RESEARCH ARTICLE

Adsorption, Modeling, Thermodynamic, and Kinetic Studies of Removal of Textile-dye using Low-Cost Adsorbents

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ABSTRACT

Adsorption of reactive green (RG) dye using *Syzgium aromaticum* flower bud (SAFB) and ACTIVE -SAFB was studied in detail *via* conducting batch model kinetic, thermodynamic and desorption investigations. The experimental kinetic data at several primary reactive green dye concentrations were also analyzed through model first-order, model second-order. The obtained result appears that the model pseudo-first-order fits the adsorption kinetic result through (R^2 0.9797) and (R^2 0.9016) of SAFB and ACTIVE-SAFB in the same order. Finally, the thermodynamic factors appear that dye's adsorption onto SAFB and ACTIVE-SAFB was endothermic and spontaneous. This suggests that SAFB and ACTIVE-SAFB is a *via*ble adsorbents for effective dye removal from wastewater effluent.

Keywords: Activated Carbone, Adsorption, Equilibrium, Kinetic, Reactive green, Removal.

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INTRODUCTION

Contamination water of ground and surface waters causes a risk to human and environmental health because of the possible health hazards of their contents of organic and inorganic complexes. The pollution of these waters *via* dye is an arduous task that scientists have been battling to resolve over the years. Dyes have undesirable side effects; for example, their carcinogenic toxicity and nature mutagenic.[1,2] Dyes, the effluent of textile industries, might seriously damage the environment and public health. Activated carbon (AC), a commonly used adsorbent in industrial ways, is composed of a micro-porous structure homogenous by excellent surface area and displays radiation stability.[3] The technique for producing great-capacity activated carbon is not completely studied in developed countries. There are more than a few hitches through the regeneration of make use of activated carbon. At present, there is a great interest in finding low-cost and effective alternatives to the existing commercial activated carbon.[4-7] The adsorption efficiency of AC be contingent on several parameters: pore size distribution, polarity, surface area, and functional groups of adsorbent surface; molecular size and solution of pH, adsorbate of solubility.

MATERIALS AND METHODS

Preparation of Absorbent

The surface of *Syzgium aromaticum* flower bud (SAFB) in powder forms was washed *via* excessive quantities of D.W; more than a few washings were executed to eliminate dust and soluble materials. The SAFB was washed, dried in an oven at 110°C for 2 hours, mashed in a laboratory grindery to a size of 0.6–4.0 mm, and kept airtight containers.

Activated Carbon (AC)

SAFB was washed, ground, and mashed in a laboratory grindery to a size of 0.6–4.0 mm and after that, it dried in the oven. A standard procedure of activation was followed: impregnation, through H_2SO_4 at (300°C) calcination at 1-hour. The best *via* several agricultural raw materials. The prepared activated carbon (ACTIVE-SAFB) was washed several times by D.W until neutral pH and filtrate then dried at 110°C to mass constant and kept in airtight containers

Equilibrium Adsorption of Reactive Green

A stander solution of reactive green RG was prepared *via* way of dissolving 1 g in 1000 mL of D.W; preferred conc. were found through dilution by D.W. For adsorption investigations,

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Table 1: Statistical of the calibration curve (Figure 1) for different concentration of reactive green dye

Parameters	*Proposed method RG dye*
Beer lambert law (μg mL^{-1})	2-100
λ_{max} (nm)	625
Regression equation	Y= 0.00848X-0.01854
(R^2)	0.99871
Slope (*m*)	0.00848 (± 8.44741*10^{-5})
Intercept (*C*)	0.01854 (± 0.00444)
Standard de*via*tion (SD)	0.12
% Relative standard de*via*tion (RSD%)	0.33
Color	Green

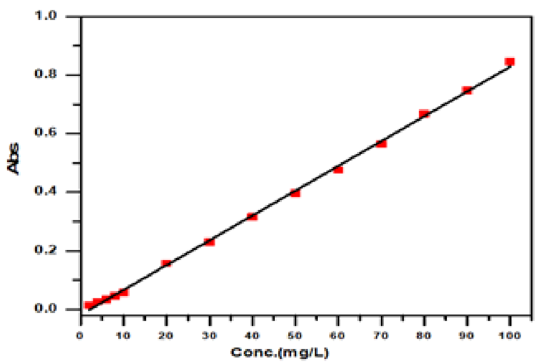

Figure 1: Calibration curves of reactive green dye.

