

Assessing Bleaching Performance of Hydrochloric Acid Leached Clay from Chelel, Kapchorwa District, Eastern Uganda

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Abstract

Slurry of Chelel clay powder separately leached in 10, 20 30 and 40% hydrochloric acid yielded bleaching earths of varying mineral compositions and bleaching efficiency. The raw and acid-leached samples were characterized using chemical elemental analyses and infra-red spectroscopy and data accumulated used to elucidate the clay structure. This study aimed at determining changes in clay structures and how the changes affect bleaching efficiency of edible oils. The analyses showed that acid-leaching caused modifications in the clay structures resulting from removal of octahedral ions. Both the Si/[Al + Fe +Mg] ratio and bleaching capacity increased with increase in mass percent of hydrochloric acid used to leach the clays. The acid-leached clays tested showed increase in bleaching efficiency in range from 29.8% to 58.9% for cotton and 31.1 to 72.1% for sunflower oils. The bleaching process obeyed the first class Freundlich isotherms and an increased from -0.054 to -0.199 yet k increased from -0.083 to -0.297 as mass percent of hydrochloric acid used respectively increased from 0 to 40%.

Keywords: Acid-leaching; Adsorption; Bleaching; Hydrochloric acid; Isotherm.

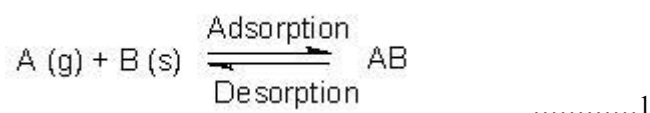
1. Introduction

The quantity of impurities present in vegetable oil can be reduced by adsorption process or bleaching by using clay adsorbents. Both raw treated clays can be used to bleach oils. Treatment of clay to enhance bleaching capacity may be chemical or physical. Such treatments may include acid activation, calcinations and pillaring [1,2]. Clay from Udi in Nigeria was leached in 7M hydrochloric acid to produce adsorbent which bleached palm oil with 66.7% efficiency [3,4]. Clay minerals show limited capacity to bleach in their raw or natural state. Their capacity to adsorb is increased by heating, leaching with mineral acids at elevated temperature [5-8]. When clays are leached with acids metal ions are progressively replaced with hydrogen ions. There is also dissolution of structural cations. In this way ions that retard bleaching are removed from the clay matrices [9]. The desired changes in the adsorptive capacity of clay may occur as a result of acid activation depending on the acid leaching conditions [10]. The methods used to activate clay depend on the apparatus and conditions applied; so many authors have reported different acid activation procedures. The conditions of bleaching clay activation include: the choice of acid, concentration of acid, activation time, activation temperature, and clay-to-acid ratio [5, 6, 8, 10-24]. The process by which clays and clay mineral are transformed in bleaching materials is called acid activation. In this process clay powders are leached with acids like sulphuric or hydrochloric at boiling temperatures [25]. The concentration of sulphuric acid can be varied between 0 and 40% to attack the interlayer cations replacing them with hydrogen ions [26,27]. The extent of removal of octahedral ions influences the bleaching capacity of the product formed. Retention of acid in the clay matrix is known to reduce bleaching power, so clay must be washed to neutrality [28,29]. Activation of clay is a chemical or physicochemical treatment applied to clay to develop capacity to adsorb colouring matter and other impurities in vegetable, animal or petroleum oils [30]. Acid activated clays are widely used as catalysts, catalyst beds, adsorbents, and bleaching earths. The most important applications of the bleaching earths are purification, decolourization, and stabilization of vegetable oils which they perform during bleaching. The interactions of clay surfaces with gases or liquids that are relevant in the fields of adsorption and catalysis are governed by the acid-base interactions mainly [31,32]. These solid acid properties make clay materials attractive due to active centres on the surface which exhibit Brønsted and Lewis acidity [33]. Other applications of bentonites include drilling fluid preparation, pelletizing iron ores, and in the activation for bleaching oils [17,34-38]. Clays remove undesired colouring bodies by adsorbing chlorophyll, carotene, copper(II), iron(III) ions, phospholipids, and soaps. The bleaching capacity of bentonite from Aegean, Greece, was observed to increase

due to a five-fold increase of the specific surface area of the raw clays after acid activation [39, 40]. The acid-activated clays were reported to be suitable for bleaching of corn, rapeseed, soybean and hazelnut oils [39-41]. It was further reported that the optimum bleaching capacity was not associated with maximum surface area. The optimum conditions for activation were obtained by using a variety of combinations of acid strength and residence time. The preparation of acid-activated clays must take place under controlled conditions to yield material having maximum bleaching capacity [22,42,43]. Whereas acid activation of clay from Ibeshe, Nigeria only increased the colour reduction from 9.1 % to 27.3%, [43] the activation of clay from Khorasan, Iran, increased its adsorbing ability from 6.35% to 96.4% using 5N sulphuric acid [10]. Clay from Udi in Nigeria when leached in 7M hydrochloric acid caused its bleaching efficiency on palm oil to increase from 29.8 to 66.7%. This work investigated the performance of Chelel clay after acid-leaching with hydrochloric acid in bleaching cotton and sunflower oils.

Cotton-seed and sunflower-seed oils are some of the edible oils which are used widely in food items. Crude vegetable oils are degummed, neutralized and bleached to become suitable for human use. Edible oils for human food are bleached with clays to reduce colour values by adsorption [44].

Langmuir isotherm for gases adsorbed to solids was published in 1909 [1,2]. The Desorption took place through the mechanism given in equation 1:



Where, A(g) was unadsorbed gaseous molecule; B(s) was unoccupied metal surface; AB was adsorbed gaseous molecule; the direct and reverse rate constants are k and k⁻¹. Basing on this theory, equation 2 was derived to explain the relationship between the number of active sites on the surface undergoing adsorption and pressure.

$$\theta = \frac{KP}{1 + KP} \quad \dots\dots\dots 2$$

Where, θ was the number of sites of the surface which were covered with gaseous molecule, P was pressure; K is the equilibrium constant for distribution of adsorbate between the surface and the gas phase. An equation representing variation of adsorption of a quantity of gas adsorbed by unit mass of solid adsorbent with pressure is given in equation 3 [46].

$$\frac{x}{m} = kP^{\frac{1}{n}} \quad \dots\dots\dots 3$$

Where, x/m is adsorbate per gram of adsorbent which is obtained are dividing the amount of adsorbate (x) by the weight of the adsorbent (m). P is Pressure, k and n are constants whose values depend upon adsorbent and gas at particular temperature. The plot of adsorbate per gram of adsorbent, (x/m) versus Pressure gives the Freundlich adsorption isotherm. The value of x/m is increasing with increase in p but as $n > 1$ it does not increase suddenly [47].

