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Kinetics and Equilibrium Studies of Colour Pigments Removal from Crude Palm Oil Using Acid Activated Kaolin Clay and Mathematical Method

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Abstract- This study looked into the adsorptive removal of the color pigment (due to the high content of carotenoids) from palm oil using ortho-phosphoric acid activated kaolin clay. To boost its adsorptive capability, the clay was activated at various acid concentrations. Adsorbent dosages (1.0 – 3.0 g); reaction temperatures (30 - 120°C); and reaction time (5 – 60 minutes) were used for the adsorption experiment to determine the impact of process variables on the bleaching efficiency of raw and activated clay samples. The experimental results were analyzed using Freundlich and Langmuir adsorption isotherms. With a regression coefficient of 0.9673, the data fitted the Freundlich Isotherm model better than the Langmuir Isotherm Pseudo-first order, Pseudo-second order, and intra-particle diffusion kinetic models were also used to analyze the experimental results. With a regression coefficient of 0.9982, the experimental data matched the Pseudo-second order kinetic model better than other kinetic models. Since the magnitude is less than 20kJ/mol, the value of H obtained is -11.108kJ/mol, implying that the adsorption mechanism is exothermic and physisorption in nature. The results show that acid concentrations, contact time, temperature, and clay dosage all improve bleaching performance.

Keywords- *Adsorption Isotherm, Bleaching Efficiency, Ortho-Phosphoric Acid, Kaolin Clay, Palm Oil, Mathematical Method*

I. Introduction

Palm oil is the maximum extensively-used vegetable oil in the world. Palm oil is squeezed from the end result of the oil palm tree (Elaeis Guineensis). Oil palm timber develops in areas across the equator. The oil palm is a tropical tree with leaves approximately five meters lengthy. When the oil palm timber are 3 to 4 years old, they expand palm fruit in bunches. The fruit bunches are harvested for the duration of the yr. Each bunch consists off loads of palm end result. Palm end results are approximately the dimensions of massive olives. The fruit has unmarried seed or kernel, that's used to supply palm kernel oil. Palm oil has a special orange-pink colour because of its excessive content material of carotenoids. Palm oil is used especially for cooking, margarine and shortening. It additionally has non-meals programs which includes in cleaning soap, detergent and cosmetics manufacturing (Madya, D.R., Morad, N.A., Aziz and Rohanibinti, M.Z 2015). A mesocarp debt for approximately 60% of the full composition of palm oil fruit and crude palm oil is derived from this element. Crude palm oil is acquired from the mesocarp after passing via numerous methods which includes sterilization, stripping, extraction and purification (Madya, D.R., *et al*., 2015). Crude oil generally consists of suitable triglyceride, unsaponifiable remember collectively with small quantity of impurities which includes natural pigments, oxidation metals, hint metals and hint soaps. (Ejikeme, E. M., Egbuna, S.O., and Ejikeme, P.C.N., 2017). For palm oil to be fit to be eaten those impurities which negatively have an impact on the flavour and odour of the oil in addition to its look and shelf existence balance, therefore lowering client attractiveness and marketability need to be eliminated. Thus, the refining of palm oil via adsorptive bleaching stays inevitable in the oil refining enterprise (Bockisch, M. E, 2017). Bleaching is one degree of the refining methods that's the maximum delicate. In this degree, the unwanted material which includes oxidation merchandise, colour our bodies, phospholipids and glycolipids, cleaning soap contaminants and metallic lines are eliminated through bringing into touch with a floor-energetic substance that adsorbs the undesired debris. Bleaching of fit to be eaten oils facilitates in elevating their smoke factor and garage durability (Ajemba, R. O., Igbokwe, P. K. and Onukwuli, O. D., 2016).

According to Gunstone and Norris (1983), there are 3varieties of bleaching. These are:

i. Heat Bleaching
ii. Chemical Oxidation, and
iii. Adsorption

Heat bleaching includes the oil being heated so the carotenes come to be colourless. Nevertheless, the consistency of oil can be affected. The decolourisation of carotene calls for chemical oxidation. One large disadvantage of this method is that the glycerides and herbal antioxidants are killed through it. It isn't normally used for bleaching of fit to be eaten oils, however restricted to oils used for technical purposes. Finally, with the useful resource of bleaching marketers, adsorption procedure is extensively used to bleach fit to be eaten oil. The gain of the adsorption procedure over different procedures is the potential to without affecting the consistency of the oil, cast off the colour of the oil, for the reason that bleaching agent has a massive floor this is extra or much less prompted through the pigment kind molecules (Ejikeme, E. M., *et al*., 2017).

Many adsorbents like acid activated bleaching earth, activated carbon and artificial silicates are used for the adsorption of colour from fit to be eaten oils. These bleaching earths are generally silicates of aluminium and are montmorillonitic clays that display adsorptive homes of their herbal and activated state (Baptiste, B. J., Esther, N., Mirela, P., and Richard K., 2013)

Normally, bleaching marketers have a vast floor that has an extra or much less particular affinity for Molecules of the pigment shape, therefore isolating them from the oil without negative the oil itself. A massive floor, excessive precise floor place (m2/g) and a completely porous adsorbent are required for powerful adsorption.

Thermodynamics and kinetics are typically used to degree the overall performance and mechanisms of adsorption. Organic clay minerals from the earliest days of records are widely recognized and not unusual place to mankind. (Preeti, S. N. and Singh B. K., 2017). Their low value, abundance in the majority of continents Worldwide, excessive homes of sorption, excessive dissolubility in acidic answers and ion ability Exchange way the clay merchandise are perfect adsorbents of materials. Minerals from Clay are Phyllosilicates or layer silicates are not unusual placed.

These minerals have the platy morphology because of the business enterprise of atoms in the shape. The shape has critical elements: A corner-connected tetrahedral sheet and an octahedral edge-sharing sheet. The interconnection of the 2varieties of sheets may be organized to shape the two variables of sheets.

Clay deposits are not unusual place in Nigeria's areas and are generally below-used in the Industries. It is feasible to mine, purify and refine those clay deposits into usable uncooked substances for Process industries. The composition of those clays may be modified through heating or through chemical reactions with robust acids or bases a good way to decorate their adsorptive homes and colour. In order to decorate the adsorption homes and variety of applicability, some of bodily and chemical strategies had been investigated to alter the clays which include warmness treatment, acid activation, treating the cationic surfactants and polymer modification. (Akinwande, B.A., Salawudeen, T. O., Arinkoola, A.O. and Jimoh, M .O., 2015).

Several authors have studied using activated clay in the bleaching of oils. (Salawudeen, T. O., Dada, E.O., and Alagbe, S.O., 2017; Kashani, M. M., Youzbashi, A. A and Amiri, R.Z., 2011); Dombrosku, T., and Handerson, J., 1997) studied the impact of acid activation at the structural homes of bentonite. The end result confirmed that the bentonite floor place may be improved after acid treatment. Dombrowsky T., *et al.*, (1997), mentioned a few adjustments which smectite crystal undergoes after activation, those encompass establishing of the crystal edges which exposes the Al3+ and Mg2+cations to acid and next dissolution of the cation, enlargement of the floor pore diameter, and that the precise floor place of smectite will increase to a most and decreased through extra treatment. (Ajemba, R. O., *et al*., 2016) additionally mentioned that the acid activation of ukpor clay triggered a few changes in the shape of the clays.

II. Palm Oil (Elaeis guineensis)

It is generally believed that the Oil Palm (Elaeis guineensis), in Fig. 1 started in the tropical rain forest locale of West Africa(Kwasi, P., 2002).The essential belt runs via the southern scopes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the tropical locale of Angola and the Congo. Palm oil these days is extensively stated as a bendy and nutritious vegetable oil. Transfats unfastened with wealthy substance of nutrients and antioxidant. Oil palm tree expand up to twenty m in stature and expand exceptional at temperature of 24 – 27^{o}C and calls for a muggy weather and the evolved oil palm includes herbal merchandise from their fourth year ahead and may be amassed for 40 – 50 years. (Bockish, M. E., 2018).