0.05 g of SAFB and ACTIVE-SAFB was mixed with 100 mL of series from (10–100 mg/L) concentrations. The stoppered elementary flasks were agitated occasionally in a shaker water bath for 2 hours at equilibrium. Supernatant solution was separated and investigated spectrophotometrically at 625 nm *via* spectrophotometer UV-vis.[8-10]

$$Qe = \frac{Co - Ce}{W} * V \qquad (1)$$

$$E\% = \frac{Co - Ce}{Co} * 100 \qquad (2)$$

Calibration Curve

A stander solution having different conc. (2–100 mg. L^{-1}) of solution (100 mg. L^{-1}). The value of maximum wavelength absorbance (λ max) *via* UV-visible spectrophotometer was recorded for RG dye. Absorbance was measured at the λ_{max} (625 nm) of RG and plotted against the values of RG dye, shown in Figure 1. To limit the E_{er}% and RSD% of the system, solutions having four different concentrations. The measured RSD% and (S.D.) (Table 1).

RESULTS AND DISCUSSION

FT-IR Characterization

The SAF Band ACTIVE-SAFB, was characterized by the use of spectroscopy FT-IR. Spectra FT-IR was collected in the mid-IR series of 4000 - 400 cm^{-1} by a resolution of 1-cm^{-1}. FT-IR spectroscopy was done for preliminary qualitative analysis of major functional groups present in SAFB and

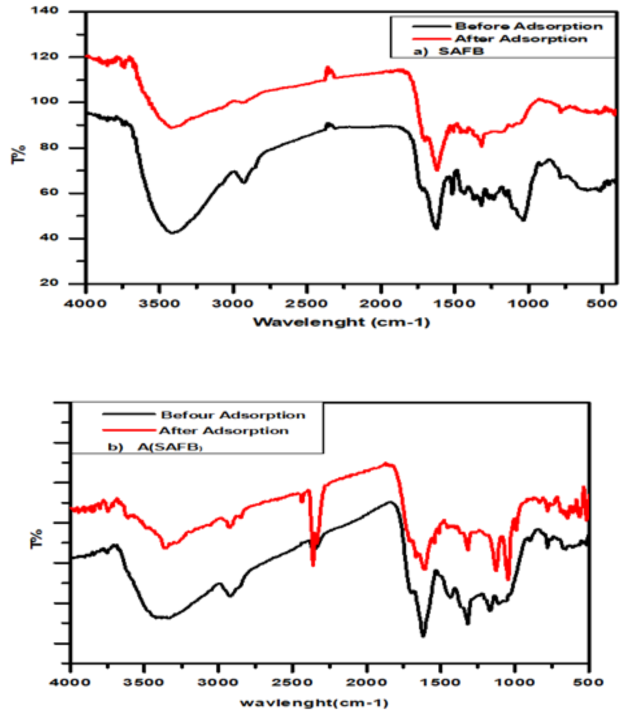

Figure 2: FTIR spectra of a- SAFB and b- ACTIVE-SAFB surface before and after adsorption of reactive green RG dye.

Table 2: Influence of temp. of the maximum adsorbed amount of adsorption of RG onto SAFB and ACTIVE-SAFB

T(K)	*1000/T (K^{-1})*	*C_e = 45*	
		X_m	*ln X_m*
SAFB			
283	3.5335	24.5	3.19867
293	3.4129	28	3.3322
303	3.3003	30	3.4012
ACTIVE-SAFB			
283	3.5335	100	4.60517
293	3.4129	108	4.68213
303	3.3003	110	4.70048

Table 3: Thermodynamic parameters for Reactive green dye adsorption on SAFB and ACTIVE-SAFB

ΔH (KJ/mol)	*ΔG (kJ/mol)*	*ΔS (J/mol/K)*	*Kequ.*
SAFB			
	-15.298		
7.242	-15.839	52.262	333.333
	-16.380		
ACTIVE-SAFB			
	-16.832		
3.419	-17.426	50.446	1279.069
	-18.021		