Taking the logarithms of equation 3 gives equation 4;

$$\frac{\log(x)}{m} = \log k + \frac{1}{n} \log P \quad \dots\dots\dots 4$$

Plotting a graph of $\log x/m$ is plotted against $\log p$ will be a straight line, which is another form of Freundlich isotherm. From this isotherm, the value of slope equal to $1/n$ and the value of intercept equal to $\log k$ can be obtained.

There are two types of adsorption processes; the physical adsorption which is weak involving van der Waals's forces [46] and chemisorption process leads to covalent bonding forces. As absorbance measurements can be taken in all experiments involving the bleaching processes, the relative quantity of pigment adsorbed, x and the residual relative quantity at equilibrium, X_e are obtained from equations 5 and 6 [48].

$$x = \frac{(A_0 - A_t)}{A_0} \quad \dots\dots\dots 5$$

$$X_e = \frac{A_t}{A_0} = 1 - x \quad \dots\dots\dots 6$$

Where A_0 is the absorbance of unbleached crude oil and A_t is absorbance of bleached oil at time t .

Using equations 5 and 6 and writing X_e instead of equilibrium pressure, P and the residual concentration, C ; equations 1 and 2 have been rearranged to equations 7 and 8 [49,50].

$$\frac{X_e}{x/m} = (1/a) + (b/a) X_e \quad \dots\dots\dots 7$$

$$x/m = K X_e^n \quad \dots\dots\dots 8$$

Application of Langmuir and Freundlich equations to adsorption isotherms involving bleaching of vegetable oils with bentonite has been reported by many authors purifying oils [22,41,51]. Successful application of Langmuir and Freundlich isotherms was based the decrease in absorbance of bleached oils as compared to unbleached oils. As clays leached in acid, solid mesoporous silica hydrate with high adsorptive capacity is left; it adsorbs colouring substances as well as nutritive ingredients and oxidation products from the oils very successfully [22,52-58].

2. Materials and Methods

2.1 Materials

Brown-colored clay from Chelel was used as the primary raw material. Cotton and sunflower oils were obtained from seeds.

2.2 Experimental Methods

2.2.1 Acid activation of the clay sample:

The clay was prepared for activation by air-drying and grinding to a particlesize of 200 μm . 10 g of the prepared sample was weighed into flask and hydrochloric acid solution (100 mL) was added. The resulting suspension was heated on a magnetically stirred hot plate at the temperature of 105°C for 2 hours. The resulting slurry was filtered. The residual was washed to neutrality with distilled water, and then dried to constant weight at 80°C in an oven. The dried samples were crushed using porcelain mortar and pestle and sieved to pass 200 μm meshes. The activation process was repeated with varying acid strength from 0 to 40% of hydrochloric acid. The clay samples prepared were labelled C0, C10, C20, C30 and C40, where the numbers indicate the mass percent strength of hydrochloric acid used to leach the clay.

2.2.2 Characterization:

The chemical and mineralogical compositions of the natural and activated clay samples were determined. The chemical composition was determined using x-ray Powder diffraction (Philips diffractometer with PW1710 control unit operating at 40 kV and 30 mA using the Ni-filtered Cu K_{α} radiation). The diffractograms were automatically matched with JCPDS-cards in the computerized XRD CD-ROM. Bulk mineralogy was studied with randomly oriented air-dried samples [59]. The XRD data on Chelel clay was reported in earlier papers by Mukasa-Tebandeke et al. in 2015 [16].

The clay powder (3mg, 0.01mmol) was mixed with KBr (100mg, 0.08mmol) ground to powder and pressed into discs. The infrared spectra were run using the KBr discs using B10RD FT540 Fourier Transform IR spectrometer in the frequency range of 3700 – 400 cm⁻¹[60]. The chemical analyses of elements like aluminium, iron, calcium, sodium and potassium in clays were carried out three times for clay and done by decomposition using sodium carbonate fusion method [61] in platinum crucibles. Silica was determined by gravimetry and the other elements were analysed using the Perkin–Elmer 3030 model Atomic absorption spectrometer after dissolution of the sample in the hydrofluoric acid–perchloric acid digestion mixture.

2.2.3 Adsorption experiment: Alkali-refined crude oil (100.0 g, 0.43mol) was mixed clay powders (5.0 g, 12.4

mmol) and placed in a 250 mL Pyrex glass flask fitted with a magnetic stirrer. The flask was immersed in a thermostated iso-electric mantle at temperatures, 40, 50, 60, 70, 80 and 90°C[62]. The mixture was heated while stirring continuously for two hours at the set temperature under vacuum of 700mmHg [22,63]. The hot oil and clay mixture was filtered in a nitrogen atmosphere, cooled to 25°C. At the end of the reaction the slurry formed was filtered through a dry filter paper. The bleaching capacity of the clay was then determined by measuring absorbance of the bleached oils using a UV-Visible spectrophotometer, Shimadzu, 1201 at wavelength of 550 nm. The bleaching efficiency of the acid activated clay was calculated in this study using equation 1 below.

$$\% \text{ bleaching efficiency} = [(T_{\text{unbleached}} - T_{\text{bleached}}) / T_{\text{unbleached}}] \times 100 \dots\dots\dots 1$$

Where $T_{\text{unbleached}}$ and T_{bleached} are the absorbances of the unbleached and bleached oils respectively.

2.2.4 Absorbance of oil:

The bleached oil was put in a cuvette, the cuvette at its contents inserted in ultra violet-visible spectrophotometer running at 550 nm. The value of absorbance was recorded.