Palm oil is gotten from the fleshy element or the mesocarp of the fruit of the palm species Elaeis guineesis. Structure of the palm fruit indicating the mesocarp and little bit of the fruit is proven in Fig. 2. Palm oil is rich in carotenoids from which it derives its profound pink colour, and the predominant aspect of its glycerides is the soaked fatty palmitic acid. It can be a thick semisolid, even at tropical encompassing and a robust fat in slight climates. (Kwasi, P., 2012).Oil palm is the simplest herbal product which could donate those forms of oil: Palm oil from the fibrous mesocarp and Palm kernel oil from the palm kernel.

Both are eatable oils however with tremendously various chemical composition, bodily homes and programs. Each palm herbal product produces round ninety% palm oil and 10% palm element oil.

Figure 1. Oil Palm (Elaeis guineensis)

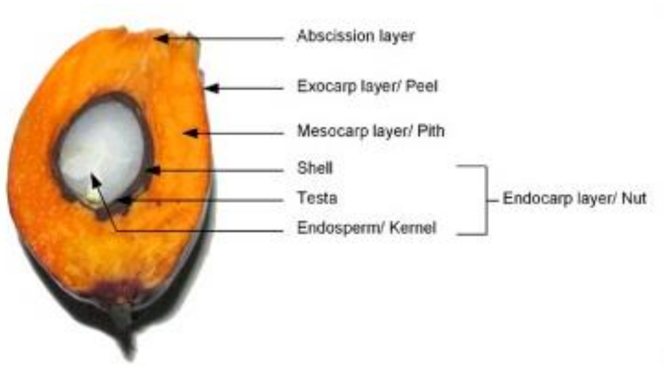

Figure 2. Structure of the Palm Fruit

Palm oil and palm bit oil have an extensive range of programs; about eighty% are applied for meals programs while the relaxation is feedstock for some of non-meals programs.

A. Chemical composition of palm oil

Sundram (2013) expressed that crude vegetable oil normally incorporates of suitable triglycerides, unsaponifiable remember along little sum of impurities. The compositions of crude palm oil may be labeled as a mix of 5essential chemical bunches as proven in Table 1. A few of those chemical bunches have to be expelled generally or absolutely via the refining procedure a good way to supply exquisite consumable oil that has higher balance and garage.

1) Fatty Acids

Fatty acids are characterised as compounds which are composed of lengthy chains of carbon and hydrogen iotas containing a carboxylic acid at one end. Fatty acids comparison from each other in duration of the hydrocarbon tails, diploma of unsaturation (double bond) and function of the double bonds in the chain. Palm oil incorporate kind of 44% palmitic acid (saturated), five% stearic acid (saturated), 39% oleic acid (monosaturated), and 10% limoleic acid (polyunsaturated). (Prada F., Ayala-.Diaz, I. M., Delgado, W., Ruiz-Romero, R., and Romero, H. M., 2016); (Sambanthamurthi, R.,Sundram K., and Tan, Y.,2010)

TABLE I. COMPOSITIONS OF CRUDE PALM OIL SOURCE: ABDUL AZIS, (2000)

Group	Components
Oil	Triglyceride, Diglyceride Mono glyceride Phospholipids, Glycolipid and Lipoprotein, Free fatty acids
Oxidized Products	Peroxides, Aldehydes, Ketones.
Non-oil (but oil soluble)	Carotene, Tocopherols, Squalene, Sterols
Impurities	Metal particles, Metal ions, Metal complexes.
Water Soluble	Water (moisture), Glycerol, Chlorophyll pigments, Phenols Sugars (soluble carbohydrates)

2) Carotenoids:

Carotenoids are an own circle of relatives of compounds of extra than six hundred fats-soluble plant pigments that offer plenty of the colour we see in nature. The dim pink-orange colour of oil palm herbal product is because of the excessive attention of carotenoids and anthocyanins. (Kwasi, P., 2012; Choo and Ng, M. H., 2016).

Crude palm oil consists of the maximum noteworthy concentration of not unusual place carotenoids, which proves to be the foremost promising vegetation for carotenes reasserts in nature. Crude palm oil, extracted commercially through sterilization and press, consists of 500-seven-hundred ppm of carotenoids, the variety being because of procedure situations, species of oil palm and degree of oxidation. The predominant additives are α-carotene (37%) and β-carotene (47%) representapproximately84% of the carotenoid substance in pink palm oil, (Fife, 2007). Physically subtle oils display no hint of the carotenoids on account that they're either retained onto the fading earths or destroyed amid warm treatment.

3) Tocols (tocopherols and tocotrienols)

Oil palm is the richest supply of tocotrienols (as much as 800 mg/kg) and is made of78% tocotrienols and 22% tocopherols. (Gapor, A., 1989; Chandan, K. S, Cameron, R. and Savita, K., 2010). Tocotrienols are tremendously now no longer observed in some other vegetable oils like soy bean oil, canola oil, assault seed oil and sunflower oil however may be observed generally however in plenty lesser quantities in rice barn, barley, wheat pearl and oats. (Heinnen and Piironen, 1991; Sambanthamurthi, R.,*et. al*., 2010). Tocols, are herbal antioxidants observed in plant-primarily based totally oils, incorporate 4tocopherols and 4tocotrienols isomers, every assigned as alpha (α), beta (β), gamma (γ), and delta (δ) (Brigelius-Flohé, and Trabe., 1999). The composition of the predominant nutrition E isomers in palm oil: α - tocotrienol, α - tocopherol, γ - tocotrienol and δ-tocotrienol as appeared in Table 2.

TABLE II. COMPOSITIONS OF TOCOLS IN CRUDE PALM OIL SOURCE: GAPOR, (1995)

Tocols	%
α –Tocopherol	22
α –Tocotrienol	20
γ -Tocotrienol	46
δ -Tocotrienol	12
Total tocols (ppm)	600-1000

Tocotrienols are contributors of the nutrition E own circle of relatives and may be applied as a nourishment additive as properly rather for Vitamin E (α tocopherol proportionate movement). The nutrition E own circle of relatives are critical nutritional additives because the frame can't synthesize ok itself. Be that as it could those have one-of-a-kind antioxidant sporting events while measured in human plasma. The predominant distinction among tocotrienols and tocopherols is in that tocopherols have saturated facet chains, while tocotrienols have unsaturated isoprenoid facet chains with 3 double bonds. (Kamal-Eldin and Appelqvist, 1996).

B. Applications and preferences of palm oil

Palm oil is broadly applied in cooking and meals making. It is applied as cooking oil, crispy fats and margarine. Palm oil can effortlessly be processed, retained, and it promotes human frame health. A few of the uses of palm oil are:

- Palm oil can be a predominant supply of vegetable fat applied for the fabrication of soaps.
- Palm oil is wealthy in nutrition A and nutrition E
- Large sum saturated fatty acid, and it's miles much less inclined to oxidative deterioration.

III. REFINING OF OIL

Crude oil generally consists of suitable triglyceride, unsaponifiable remember at the side of small amount of impurities like natural pigments, oxidation metals, hint metals and hint soaps (Higuchi, 1983). These impurities might be eliminated through purification step with a view to deliver desirable first-rate oil. To deliver higher fit to be eaten oil with pinnacle first-rate balance, some of those chemical businesses need to be absolutely or partly eliminated via refining methods. The characteristics of the completed product that require to be monitored are flavour, shelf-existence balance and colour of the merchandise. Looking at the running characteristics, the form of chemical compounds used and mode of disposing of the unfastened fatty acids, FFA, there are vegetable oil refining technology which can be: (Belaw, D.B and Tribe, G. K., 2012; Madya D. R.,*et. al*., 2015; Laidler, K. J., 2015).