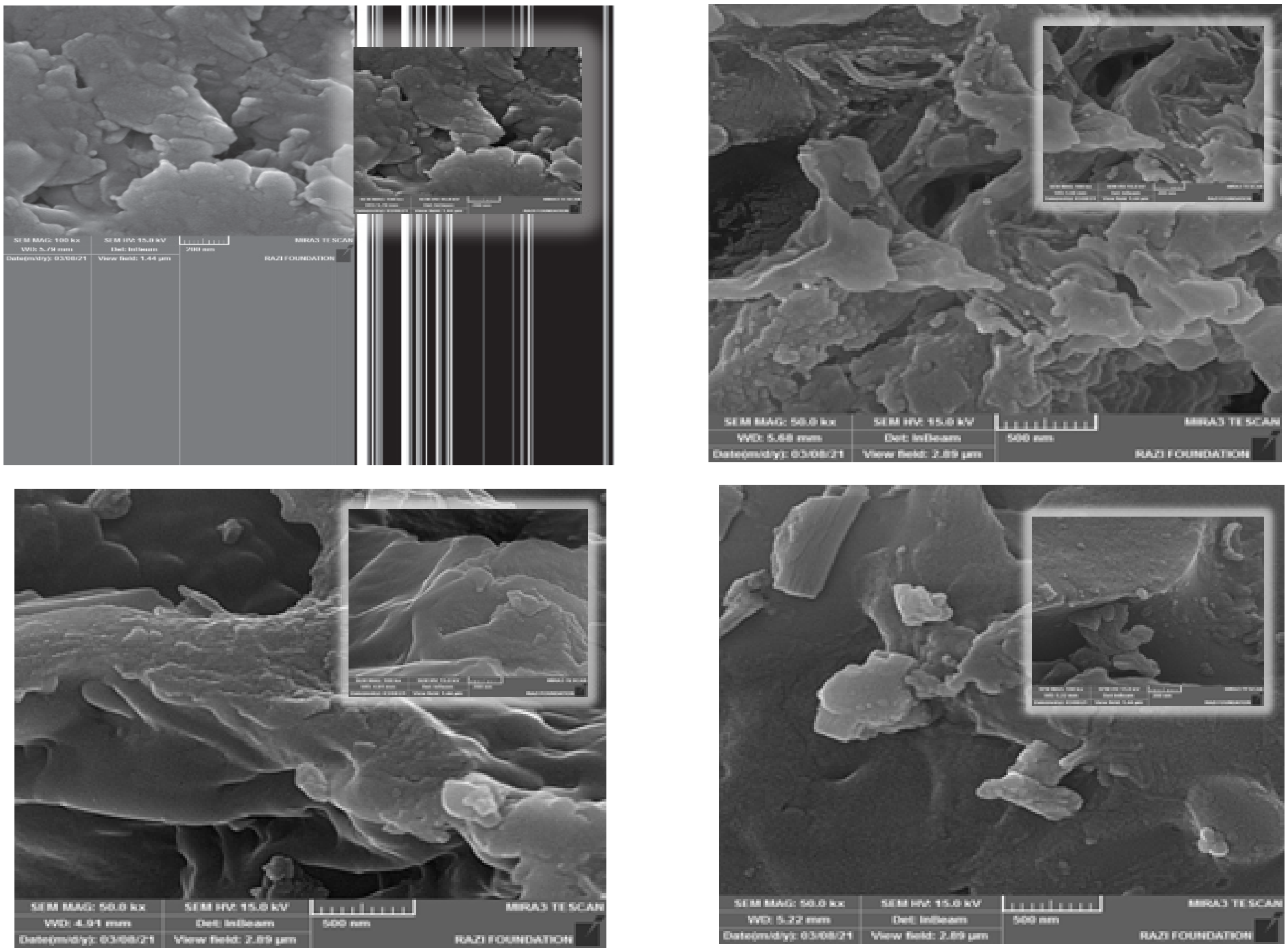

Figure 3: FESEM micrographs of SAFB and Active-SAFB before adsorption after adsorption of RG dye.