These changes lead to modification of the chemical composition, bleaching efficiency and Si/[Al + Fe + Mg] ratio of the raw and hydrochloric acid-leached Chelel clay. The data summarized in Table 1 show the effect leaching the clay in hydrochloric acid. As shown in Table 1 the effect concentration of hydrochloric acid changing respectively from 0, 10, 20, 30 to 40% caused the following percentage decrease in metal content of clay: in iron there was 21.1, 35.5, 44.75 and 53.28%; for calcium there was 57.14, 64.29, 78.57 and 78.57, for aluminium there was 19.12, 28.67, 38.33 and 41.56%, for magnesium there was 51.67, 65.83, 71.67 and 75.28% yet for potassium there was 56.59, 62.17, 68.7 and 69.1%. Since silicon dioxide did not dissolve during leaching in acid, its content increased with increase in acid concentration because of removal of the cations from the interlayer and octahedral sheets of the clay [10]. Many exchangeable cations like calcium, sodium and potassium ions were removed under mild treatment with the acid. The quantity of calcium and potassium ions remaining in clay matrix did not change significantly when the clay was treated with 30 or 40% acid mixture probably due to passivation. While aluminium was least affected by leaching in 10% acid, potassium was most affected at this low concentration. This is due to the fact that potassium lies in the interlayers yet aluminium is held in the aluminosilicate layers. Aluminium was least affected by leaching in 40% hydrochloric acid yet calcium and magnesium were most affected due to difference in reactivity.

3.0 Results and Discussion

3.1 Characterization

The percentages of iron, aluminium and silicon among bentonites worldwide are approximately 11, 18, and 60% respectively [64]. Basing on data given in Table 1, Chelel clay containing resemble bentonites and can serve as replacements for commercial bleaching earths and cracking catalysts. On the basis of relative percentages of aluminium, silicon and alkaline metals or alkaline earth metals [65], the Chelel clay satisfies the formula for nontronite $\text{Ca}_{.5}(\text{Si}_{1.7}\text{Al}_{.8}\text{Fe}_{.2})(\text{Fe}_{3.5}\text{Al}_{.4}\text{Mg}_{.1})\text{O}_{20}(\text{OH})_4$ [65].

When clays were leached in hot hydrochloric acid, metal ions in the interlayers of clays were progressively replaced with hydrogen ions. There was also dissolution of structural cations. In this way ions that retard bleaching got removed from the clay matrices [9].

The content of aluminium, iron and magnesium which constitute the octahedral ions decreased as the concentration of acid increased leading to increased surface area and bleaching capacity. Removal of Al^{3+} , Fe^{3+} , and Mg^{2+} ions the clay layer must have left unoccupied octahedral sites. The surface area must have risen as a result of the

unoccupied octahedral spaces. As the activation progressed, the empty spaces grow larger and the micro pores are transformed into mesopores and finally, because of the destruction of the crystal structure at some locations, some of the mesopores disappeared, leading to a drop in sites at which adsorption takes place [10, 17].

Table 1: Chemical analysis, bleaching efficiency, BE, of the raw and acid leached Chelel clay

Clay	C0	C10	C20	C30	C40
Element%					
Al_2O_3	24.42	19.75	17.42	15.06	14.27
SiO_2	42.28	52.69	59.76	64.48	67.33
Fe_2O_3	17.25	13.61	11.12	9.53	8.06
CaO	0.14	0.06	0.05	0.03	0.03
MgO	3.60	1.74	1.23	1.02	0.89
K_2O	2.33	1.03	0.87	0.72	0.71
LOI	5.73	3.28	2.65	2.33	2.06
BE(%) cotton oil	29.8	37.5	46.4	51.8	58.9
BE% sunflower oil	31.1	38.2	48.2	54.2	72.1
Si/(Al + Fe + Mg)	0.93	1.50	2.01	2.52	2.90

The respective increase in mass percent of hydrochloric acid used to activate Chelel clay from 0, 10, 20, 30 and 40% caused the following increase in bleaching efficiency: for cotton oil 20.5, 19.2, 10.4 and 12.1 yet for sunflower oil it was 18.6, 20.7, 11.1 and 16.8%. The highest increase in bleaching efficiency occurred when the mass percent increased from 0 to 10% for both cotton and sunflower oils. The smallest increase in bleaching efficiency occurred when the mass percent increased from 20 to 30% probably due to passivation and collapse of mesopores [10].

3.2 IR Analysis

IR spectrum of Chelel clay showed band at 800cm^{-1} due to Si-O mode and the bending mode of Al-Fe-OH bonds and absorption bands at 845cm^{-1} due to Al-Fe-OH [16,39,40]. The IR spectra of the raw and acid-leached Chelel clays are shown in Figures 1 and 2, respectively. By comparing

Figures 1 and 2, it is clear that there were some structural modifications in the clay as a result of acid activation. The untreated clay sample shows absorption bands at 473, 559, 685, 793, 920, 1038, 1104, 1640, 3450, 3525, 3626 and 3692cm^{-1} . After acid treatment, the bands at 3692 and 3626cm^{-1} attributed to the O-H stretching of kaolinite were modified to 3694 and 3623cm^{-1} , respectively. The vibration bands at 3525 and 1104cm^{-1} associated with Al - O - Al were completely absent after acid activation, while bands at 1037, 920, 792, 685, and 559cm^{-1} related to the Si - O - Si and O - Si - O stretching remained after acid leaching. This explains why elemental analyses showed that the silica content increased with increase in strength of acid used to leach clay; while the octahedral cations like aluminium, iron (III), and magnesium ions decreased. This indicated that there was damage to the crystal structure of the clay caused by acid-leaching [14,21,66-68].