- Chemical (alkaline) refining, and
- Physical refining

Chemical refining is the conventional approach used in the beyond centuries. It became now no longer till the past due 1970s, that bodily refining of oil in Malaysia commenced to end up a better alternative, in a few approaches, to alkali refining (Yusoff, M. S. A., and Thiagarajan, T., 2018). In latest years, with the continuous development procedure of bodily refining strategies and equipment, making the blessings of bodily refining approach come to be an increasing number of evident. Physical refining has confirmed to be very a success for oil and current refineries in Malaysia are especially the use of bodily refining routes. Vegetable oil is typically subtle through the bodily procedure, that's desired over the motion on account that excessive acidity (as much as5%) can bring about immoderate lack of impartial oil in cleaning soap inventory after alkali neutralization. (Madya, D. R.,*et. al*., 2015).

A. Chemical (Alkaline) Refining

Chemical or Alkali refining is that using alkali neutralization and elimination of maximum of the unfastened fatty acids in the sort of cleaning soap. The maximum cause of the chemical refining is to saponify the FFA through an alkaline answer and dilute the ensuing soaps in a completely water segment. These soaps are eliminated through separators. The impartial oils are sooner or later bleached and deodorized. The chemical refining can be used for reliably refining truly all crude oils, which include oils of low first-rate, aside from purgative. (Zeldenrust, R. S., 2015). Sixteen other unwanted non-glyceride substances are also eliminated moreover to the elimination of Free Fatty Acids, FFA consists of: Phospholipids (gums), Oxidized merchandise, Metal ions (e.g. iron, copper), Colour pigments (e.g. gossypol), Insoluble Impurities (e.g. meal fines). (Madya, D. R.,*et. al*., 2015).

B. Physical Refining

An excessive temperature and below vacuum situations of the oil subjected to a steam distillation of the unfastened fatty acids is connected in bodily refining procedure. The bodily refining procedure is composed of some steps and every step expels positive sort of impurities. The bodily refining points at disposing of the unfastened fatty acids, phosphatides, gummy substances, conjointly to enhance its colour. The steps taken are; degumming, neutralization, bleaching and decolourization

(Mustapha,S. I., Mohammed, A. A., Zakari, A. Y., Mohammed, H. A.,2013).

1) Degumming

The number one goal of degumming is to expel the unwanted gums from the oil, on the way to intrude with the steadiness of the very last product in in a while degree. Typically completed through treating the crude palm oil with the specified amount of meals evaluate acid (generally phosphoric or citric acid) of positive attention. The maximum aspect contained in the gums, which needs to be eliminated, is phosphatide. (Madya, D. R., *et. al*., 2015). It is critical to cast off the phosphatide content material in the crude oil for the reason that nearness of this aspect will confer unwanted flavour and colour, and shorten the shelf existence of oil. The phosphatides emulsifying interest is the maximum offender that reasons the oxidative instability of the crude palm oil. The various forms of degumming procedure in vegetable oil enterprise incorporate (Madya, D. R., *et. al*., 2015): membrane degumming, dry degumming, water degumming, enzymatic degumming, ethylene diamine tetra acetic acid (EDTA) degumming and acid degumming. The contrasts among all of the variations among a lot of these sorts depend on strategies of processing, chemical compounds used and the content material of phosphatides in the crude vegetable oil.

2) Bleaching

Bleaching is one step of the refining forms that's the foremost fragile. In this degree, the undesirable materials which include oxidation objects, colour bodies, phospholipids and glycolipids, cleaning soap contaminants and metallic follows are expelled. The reason of bleaching is to lessen the degrees of pigments which includes carotenoids and chlorophyll, however it additionally in addition gets rid of residues of phosphatides, soaps, lines of metals, oxidation objects, and proteins. (Brooks, D. D., 1999; Bockish, M., 2018; Madya, D. R., *et. al*., 2015; Ajemba, R. O., Igbowe, P. K., and Onukwuli, O. D., 2016) Bleaching expel shades and different undesirable compounds which adversely affect the flavour of the oil through bringing into touch with a floor-energetic substance that adsorbs the undesired debris. Bleaching of palm oil is achieved through using adsorbents; extra frequently than now no longer activated carbons and activated bleaching earths (Foletto E. L., Collazo, G. C., Volzone, C., and Porto, L. M., *et al*., 2006; Salawudeen,T. O., *et. al*., 2017; Nwabanne, J. T. and Ekwu, F. C., 2013; Regina, O. A. and Okechukwu, D. O., 2012; Usman, M. A., Oribayo O. A. and Adebayo, A. A., 2013). These bleaching earths are typically silicates of Aluminium which can be extra frequently than now no longer montmorillonitic clays that showcase adsorptive homes of their function and enacted state (Oboh, A. O., Aworh, O. C. and Agagu, O. K., 2017).

3) Deodorization

Deodorization is a procedure of disposing of the fatty acids, odour, taste and destabilizing impurities, and additionally some colour bodies through subjecting the oil to excessive vacuum and temperature, augmented through coordinate steam disturbance, below situations in order that the impurities are vaporized and eliminated while the oil stays fluid. (Madya, D. R., *et. al*., 2015). Cautious execution of this procedure will furthermore enhance the steadiness and the colour of the oil, whilst defensive the nutritional cost. During this deodorization procedure, unfastened fatty corrosive (FFA) in the form of palm fatty acid distillate (PFAD) is evacuated as refining waste, on the higher phase of deodorizer. Aside FFA, carotenoids pigments, critical and auxiliary oxidation objects also are being eliminated as it could make contributions to off-flavours (Madya, D. R., *et. al*., 2015). The deodorization procedure is done below vacuum (0.5 – 8 mbar) and at temperatures among 180° C - 270°C, and the use of a stripping media.

IV. BLEACHING THROUGH ADSORPTION

A. Adsorption

Adsorption is a procedure that occurs while a gas or fluid solute aggregates at the outdoor of a robust or a fluid (adsorbent), shaping a sub-atomic or nuclear film (adsorbate). Contingent upon the form of ranges in touch, adsorption may be taken into consideration in the accompanying frameworks (Dabrowski, A., 2017): fluid gas, fluid, robust fluid and robust gas. The time period 'adsorption' become proposed through du Bois-Reymond but delivered into writing through Kayser, (1881). The terms 'isotherm' and 'isothermal bend' have been applied to depict the outcomes of adsorption estimations at regular temperature. The cycle of dust blanching of palm oil is an adsorption degree wherein blanching dust recognizes into its floor the debris of the shading remember on this manner decolorizing the palm oil (Foletto E. L.,*et a*l., 2006).

Adsorption procedure consists of parts, adsorbent and adsorbate. Adsorbent is the substance at the outdoor of which adsorption occurs whilst adsorbate is the substance that's being adsorbed at the outdoor of adsorbent as an instance adsorbate receives adsorbed. Forces of appeal exist amongst adsorbate and adsorbent and due to those forces of appeal, warmness strength is added sooner or later adsorption is an exothermic cycle.

Based at the form of forces of appeal current among adsorbate and adsorbent, adsorption may be grouped into types which can be bodily adsorption and Chemical adsorption. (Laidler, K. J., 2015).

1) Physical Adsorption

When the pressure of appeal that exists among adsorbate and adsorbent are vulnerable Vander Waal forces of appeal, its miles referred to as Physical Adsorption or Physisorption. Physical Adsorption occurs with formation of multilayer of adsorbate on adsorbent. It has low heat of adsorption i.e. ΔH adsorption is 20-40KJ/mol. It takes location at low temperature below boiling factor of adsorbate and reduces with growth in temperature.

2) Chemical Adsorption

When the pressure of appeal current among adsorbate and adsorbent are chemical forces of attraction or chemical bond, the procedure is referred to as Chemical Adsorption or Chemisorption. Chemisorption takes location with formation of unilayer of adsorbate on adsorbent. It has excessive warmness of adsorption, i.e. ΔH adsorption is 200 - 400KJ/mol. It can take place at all temperature. With the will increase in temperature, Chemisorption first will increase and then decreases. (Adsorption and its sorts Chemistry Learning, 2010).