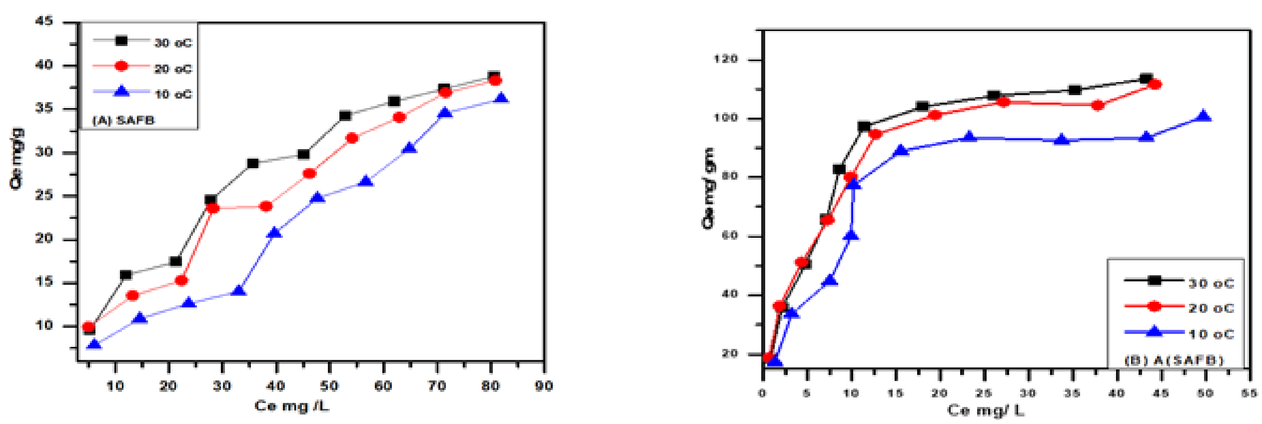

Figure 4: Adsorption isotherms of reactive green dye on (A)SAFB, (B) ACTIVE-SAFB at different temperatures.

ACTIVE-SAFB before and after reactive green dye adsorption are appear (Figure 2 (a) and (b)). The FT-IR pattern looks reduced in the intensity of bands next to the adsorption; too, there is a difference real between SAFB and ACTIVE-SAFB, before-after interaction *via* dye that has been suggested a phenomenon physorption happens as data of attractive forces among the SAFB, ACTIVE-SAFB and dye under investigation.[9-11]

SEM Analysis

The SAFB and ACTIVE-SAFB was too characterized *via* (FESEM) before adsorption and after adsorption study make use of RG. pictures FESEM of the SAFB and ACTIVE-SAFB (Figure 3) appear bright color dark onto surface. After dye RG adsorption the SAFB and ACTIVE-SAFB was turned to color light (Figure 3). This might be due to the adsorption of RG dye onto SAFB and ACTIVE-SAFB surface.[2]

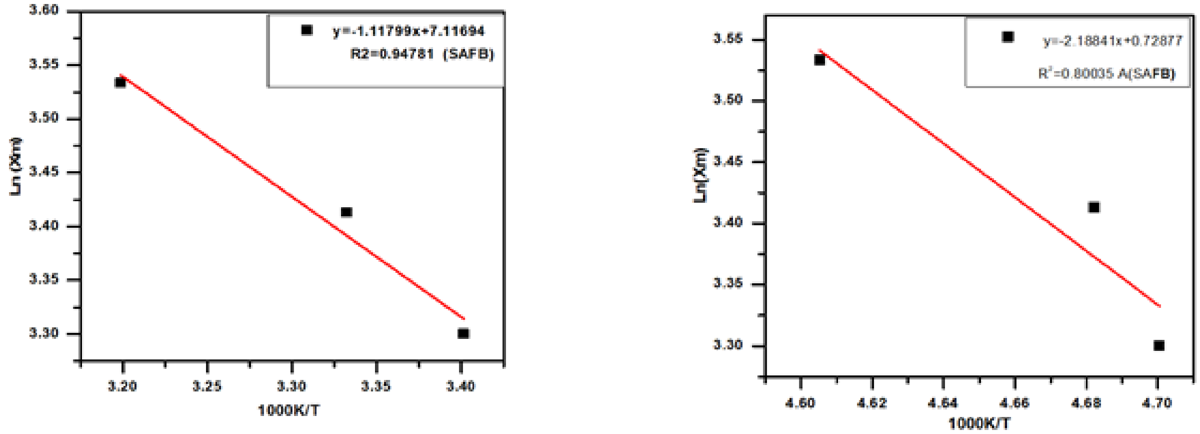

Figure 5: Plot of ln Xm against reciprocal absolute temp. of adsorption RG dye onto SAFB and ACTIVE-SAFB.