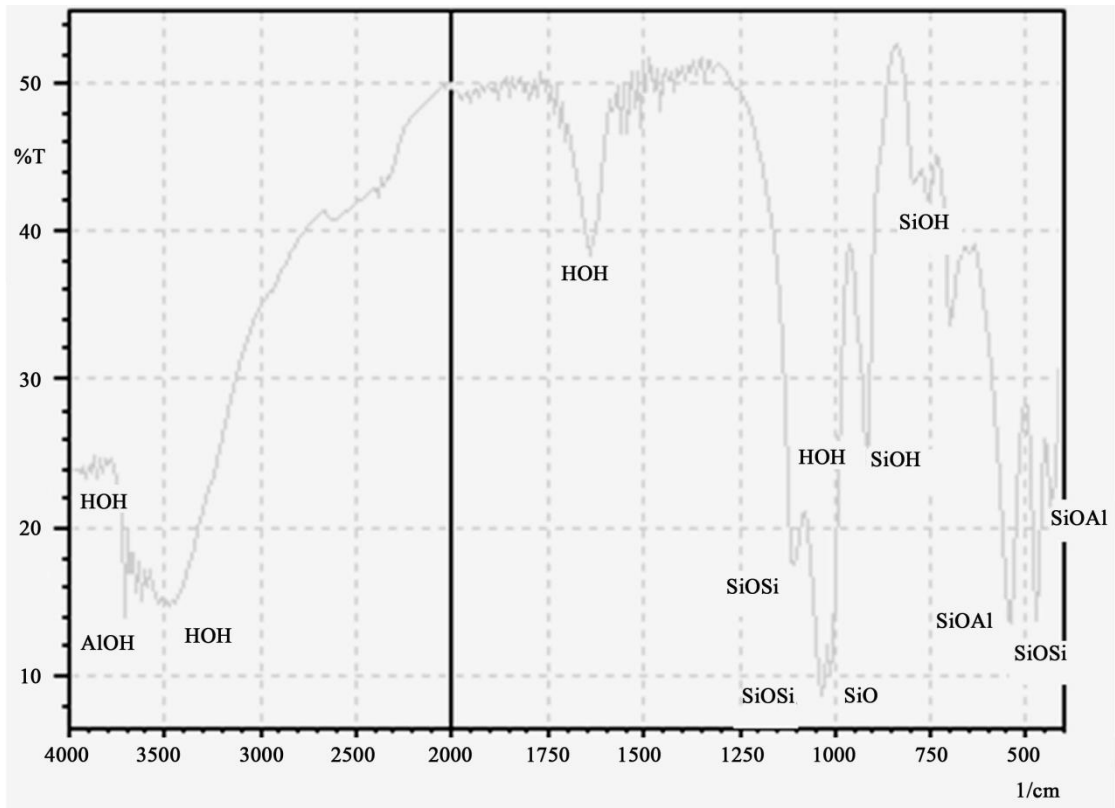


Figure1: IR spectra of raw Chelel clay

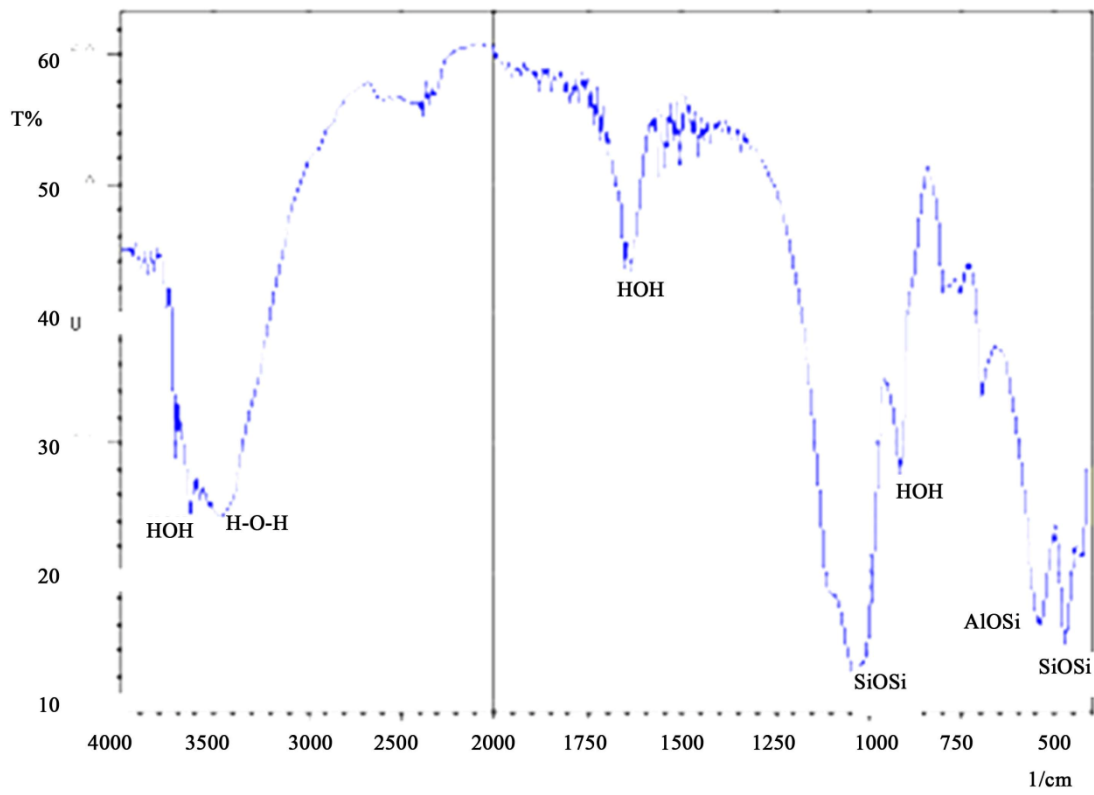


Figure2: IR spectra of acid-activated Chelel clay

In Figure 2, the leached clay shows peaks due to water and hydroxyl groups because the octahedral ions were replaced by hydrogen ions which got attached to the silica skeleton. When the hydrogen ion attaches itself to oxygen on silicon, more and more hydroxyl groups result. So the IR spectrum for the sample formed has many H-O stretches.

3.3 Bleaching Efficiency

The results of the bleaching studies performed using the raw and acid-leached clays are shown in Figures 3a and 3b. The bleaching efficiency increased with an increase in the acid

concentration used in the activation of clay. The increase in bleaching capacity with increase in mass percent of acid was probably due to removal of octahedral ions, organic matter or impurities covering the active sorption sites and the formation of active acid sites on the clay resulting in structural modifications caused by activation. It has been observed that the sample activated with 40% hydrochloric acid showed the highest bleaching efficiency. The figure also shows that contact time is important, because the bleaching efficiency increased with increase in time. Thus Chelel clay activated using 40% acid when left in contact with oil for 60 minutes showed the highest bleaching efficiency.