B. Adsorption Isotherms

The procedure of Adsorption is typically studied via graphs referred to as adsorption isotherm. Itis the graph among the quantities of adsorbate adsorbed at the floor of adsorbent and pressure at consistent temperature. It is the equilibrium dating among the concentrations in the fluid segment and the attention in the adsorption debris at a given temperature. Adsorption isotherms to be had in the literature encompass (Foo, K. Y., and Hameed, B. H., 2010)

- Freundlich isotherm,
- Langmuir isotherm,
- Gibbs isotherms,
- Brunauer, Emmett, Teller (BET) isotherm, and
- Temkin isotherm.

The varieties of isotherms fluctuate in a single or extra of the assumptions made in deriving the expression for the floor insurance; in particular, on how they deal with the floor coverage dependence of the enthalpy of adsorption. Langmuir isotherm is one of the only and it provides a beneficial perception into the stress dependence of the quantity of floor adsorption. Usually bleaching or purification of palm oil follows the Freundlich adsorption isotherm on account that they contain adsorption from liquids (Rohani, B. M. Z., 2016).

1) Langmuir adsorption isotherm

In 1916, Langmuir proposed some other Adsorption Isotherm referred to as Langmuir Adsorption isotherm. (Czepirski, L., Bayls M. R. and Komorowska-Czepirska, E., 2000).This isotherm become primarily based totally on one-of-a-kind assumptions, one in every of which is that dynamic equilibrium exists among adsorbed gaseous molecules and the unfastened gaseous molecules. Langmuir adsorption equation is relevant below the situations of low stress. Under those situations, gaseous molecules might own excessive thermal strength and high escape velocity. As an end result of this much less range of gaseous molecules might be to be had near the floor of adsorbent. (Adsorption and its sorts Chemistry Learning, 2010). Langmuir considered adsorption to distribute molecules over the floor of the adsorbent in the shape of a unimolecular layer and for the dynamic equilibrium among adsorbed and unfastened molecules, and proposed the subsequent relation:

$$\frac{p}{x/m} = \frac{1}{a} + \frac{a}{b}(P) \tag{1}$$

where:

P is equilibrium stress for a given quantity of substance adsorbed,

X is the quantity of substance adsorbed, m is the quantity of adsorbent,

a and b are constants.

From equation 1, writing X_e rather than equilibrium stress P and the residual substance C,

$$\frac{Xe}{x/m} = \frac{1}{a} + \frac{a}{b}(Xe) \tag{2}$$

The relative quantity of pigment adsorbed, X and the residual relative quantity at equilibrium, X_e may be calculated from:

$$X = \frac{(A_o - A)}{A_o} \tag{3}$$

$$Xe = \frac{A}{A_o} = 1 - X \tag{4}$$

Where:

A_o is the absorbance of unbleached oil and A is the absorbance of bleached oil. The plot of $\frac{Xe}{x/m}$ versus X_e offers a slope of (a/b) and intercept of (1/a).

2) Freundlich Adsorption Isotherm

In 1909, Freundlich gave an empirical expression representing the isothermal version of adsorption of an amount of gas adsorbed through unit mass of strong adsorbent with stress. This equation is referred to as Freundlich Adsorption Isotherm. (Suresh and Sundaramoorthy, 2015) The Freundlich isotherm equation have been extensively carried out to adsorptions from dilute answers. Though Freundlich Isotherm effectively set up the connection of adsorption with stress at decrease values, it didn't are expecting cost of adsorption at better stress. (Adsorption and its sorts Chemistry Learning, 2010). The equation become derived through assuming an exponential distribution of adsorption ability energies and it takes the shape:

$$\frac{X}{m} = KC^{n} \tag{5}$$

Where: "X" is the quantity of solute adsorbed through m grams of the adsorbents at attention C in the answer.

K and n are constants.

Expressing equation 5 in logarithmic shape, and writing X_e rather than the residual substance C

$$\log\frac{x}{m} = n\log Xe + \log k \tag{6}$$

A plot of Log $\frac{x}{m}$ in against to Log X_e offers a straight line referred to as the adsorption isotherm plot with an intercept of LogK and slope n.

3) Brunauer, Emmett, Teller (BET) Adsorption Isotherm

BET Theory recommend through Brunauer, Emmett and Teller defined that multilayer formation is the real image of bodily Adsorption. (Adsorption and its sorts Chemistry Learning, 2010). Under the situation of excessive stress and coffee temperature, thermal strength of gaseous molecules decreases and increasingly gaseous molecules might be to be had in step with unit surface place. Due to this, multilayer adsorption might arise. The BET equation is given as:

$$V = \frac{V_m C X}{(1-X)(1+(C-1)X)} \tag{7}$$

Equation 7 may be rearranged to give,

$$\frac{X}{V(1-X)} = \frac{1}{V_m C} + \frac{X(C-1)}{V_m C} \tag{8}$$

where:

$$C = \frac{K_1}{K_L} \tag{9}$$

and

$$X = \frac{P}{P_o} \tag{10}$$

V_m is the adsorbed quantity of gas at excessive stress situations with a view to cowl the floor with a unilayer of gaseous molecules, K_1 is the equilibrium consistent while unmarried molecule adsorbed in step with vacant web website online, K_L is the equilibrium consistent to the saturated vapor liquid equilibrium, P_o is the saturation stress of gas and P is the stress of the adsorbate gas.

4) Temkin Adsorption Isotherm

Temkin isotherm, is one of the earliest mentioned isotherms. The Temkin isotherm has a convenient linear shape and assumes that warmness of adsorption of all molecules in the layer would decrease linearly in preference to logarithmic with insurance of the adsorbent floor. (Aharoni and Ungarish, 2017) and that adsorption is characterized through a uniform distribution of binding energies, as much as a most binding strength. The version is given through (Temkin, and Pyzhev,1940; Piccine, J. S., Dotto, G. L., and Pinto, L. L. A., 2011; Dada, A. O., Olalekan, A.P., Olatunya, A. M., and Dada, O.,2012)

$$q_e = \frac{RT}{b}\ln(A_T C_e) \tag{11}$$

$$q_e = \frac{RT}{b}\ln A_T + \frac{RT}{b}\ln C_e \tag{12}$$

where

A_T is the Temkin isotherm equilibrium binding consistent (L mol^{-1}),

b is associated with the adsorption warmness,

R is the everyday gas consistent (8.314 $JK^{-1}mol^{-1}$), and

T is the temperature(K).

Plotting the amounts orbed, q_e against in (C_e) offers an immediately line of slope $\frac{RT}{b}$ and intercept $\frac{RT \ln K_T}{b}$.

C. Adsorption Thermodynamics

Thermodynamics has the notable cap potential to attach reputedly unrelated properties. For example, the temperature coefficient of adsorption is at once proportional to the warmth of27immersion of the strong adsorbent in the gas. The foundation for thermodynamic calculations is the adsorption isotherm, which offers the quantity of gas adsorbed in the Nano pores as a characteristic of the outside stress. Thermodynamic issues of an adsorption procedure are necessary to decide the spontaneity of the response. The Gibbs unfastened strength change, ΔGo, is used to explain the spontaneity of a procedure. Reactions arise spontaneously at a given temperature if ΔGo is bad. (Ajemba, R. O.,*et al*., 2016; Chowdhury, S. and Saha, P.,2010).The unfastened strength of an adsorption, thinking about the adsorption equilibrium consistent K_f is given by the subsequent equation:

$$\Delta G^o = -RT\ln K_f \tag{13}$$

The contribution to the unfastened strength of the response from the enthalpy time period is consequently consistent, however the contribution from the entropy time period will become smaller because the temperature is lowered. The significance of ΔG^o relies upon at the temperature of the response. According to Chowdhury, S., *et al.,* 2010), a lower in the bad cost of ΔG^o with a growth in temperature indicates that the adsorption procedure is extra beneficial at better temperatures. Thus, for any change in state, we will write the relation:

$$\Delta G^o = \Delta H^o - T\Delta S^o \tag{14}$$

Equating 14 and 15, we have;

$$-RT\ln K_f = \Delta H^o - T\Delta S^o \tag{15}$$

$$\ln K_f = \frac{\Delta S^o}{R} - \frac{\Delta H^o}{RT} \tag{16}$$

The plot of $\ln K_f$ against 1/T offers a negative slope of $\Delta H^o / R$ and intercept $\Delta S^o / R$

Where,

ΔG^o is the standard free energy change (J/mol),

ΔH^o is the enthalpy;

ΔS^o is the entropy;

R the universal gas constant (8.314 J/mol K), and

T is absolutely the temperature (K)

D. Adsorption kinetics

Adsorption kinetics offers with the charge at which the adsorption procedure occurs. Kinetic fashions is used to analyze the mechanism of sorption and ability charge controlling steps, that's beneficial for deciding on foremost running situations for the full-scale batch procedure. Tempkin, M. I., and Pusev, V. (1940) studied the kinetics of sunflower seed oil bleaching and proposed a charge formula:

$$\log \frac{A}{A_o} = -K\sqrt{t} \qquad (17)$$

where,

A is the absorbance of the oil bleached a time t,

A_o is the absorbance of the crude oil, and

k is the charge constant.

