9 and 10 shows that the Temkin adsorption model can also be used to predict the sorption of crude oil using dry Cassava Peels. The values of a , and b (Constant related to energy and capacity of adsorption) for Sample A were 55.89 and 0.178 respectively while the values of a and b for Sample C were 20.477 and 0.1449 respectively from equation 8.

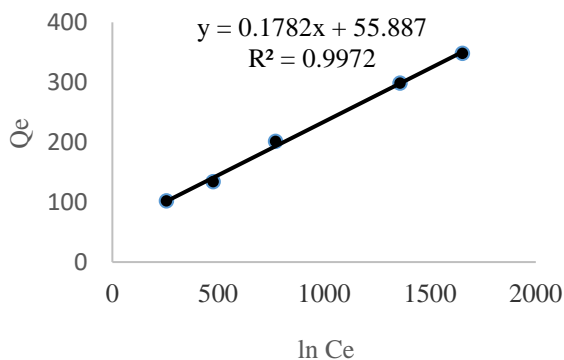


Figure 9 Temkin Adsorption Isotherm for Batch Adsorption of Crude Oil on Sample A at 30°C

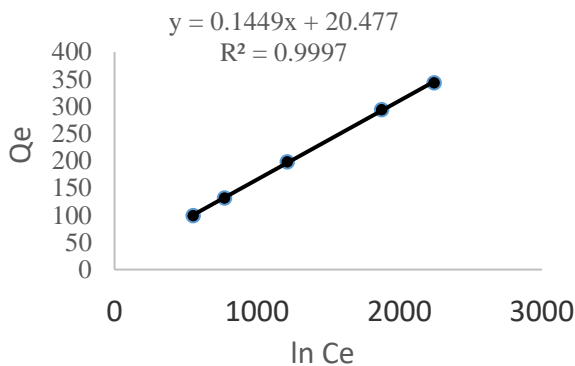


Figure 10 Temkin Adsorption Isotherm for Batch Adsorption of Crude Oil on Sample C at 30°C

3.7.3 Freundlich Adsorption Isotherm for Crude Oil adsorption using dried Cassava Peels

Fig 11 and 12 show the batch adsorption isotherm of crude oil on Sample A and Sample C at 30°C. The

amount of crude adsorbed at equilibrium (Q_e) was plotted against the concentration of the crude oil adsorbed at equilibrium (C_e). The slopes show the adsorption capacity K_f and intercepts of the linear plot show the adsorption intensity $1/n$. The linear plot has a high correlation coefficient R^2 of 0.989 for Sample A and 0.9998 for Sample C. The R^2 is greater than 0.89 showing the consistency of the isotherm with the Freundlich model as well as the conformity to the model. (Atef, 2009). The values of the adsorption intensity for Sample A ($n = 1.478$) and Sample C ($n = 1.125$) were greater than one, which reveals that the adsorption of crude oil using Sample A and C is more of chemisorption than physical adsorption.

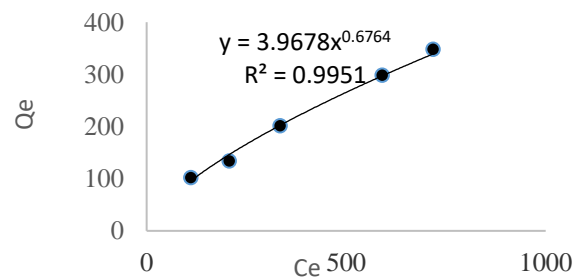


Figure 11 Freundlich Adsorption Isotherm for Batch Adsorption of Crude Oil on Sample A at 30°C

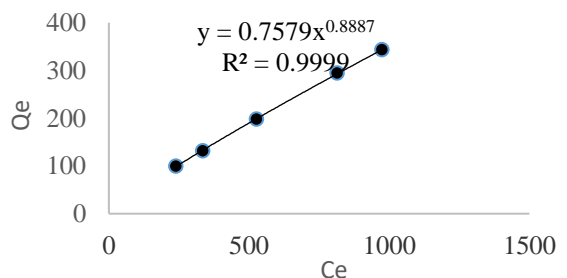


Figure 12 Freundlich Adsorption Isotherm for Batch Adsorption of Crude Oil on Sample C at 30°C



Table 4 Isotherm Models and their Constant Values for Adsorption of Crude Oil from Aqueous Solution using Adsorbents

Isotherms/Constants	Cassava Peels from the present study		Reference adsorbent	
	Sample A	Sample C	Mango Shell (Olufemi & Otolorin, 2017)	Coconut Shell (Aslam & Ayush, 2017)
Langmuir				
q_{max} (mg/g)	714	2000	2.001	526.315
K_L	0.9044	0.4288	3.665	9.33×10^{-3}
R^2	0.897	0.9438	0.93	0.8086
R_L	0.0417-0.312	0.205-0.472	-	-
Freundlich				
n	1.478	1.125	4.537	1.1669
K_f	3.9678	0.7579	1.246	0.9305
R^2	0.9891	0.9998	0.976	0.8183
Temkin				
A	55.887	20.477	N/A	N/A
B	0.1782	0.1449		
R^2	0.9972	0.9997		



4. CONCLUSION

The adsorption of crude oil in an aqueous medium using different Cassava Peels cultivars was investigated. The result of the laboratory experiment was based on the effect of particle size, dosage, initial crude oil concentration, contact time, and microbes on the adsorption of crude oil. The different Cassava Peels adsorbed crude oil in the aqueous medium at different rates. In this study, the adsorption of crude oil increased with an increase in biosorbent dosage. The rate of adsorption increased from 97% to 99% in Sample A and 96% to 99% in Sample C, as the concentration of crude oil decreased from 18130.96mg/L to 5207.744mg/L within 120mins of adsorption. The maximum adsorption capacity obtained for the two optimal cultivars was 714mg/g and 2000mg/g respectively. The values of the adsorption

intensity for Sample A ($n = 1.478$) and Sample C ($n = 1.125$) was greater than 1, which reveals that the adsorption of crude oil using Sample A and C is more of chemisorption than only physical adsorption. These results showed that Cassava Peels (inactivated) have high adsorption capacity and are useful in the control of oil spills thus proffering a solution to the major challenge of the oil and gas industry as well as in the Niger Delta and beyond.

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