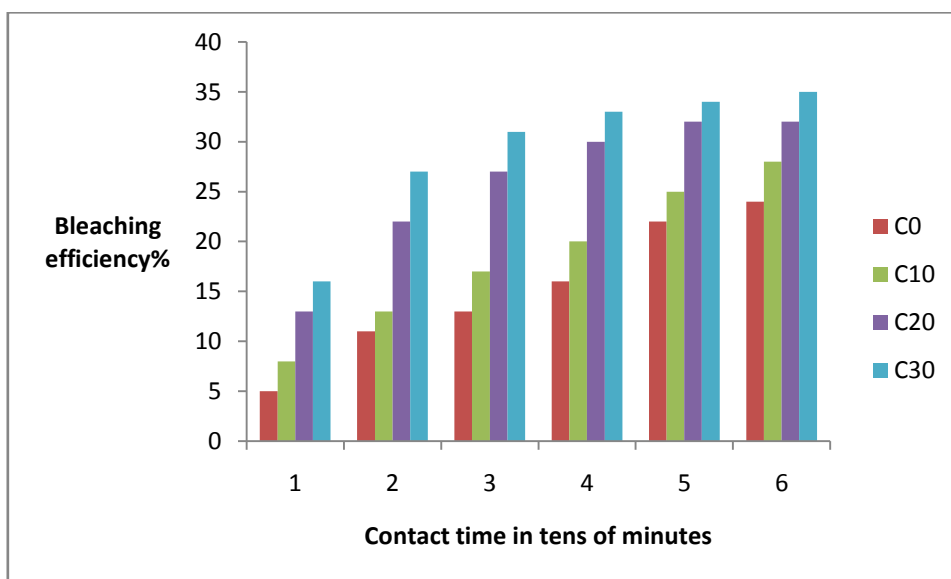


Figure3a: Bleaching efficiency of the raw and acid-leached Chelel clay on cotton oil

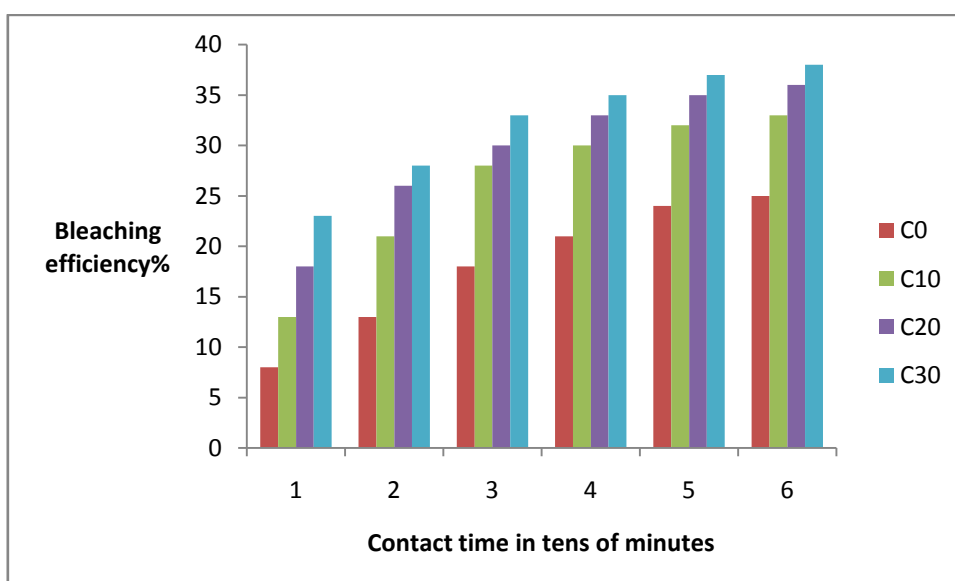


Figure3b: Bleaching efficiency of the raw and acid-leached Chelel clay on sunflower oil

For both cotton and sunflower oils irrespective of the contact time, clay leached in 40% acid had the highest bleaching efficiency because it suffered the greatest structural changes during leaching and therefore acquired the largest number of Lewis and Broenstedcenters at which adsorption of impurities in oils could get attached[69]. Similarly, the acid leached in 40% acid would not easily get saturated with impurities, so it would clarify oils longer than others. The capacity of leached Chelelclay to bind colored impurities was high because there was no steric interference

between the adsorbed and free impurities present in oils being bleached as the clay had acquired many adsorption sites during acid leaching, so the clay did not easily reach saturation[70,71]. However, Chelel clay had higher capacity to bleach sunflower than cotton because sunflower oil was less intensely colored than cotton oil.

The data plotted in Figure 4 has indicated that the bleaching efficiency of the clay samples increased with loss of octahedral cations of aluminium, iron (III), and magnesium ions during the activation process.

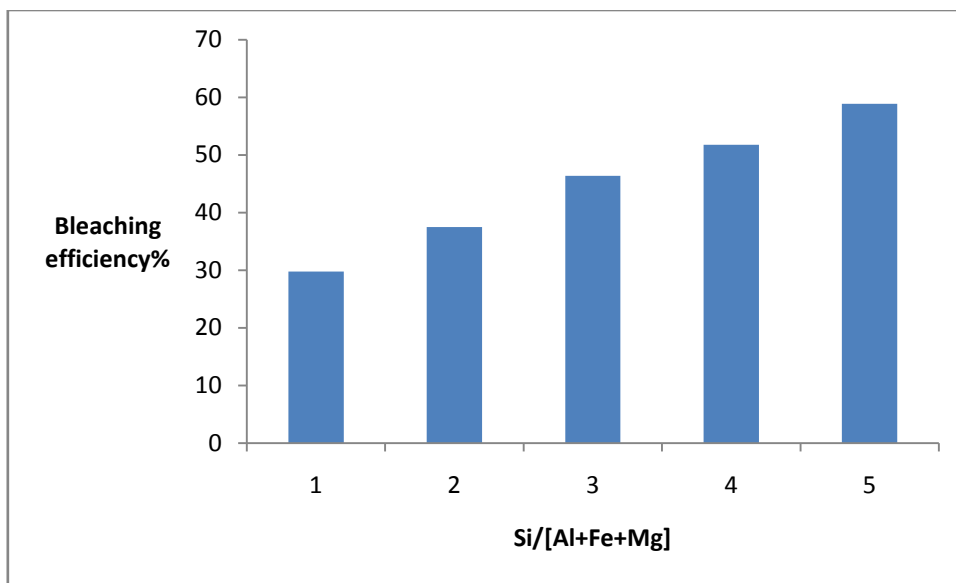


Figure4: Variation of bleaching efficiency with Si/[Al+Fe+Mg] for cotton oils

Figure 4 revealed that clays or aluminosilicates in general, once leached in acid, turn into silica hydrate or silicic acid. So Chelel can be turned to bleaching earth, but the concentration of acid used, temperature at which the reactions are performed and duration of time over which the reactions are allowed to occur will determine the bleaching capacity the clay acquires. Bleaching efficiency of leached clay increased with increase in silica content of leached clay because hydrated silica plays the major role in bleaching of oils. The higher the silica content in the leached clay the greater the ability of material to adsorb colored and other impurities in oils.