Nwankwere, E. T., Nwadiogbu, J. O., Tilleng, M. T., and Eze, K. A. (2016) investigated the kinetics of beta-carotene elimination from palm oil the use of unmodified herbal clay and concluded that the adsorption observed the zero order kinetic equation. Al-Zahrani, A. A., Al-Sahahrani, S. S., and Al-Tawil, Y. A., (2010) investigated the kinetics of sulphuric acid activation of Saudi bentonite and observed out that it observed the zero order kinetic equation.

1) Pseudo-first-order charge equation

Lagergren (1898) offered a first-order charge equation to explain the kinetic procedure of liquid solid segment adsorption of oxalic acid and malonic acid onto charcoal, which is thought to be the earliest version bearing on the adsorption charge primarily based totally at the adsorption potential. It may be offered as follows: (Ajemba, R. O.,*et al.*, 2016)

$$\ln(q_e - q_t) = \ln q_e - k_1 t \qquad (18)$$

where,

q_e and q_t (mg/g) are the adsorption capacities at equilibrium and time, t (min), respectively, and k_1 (min-1) is the pseudo-first-order rate constant for the kinetic version.

The linear plot of ln (qe – qt)versus t gives q_e as the intercept and k_1 as the slope of the plot. To distinguish kinetic equations primarily based totally on adsorption potential from solution concentration, Lagergren's first order rate equation has been referred to as pseudo-first-order (Ho, Y. S., and McKay, G., 1998).

2) Pseudo-2nd-order charge equation

In 1995, Ho described a kinetic process of the adsorption of divalent metal ions onto peat (Ho, Y. S., and McKay, G., 1998b), in which the chemical bonding among divalent metal ions and polar functional groups on peat, such as aldehydes, ketones, acids, and phenolics are responsible for the cation exchange capacity of the peat. The pseudo-second order kinetic can be presented as follows:

$$\frac{dqt}{dt} = k_2 (q_e - q_t)^2 \qquad (19)$$

The linearized form of equation 19 can be written as:

$$\frac{t}{qt} = \frac{1}{k_2 qe^2} + \frac{1}{qe} t \qquad (20)$$

Where, k_2 is the rate constant of second order-adsorption (g/mg.min), q_e and q_t (mg/g) are the adsorption capacities at equilibrium and time, t (min), respectively. The plots of t/q against t gives the slope $(\frac{1}{q_e})$ and intercept $(\frac{1}{k_2 q_e^2})$.

V. PRESENTATION OF EXPERIMENTAL RESULTS

A. *Physical characterization of Kaolin Clay*

The results obtained for the physical characterisation of Kaolin clay are shown in Table 3:

TABLE III. PHYSICAL PROPERTIES OF THE RAW KAOLIN CLAY

Properties	Raw	1.0 M	2.0M	3.0M	5.0M
Bulk Density(g/mL)	1.65	1.52	1.50	1.44	1.43
Specific gravity	2.5	2.5	2.5	2.5	2.5
Porosity	0.34	0.392	0.42	0.424	0.428
pH	6.0	5.0	5.0	5.0	5.0
Moisture Content (%)	12.4	14.0	14.9	15.7	16.6

1) Adsorption Results

Table 4 shows the results obtained for absorbance and bleaching efficiency at different acid concentrations.

TABLE IV. EXPERIMENTAL DATA FOR THE ABSORBANCES AND BLEACHING EFFICIENCY AT DIFFERENT ACID CONCENTRATIONS OF KAOLIN CLAY

Acid Concentration, mol/dm3	Absorbance	Bleaching Efficiency, %
Inactivated Clay,0M	1.113	36.83
1M	1.072	39.16
2M	0.644	63.45
3M	0.524	70.26
5M	0.495	71.91

Table 5 shows the results obtained for bleaching efficiency at different acid concentration and time.

TABLE V. EXPERIMENTAL DATA FOR THE BLEACHING EFFICIENCY OF THE SAMPLES AT DIFFERENT ACID CONCENTRATIONS OF THE ACTIVATED CLAY AND AT DIFFERENT CONTACT TIMES.

Contact Time, (minutes)	5M	3M	2M	1M	0M
		Bleaching Efficiency, %			
5	56.24	49.72	38.35	24.89	5.84
10	73.45	68.65	51.57	31.59	14.63
15	74.86	70.68	62.32	32.70	19.54
20	76.77	72.40	68.65	38.35	32.82
30	77.87	76.09	68.71	42.41	39.89
45	76.83	68.53	61.15	39.09	32.45
60	74.98	63.80	61.15	20.16	12.66

Fig 3 shows the effect of contact time on bleaching performance.

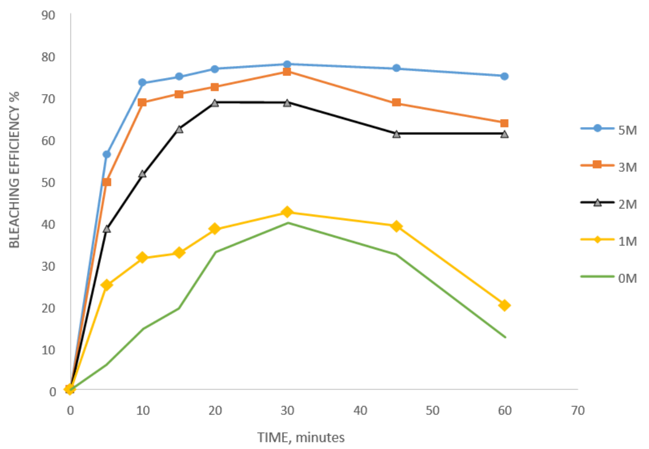

Figure 3. Effect of Contact time on bleaching performance

Table 6 shows the absorbance values obtained from varying the kaolin clay dosage and contact time at a constant temperature of 120°C.

TABLE VI. ABSORBANCE VALUES OBTAINED FROM VARYING THE KAOLIN CLAY DOSAGE AND CONTACT TIME AT A CONSTANT TEMPERATURE OF 120°C.

Absorbance of samples at different clay dosage , g Contact time,					
minutes	1.0	1.5	2.0	2.5	3.0
0	1.627	1.627	1.627	1.627	1.627
5	1.11	0.852	0.832	0.743	0.712
10	0.978	0.778	0.719	0.619	0.432
15	0.839	0.743	0.678	0.548	0.409
20	0.823	0.73	0.632	0.522	0.378
30	0.818	0.629	0.504	0.366	0.36

Table 7 shows the bleaching Efficiencies obtained from varying the kaolin clay dosage and contact time at a constant temperature of 120°C.

TABLE VII. BLEACHING EFFICIENCIES OBTAINED FROM VARYING THE KAOLIN CLAY DOSAGE AND CONTACT TIME AT A CONSTANT TEMPERATURE OF 120°C.

Bleaching Efficiency of samples at different clay dosage, g Contact time,					
minutes	1.0	1.5	2.0	2.5	3.0
5	31.78	47.63	48.86	54.33	56.24
10	39.89	52.18	55.81	61.95	73.45
15	48.43	54.33	58.33	66.32	74.86
20	49.42	55.13	61.15	67.92	76.77
30	49.72	61.34	69.02	77.50	77.87

Figure 4 shows the Effect of Clay Dosage on Bleaching Performance:

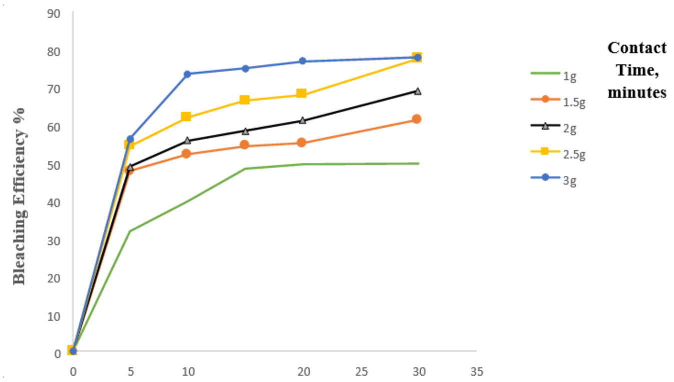

Figure 4. Effect of Clay Dosage on Bleaching Performance

Table 8 shows raw experimental values of the absorbance obtained from the varying temperature and contact time at constant clay dosage.

TABLE VIII. RAW EXPERIMENTAL VALUES OF THE ABSORBANCE OBTAINED FROM THE VARYING TEMPERATURE AND CONTACT TIME AT CONSTANT CLAY DOSAGE.

Contact time, minutes	Absorbances	of samples at different oC	Temperatures,	
	30	60	100	120
0	1.627	1.627	1.627	1.627
5	1.327	1.097	0.778	0.712
10	1.219	1	0.649	0.432
15	1.143	0.851	0.499	0.409
20	1.012	0.832	0.478	0.378
30	0.957	0.74	0.432	0.36

Table 9 shows the Bleaching Efficiency obtained from the varying temperature and contact time at constant clay dosage.

TABLE IX. BLEACHING EFFICIENCY OBTAINED FROM THE VARYING TEMPERATURE AND CONTACT TIME AT CONSTANT CLAY DOSAGE.

Contact time	Bleaching Efficiency of samples at different Temperatures, oC			
minutes	30	60	100	120
5	18.44	32.58	52.18	56.24
10	25.08	38.54	60.11	73.45
15	29.75	47.70	69.33	74.86
20	37.8	48.87	70.62	76.77
30	41.18	54.52	73.45	77.87

Figure 5 shows the effect of Temperature on the Bleaching Efficiency.

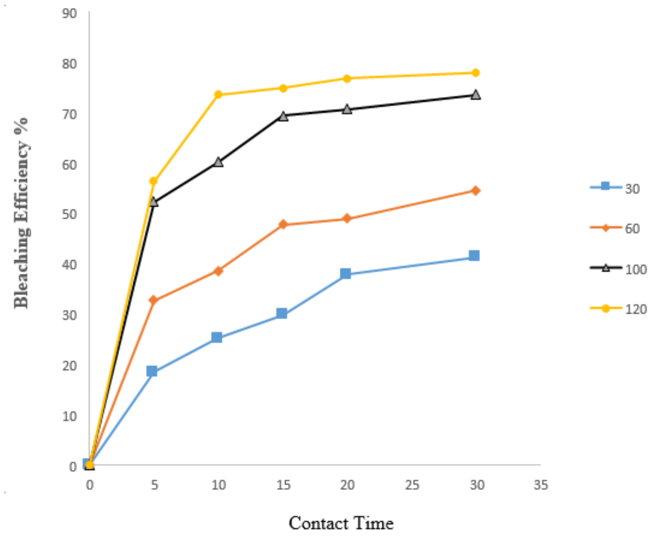

Figure 5. Effect of Temperature on the Bleaching Efficiency

Table 10 shows the experimental data obtained from bleaching of palm oil using an industrial bleaching earth and the local kaolin clay as adsorbent.

TABLE X. EXPERIMENTAL DATA OBTAINED FROM BLEACHING OF PALM OIL USING AN INDUSTRIAL BLEACHING EARTH AND THE LOCAL KAOLIN CLAY AS ADSORBENT

Adsorbent	Absorbance	Bleaching Efficiency, %
Industrial Adsorbent	0.106	93.48
5M activated Kaolin Clay	0.36	77.87

Figure 6 shows the Langmuir Adsorption Isotherm plot:

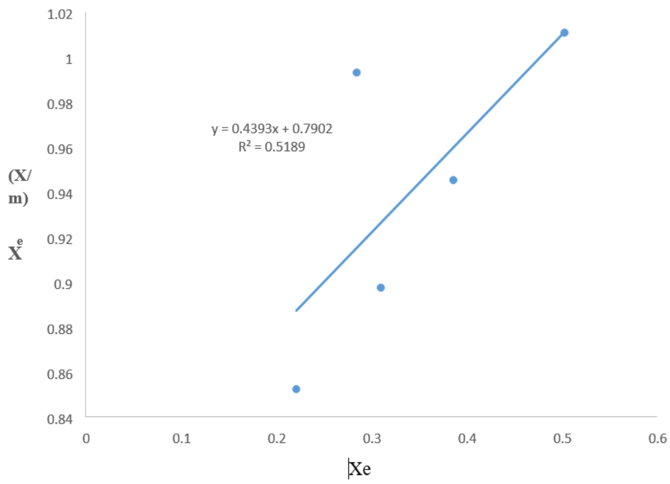

Figure 6. Langmuir Adsorption Isotherm plot

Figure 7 shows the Freundlich Adsorption Isotherm plot:

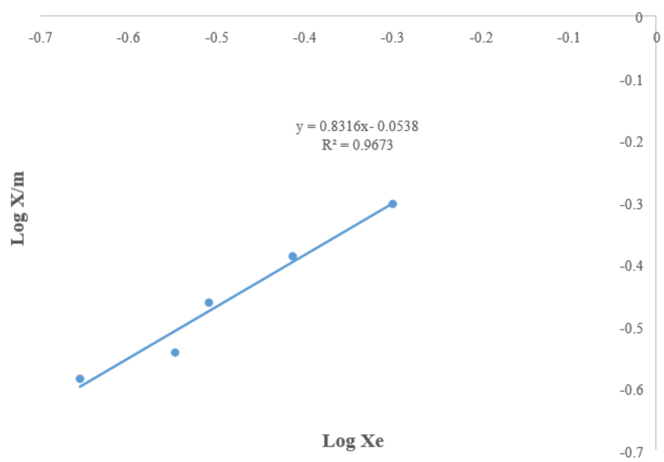

Figure 7. Freundlich Adsorption Isotherm plot

Table 11 shows the Adsorption Isotherms data:

TABLE XI. THE ADSORPTION ISOTHERMS DATA

Mass of adsorbent, (g)	X	Xe	X/m	log(X/m)	log Xe	Xe/(X/m)
1.0	0.4972	0.5028	0.4972	-0.3034	-0.2986	1.0111
1.5	0.6134	0.3866	0.4089	-0.3883	-0.4127	0.9454
2.0	0.6902	0.3097	0.3451	-0.4620	-0.5090	0.8976
2.5	0.7156	0.2843	0.2863	-0.5432	-0.5462	0.9932
3.0	0.7787	0.2213	0.2595	-0.5857	-0.6551	0.8524

Table 12 shows the Adsorption Thermodynamics data for the adsorption process:

TABLE XII. ADSORPTION THERMODYNAMICS DATA FOR THE ADSORPTION PROCESS

Temperature. (oC)	Temperature, T (K)	X	Xe	1/T	Ln Xe
30	303.15	0.412	0.588	0.0033	-0.531
60	333.15	0.545	0.455	0.0030	-0.788
100	373.15	0.734	0.265	0.0027	-1.326
120	393.15	0.779	0.221	0.0025	-1.508

Table 13 shows the adsorption Thermodynamics Parameters:

TABLE XIII. ADSORPTION THERMODYNAMICS PARAMETERS

Temperature, K	In Kf	ΔGo,kJ/mol	ΔHo,kJ/mol	ΔSo,kJ/mol
303.15	-0.531	-23.43		
333.15	-0.788	-24.64	-11.108	0.041
373.15	-1.326	-26.27		
393.15	-1.508	-27.08		

Figure 8 shows the plot of InK_fversus $1/T$:

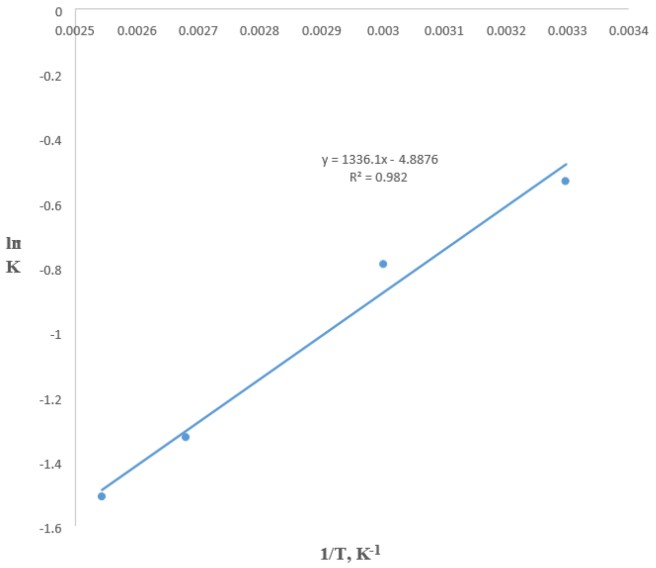

Figure 8. Plot of InK_fversus $1/T$

TABLE XIV. ADSORPTION KINETICS DATA

Time, t (minutes)	X	qt	(qe-qt)	ln (qe-qt)	t/qt	t^0.5
5.0	0.562	0.187	0.0725	-2.624	26.67	2.236
10.0	0.734	0.245	0.0151	-4.188	40.84	3.162
15.0	0.749	0.249	0.0105	-4.560	60.11	3.873
20.0	0.768	0.256	0.0041	-5.494	78.16	4.472
30.0	0.779	0.259	0.00042	-7.770	115.57	5.477

Figure 9 shows a plot of q_t against t:

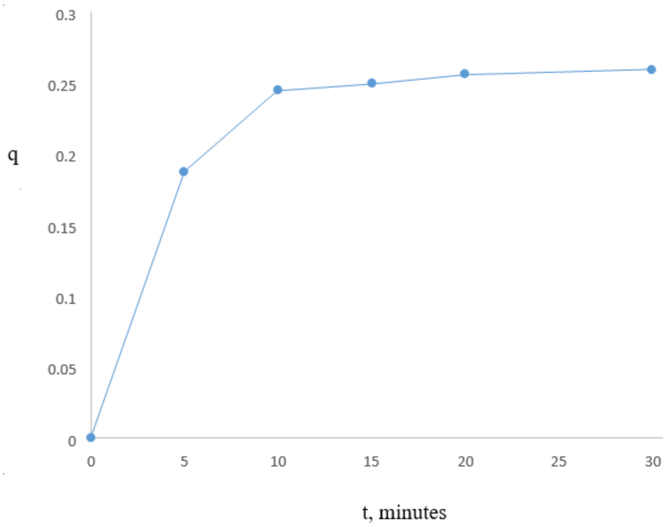

Figure 9. Plot of q_t against t

Table 14 shows the adsorption Kinetics Data:

Figure 10 shows the Pseudo-first order kinetic model plot:

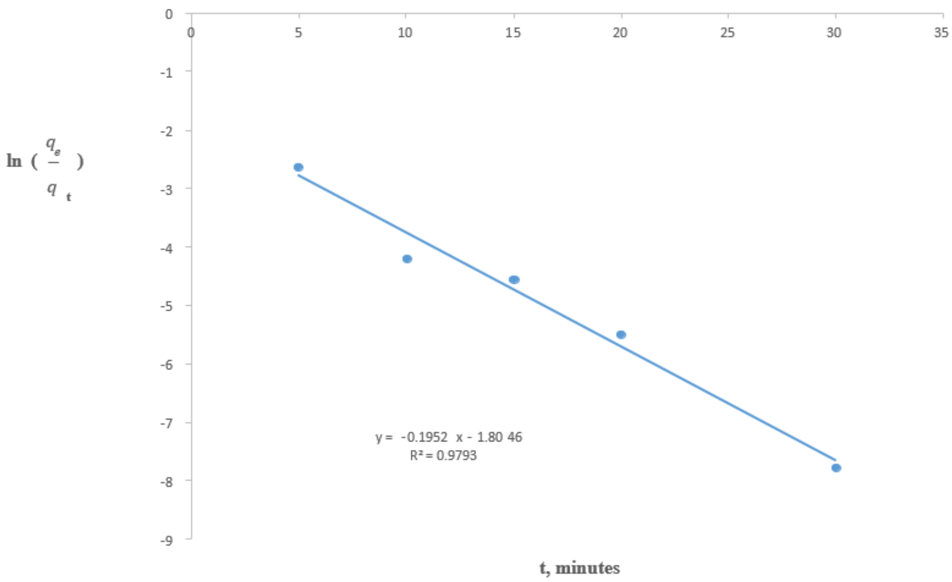

Figure 10. Pseudo-first order kinetic model plot

Figure 11 shows the Pseudo-second order kinetic model plot:

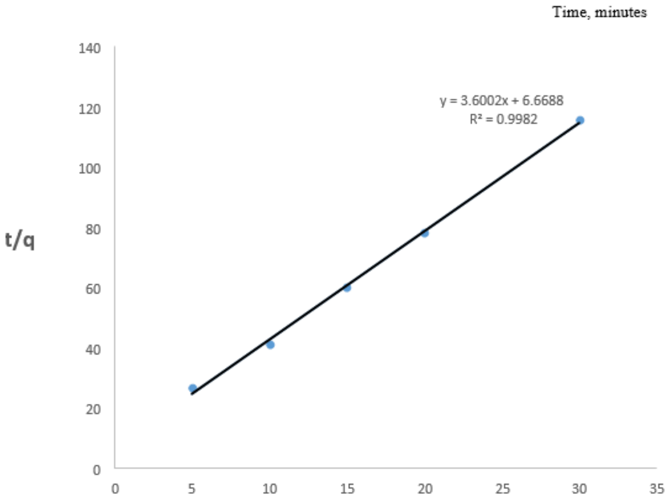

Figure 11. Pseudo-second order kinetic model plot

Figure 12 shows the Intraparticle diffusion model plot:

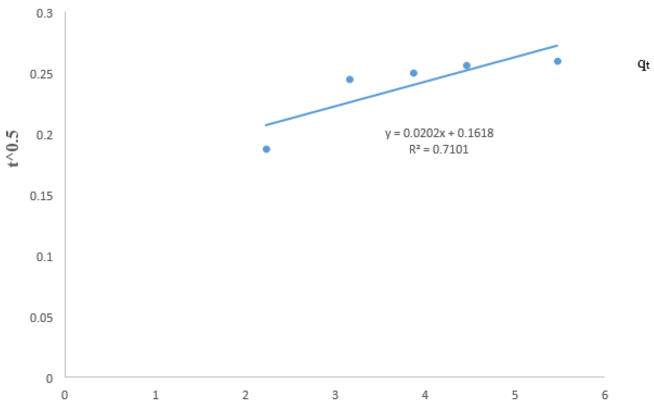

Figure 12. Intraparticle diffusion model plot

Table 15 shows the Evaluated Kinetic parameters:

TABLE XV. EVALUATED KINETIC PARAMETERS

Kinetic Models		Parameters
Pseudo-first order	K1	0.1952
	qe (calc)	0.165
	qe(exp.)	0.26
	R2	0.9793
Pseudo-second order	K2	1.944
	qe (calc)	0.28
	qe(exp.)	0.26
	R2	0.9982
Intraparticle diffusion	Kint	0.0202
	λ	0.1618
	qe(exp.)	0.26
	R2	0.7101

VI. DISCUSSION

Table 3 summarizes the effects of physical characterization of raw and activated kaolin clay at acid concentrations of 1.0M, 2.0M, 3.0M, and 5.0M. The improved ability of the clay to retain water may be due to the rise in moisture content as the acid concentration was increased.