The absorbance of oils decreased with increase in acid strength and temperature at which the oil was bleached because the effectiveness of the clay to bleach increased. So the coloring bodies progressively got more sites to adsorb to as more octahedral and interlayer ions got removed during the acid leaching of the clay.

As absorbance measurements can be taken in all experiments involving the bleaching processes, the relative quantity of pigment adsorbed, x and the residual relative quantity at equilibrium, X_e are obtained from equations 5 and 6 [41].

3.4 Adsorption Isotherms

The absorbance at 550nm of cottonseed oil and sunflower oils bleached with Chelel clay activated using hydrochloric acid of different strengths noted as C10, C20, C30 and C40 are reported in Table 2a and 2b. The absorbance for unbleached, crude sunflower-seed and cotton-seed oils were respectively determined to be 2.583 and 3.383 at 550nm.

$$x = \frac{(A_0 - A_t)}{A_0} \dots\dots\dots 5$$

$$X_e = \frac{A_t}{A_0} = 1 - x \dots\dots\dots 6$$

Where A_0 is the absorbance of unbleached crude oil and, A_t is absorbance of bleached oil at time t .

$$\frac{x}{m} = KXe^n \dots\dots\dots 8$$

Using equations 5 and 6 and writing X_e for the residual concentration, C of coloring bodies; equations 7 and 8 were obtained [49,51].

$$\frac{X_e}{x/m} = (1/a) + (b/a)X_e \dots\dots\dots 7$$

A plot of $X_e/(X/m)$ versus X_e (Langmuir isotherm)and $\log X/m$ versus $\log X_e$ (Freundlich isotherm)should give straight linesand Langmuir constants (a, b) and Freundlich constant(k, n) are calculatedfrom intercept and slope of straight lines of the isotherms.Representative plots of the Freundlich isotherm for C0, C10, C20, C30 and C40 are shown in Figures 5a to 5d.

Table 2: Mean Freundlich Data on Bleached CottonOils (n=3).

Temp ^o C	C0		C10		C20		C30		C40	
	Log x_e	Log $x_e/(x/m)$	Log x_e	Log $x_e/(x/m)$	Log x_e	Log $x_e/(x/m)$	Log x_e	Log $x_e/(x/m)$	Log X_e	Log $x_e/(x/m)$
40	-1.3	-0.005	-1.45	-0.01	-1.75	-0.02	-2.3	-0.03	-2.4	-0.05
50	-1.2	-0.01	-1.4	-0.02	-1.6	-0.038	-2.1	-0.05	-2.3	-0.063
60	-1.1	-0.015	-1.3	-0.038	-1.5	-0.058	-2.0	-0.06	-2.2	-0.07
70	-1.0	-0.038	-1.2	-0.05	-1.4	-0.07	-1.8	-0.078	-2.0	-0.09
80	-0.85	-0.06	-1.15	-0.07	-1.2	-0.085	-1.7	-0.09	-1.9	-0.11
90	-0.075	-0.07	-1.1	-0.083	-1.12	-0.095	-1.6	-0.1	-1.7	-0.13

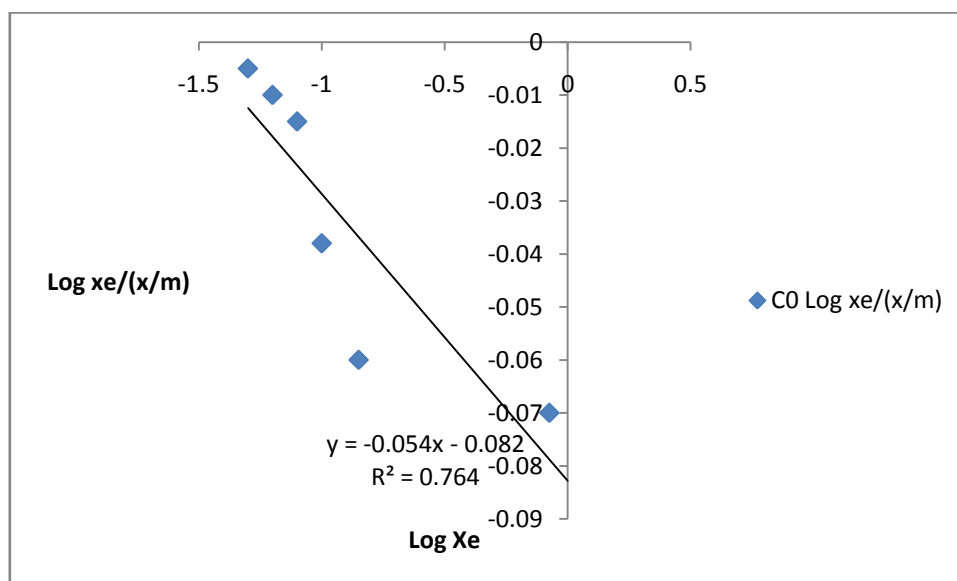


Figure 5a: Representative Freundlich isotherm for oil bleached using raw Chelel clay C0,

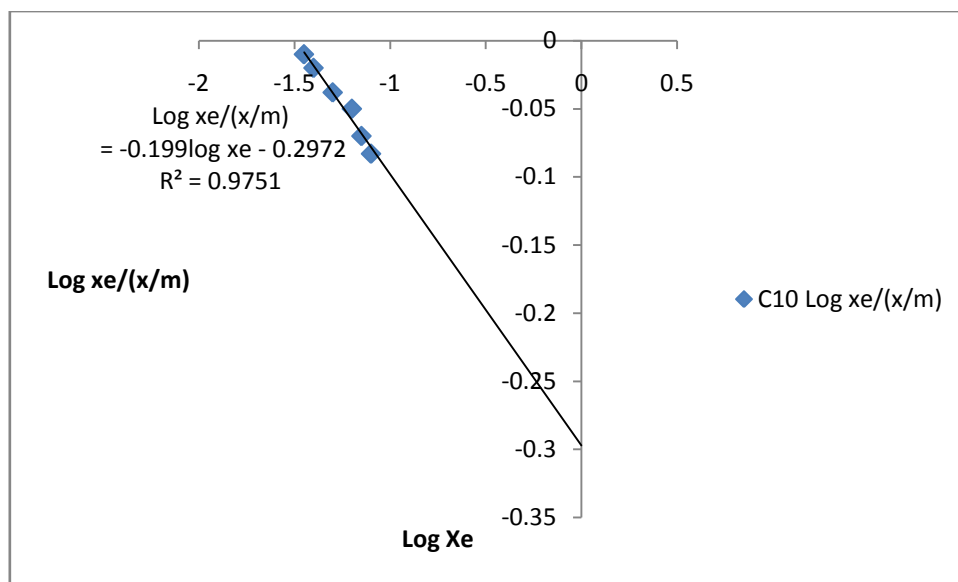


Figure 5b: Representative Freundlich isotherm for oil bleached using clay leached in 10% acid C10

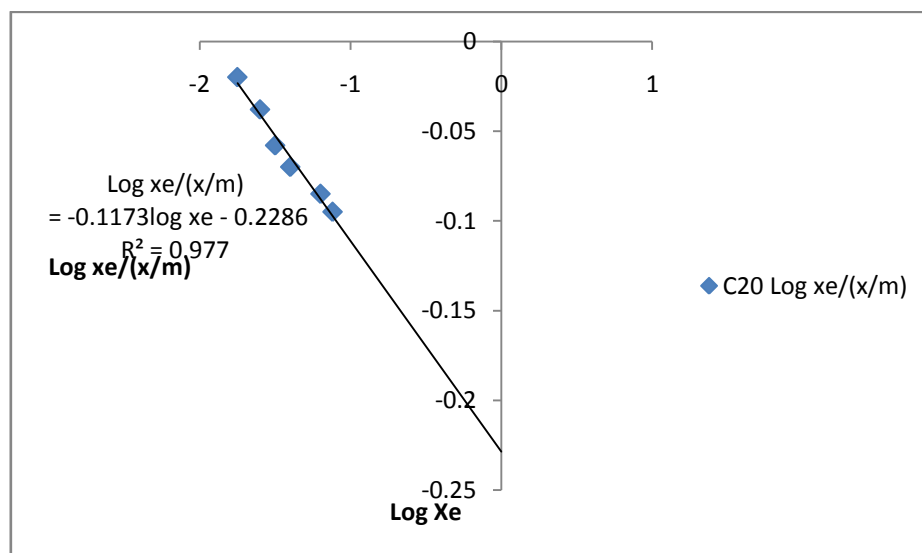


Figure 5c: Representative Freundlich isotherm for oil bleached using clay leached in acid.

The linearity of Langmuir and Freundlich isotherms was very high showing that upon leaching with acid, Chelel clay developed very high adsorptive tendencies for the impurities in the oils being bleached.

The values of the vertical intercept k , increased in magnitude from -0.1643 for raw clay, C0 to -0.285 for 40% acid leached clay, C40. However, clay leached in 10% acid had even a higher k value because the clay was highly bleaching. The values for bentonites lie in range -0.06 to -0.095 [50]. The low value of k for raw Chelel clay showed that the clay was very poor at bleaching when it has not been leached with the acid due to high levels of sodium, calcium and potassium ions which retard bleaching [9], acid leaching removed those octahedral ions leading to higher bleaching power and hence higher k . The values of the slopes of the Freundlich isotherms decreased in magnitude from -0.199 for clay leached in 10% acid, C10 to -0.0974 for clay leached in

40% acid, C40. This indicated that bleaching clay formed was highly effective in binding coloring bodies and other impurities in oils. According to James et al. [72], when the value of n is below 0.5, it depicts that the clay is a very good adsorbent. Rossi et al. [73] stated that if the n is high, the adsorbent will be effective for removing the first portions of colour but less efficient for reaching highest bleaching degree.

The Chelel clay was heterogeneous because it had Broensted and Lewis centres and as well contained different phases of clays, such as kaolinite, nontronite and illite layers, which also have active centres on their surfaces. Similarly, heterogeneity of Cyprus bentonite was attributed to different active Broensted and Lewis centres on the clay surface and the different phases present in bentonite, such as illitic layers and clinoptilolite, which also have active centres on their surfaces as the clay was a mixture of illite and smectite [19,71].