The findings indicate that the clay composition was altered as a result of the acid activation.

Table 4 displays the absorbance of the samples after 30 minutes of contact time, as well as the bleaching quality. Table 4 shows that the bleaching efficiency improves as the acid concentration in the activation increases, and that the raw clay has the lowest bleaching efficiency.

The bleaching efficiencies of 3M activated clay and 5M activated clay vary slightly. Based on the findings, it can be inferred that activated clay concentrations of 3M and 5M acid are both effective for palm oil bleaching.

The bleaching performance of the samples at various acid concentrations of the activated clay and at different contact times as shown in Table 5 Figure 3 depicts the bleaching performance versus contact time for inactivated and activated clay samples at various acid concentrations.

The bleaching efficiency increases with contact time until it approaches 30 minutes, at which point it begins to decrease with increasing contact time. This decrease can be explained by the fact that as contact time increases, desorption happens, in which pigments are released from the adsorbent's surface, interfering with the bleaching quality. The optimal contact time for bleaching palm oil with inactivated and different acid concentrations of activated kaolin clay is 30 minutes, according to the results. Tables 6 and 7 demonstrate the raw data collected by adjusting the kaolin clay dosage and contact time at a constant temperature of 120C. The bleaching efficiency increases with clay dosage, and the bleaching efficiency increases with time at each clay dosage, according to the plot in Figure 4 Increased bleaching efficiency is due to an increase in available sites, which leads to more pigment removal. The highest clay dosage and longest contact time resulted in the best bleaching efficiency, while the lowest clay dosage and shortest contact time resulted in the worst bleaching efficiency.

Tables 8 and 9 shows the raw experimental values of the absorbance and bleaching efficiency obtained from the varying temperature and contact time at constant clay dosage. From Figure 5, it can be deduced that bleaching efficiency was favoured by increase in temperature.

The increase in the bleaching efficiency shows high temperature improves access to further adsorption site since increase in temperature reduces the viscosity by increasing the speed of molecules resulting in better interaction between the adsorbent and the oil.

The result of bleaching oil at 120^oC for 30 minutes with 3g of adsorbent /100g of oil using both industrial adsorbent and local kaolin clay are shown in Table 10 From the results, it can be said that the bleaching efficiency obtained from using the local kaolin clay is low compared to that obtained from using industrial adsorbent.

The poor bleaching capacity can be as a result of the high crystalline nature of the kaolin clay and also the type of acid used for the activation of the clay. Kashani M. M., Youzbashi A.A., and Amiri RZ. (2011) concluded from their studies that hydrochloric acid and sulfuric acid gives good result when used for activation of clays compared to phosphoric and oxalic acid., (Nwankwere, E.T., Nwadiogbu, J.O., Tilleng, M.T., and Eze, K.A. (2016), reported also reported that bleaching capacity of natural clays were poor compared to that of industrial adsorbents.

The effect of clay dosage on the bleaching performance of the activated kaolin clay with 5M H_3PO_4 at constant temperature is shown in Figure 4. The Langmuir and Freundlich adsorption models were used to analyze the data. For the Langmuir adsorption isotherm, $X_e/(X/m)$ was plotted against X_e as shown in Figure 6. The slope and intercept were obtained as 0.4393 and 0.7902 respectively. The Langmuir constants, a and b were evaluated as 1.265 and 2.881 respectively. The regression coefficient, R^2 for the Langmuir model is 0.5189.

Also, for the Freundlich adsorption isotherm, Log (X/m) was plotted against Log Xe as shown in Figure 7. The slope 'n' and the intercept were obtained as 0.8316 and 0.0538 respectively. K was evaluated as 0.883. The regression coefficient, R^2 of the plot is given by 0.9673.

From the plots, it was observed that the Freundlich model described the adsorption data with the best linear fit with a regression coefficient of 0.9673 which is higher than the one obtained for the Langmuir model. The results obtained conforms to the conclusion of Rohani, 2006 that Freundlich isotherm is more applicable to a liquid phase and Langmuir isotherm is more applicable to a gaseous phase. The high value of the constant "n" obtained as shows that the adsorbent is only for removing the first portions of color but less efficient for reaching highest bleaching efficiency. (Rossie et. al., 2003). The adsorption isotherms data obtained is presented in Table 11.

The adsorption thermodynamics data for the adsorption process is shown in table 12. The thermodynamic parameters were calculated and summarized in Table 13 and the plot of InK_fversus $1/T$ which gave a negative slope of $\Delta H^o/R$ and intercept $\Delta S^o / R$ is shown in Figure 8.

The enthalpy of the process was calculated as -11.108kJ/mol which shows that the process is exothermic in which the total energy absorbed is less than the total energy released in the adsorption process, resulting in the release of heat to the surroundings. The magnitude of the enthalpy also suggests that the adsorption of pigments from palm oil is a physical adsorption process.

From Table 13, it can be seen that there's a decrease in the negative value of ΔG^o as temperature increases, this indicates that the adsorption process is favourable at higher temperatures. This conclusion was also confirmed during the study of the effect of temperature on the bleaching performance. The bleaching performance increases with increasing temperature.

The effect of temperature on the bleaching performance of the activated kaolin clay with 5M H_3PO_4 is shown in Figure 5. The experimental data obtained were tested with 3 kinetic models, namely pseudo-first order model, pseudo-second order model and intraparticle diffusion to describe the interaction between the pigments and the adsorbent.

The adsorption kinetics data used for the process is given in Table 14. The adsorption capacity at equilibrium, q_e was obtained as 0.26 by plotting the adsorption capacities at different times, q_t against time, minutes shown in Figure 9. Figure 10, 11, and 12 shows the pseudo-first order, pseudo-second order and the intraparticle diffusion plots respectively. The kinetic constants of the models, k_1, k_2 and k_{int} and other kinetic parameters were evaluated from the slopes and intercepts of the plots and presented in Table 15.

The results shows that the experimental data fits well to the pseudo-second order kinetic model since it has the most linear fit with a regression coefficient, R^2 of 0.9982. The value of q_e calculated from the pseudo-second order model was found be very close to the experimental q_e when compared to the other models.

VII. CONCLUSION

The investigation of the process of the simultaneous adsorption of carotene and free unsaturated fats of palm oil through kinetics, with construction of the adsorption isotherm and the determination of actuation energy was done in this examination. The bleaching effectiveness was directly proportional to the acid concentration of the activated clay. The temperature, clay dosage and the contact time also affected the process.

The Langmuir and Freundlich adsorption models were applied to determine the experimental equilibrium isotherms. The Freundlich model concurred well with the equilibrium adsorption information with R_2 of 0.9673 while the Langmuir gave a poor fit with R_2 of 0.5189.

The kinetic study carried out based on pseudo-first-order, pseudo-second-order and intra-particle diffusion shows that the pseudo-second order kinetic model is a better representation of the bleaching process.

The thermodynamic parameters, ΔH, ΔS and ΔG showed that adsorption of pigments onto the local kaolin clay was spontaneous and exothermic. The heat evolved during adsorption was -11.108 kJ/mol which showed that the physical adsorption (Physic sorption) took place between the adsorbate and adsorbent.

The optimum conditions obtained for efficient bleaching were as follows: temperature, 1200C; time, 30 minutes; and adsorbent dosage, 3.0g of clay/100g of palm oil with bleaching efficiency of 77.87%. The increase in the bleaching efficiency obtained after bleaching reveals that the local kaolin clay can be used for palm oil bleaching.

The bleaching efficiency of the activated Kaolin clay effectively competes favourably with the industrial adsorbents. The experiment shows that activated kaolin clay bleaches at similar conditions and produces almost equal results and responses.

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