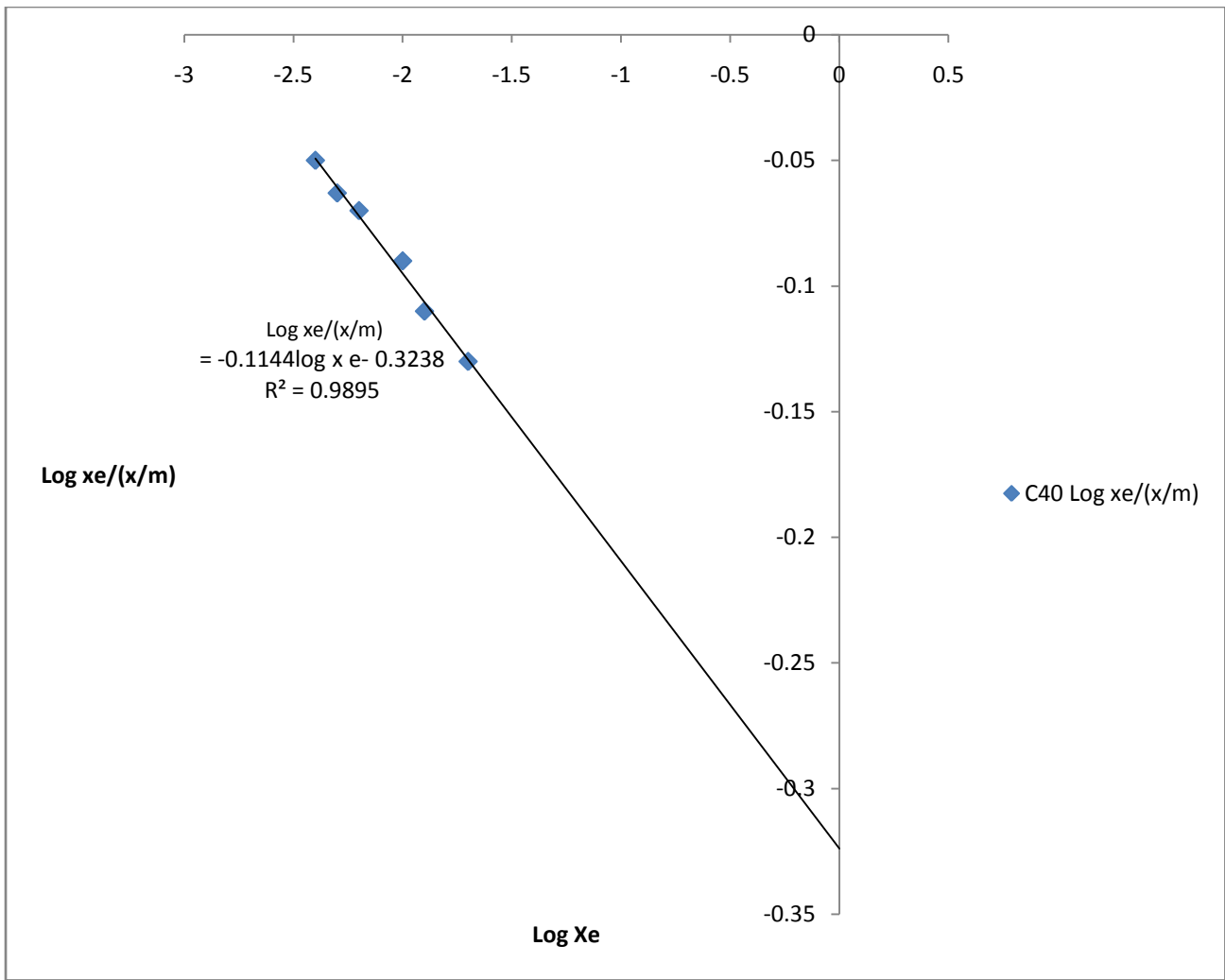


Figure 5d: Representative Freundlich isotherm for oil bleached using clay leached in 40% acid C40

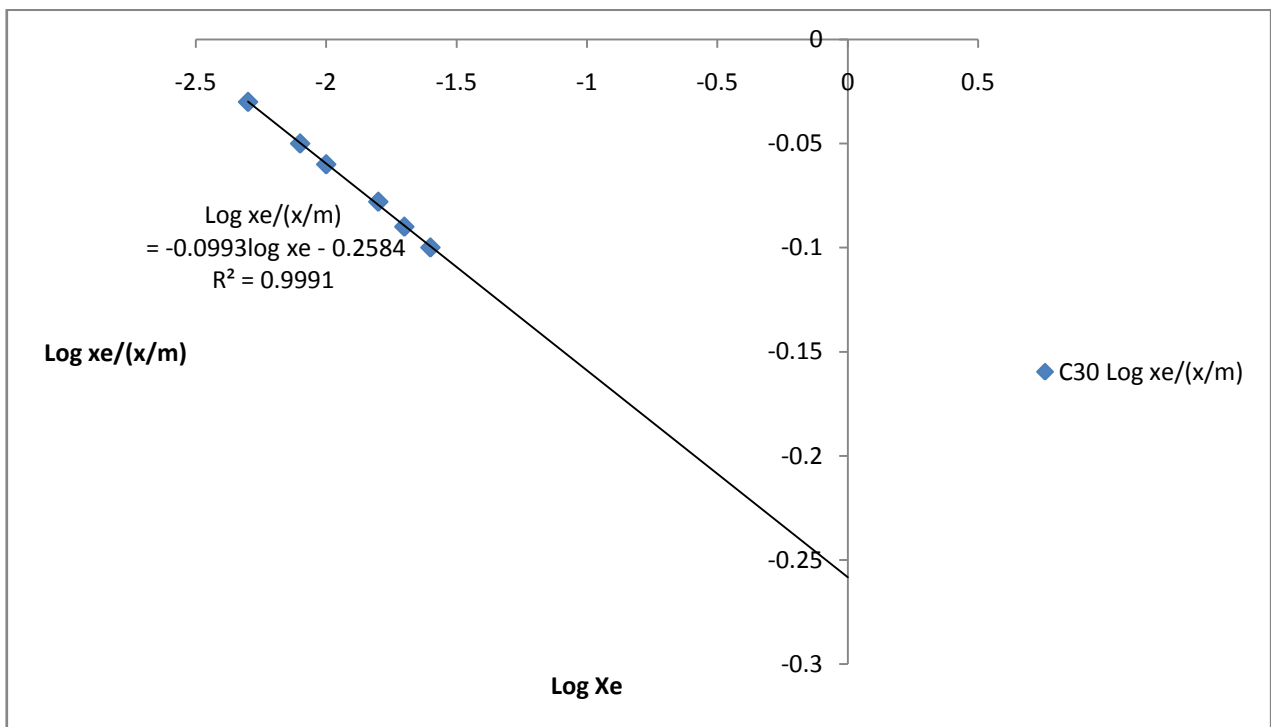


Figure 5e: Representative Freundlich isotherm for oil bleached using clay leached in 30% acid C30

Figures 5a to 5e consist of linear graphs indicating that Freundlich adsorption occurred during the bleaching of cotton and sunflower seed oils at temperatures in the range between 40 and 90°C.

The R^2 values for Freundlich isotherms in Figures 5a to 5b 0.764 ± 0.030 to 0.999 ± 0.030 showing that the clay was strongly adsorbing colouring impurities in within lower concentration ranges [74]. The linearity of Freundlich isotherms increased with concentration of acid used to leach the clay indicating the clay became better adsorptive material at higher concentrations. The linearity of raw clay was very low because the clay contained octahedral ions which retard bleaching. As linear Freundlich adsorption isotherms assume monolayer adsorption capacity, complications arose when the clay exhibited multi-layer adsorption tendencies at higher impurity concentrations; this caused deviations from linearity [75].

4.0 Conclusion

The bleaching performance of Chelel clay activated using hydrochloric acid on cotton and sunflower oils has been successfully investigated. The structural modification in clay caused by the acid activation process led to increase in

bleaching efficiency from 29.8 to 58.6% for cotton oil yet that for sunflower seed oil increased from 31.1 to 72.1% for sunflower oils when the mass percent of hydrochloric acid used to leach the clay increased from 0 to 40% respectively. Basing on the data accumulated on raw and acid leached clay, leached Chelel had higher bleaching efficiency than the raw one and the concentration of acid played the major role in increasing efficiency.

Recommendation

The results produced in this research need to be tested in industrial batch settings. This will avail chance to using Chelel clay for commercial bleaching.

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