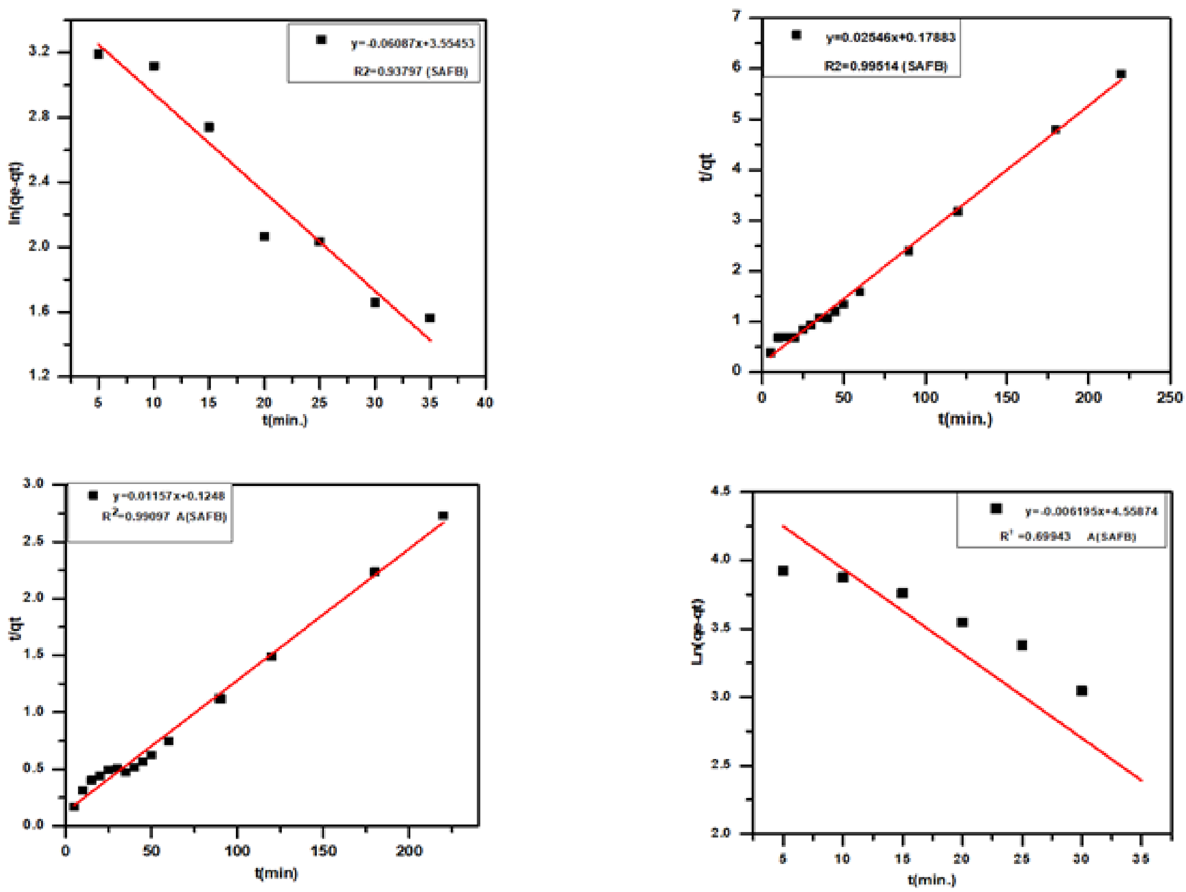

Figure 6: Kinetics model B. model first- order and C. model second-order of adsorption of dye RG.

Effect of Temperature

Figure 4 appears the influence of the temperature solution on the dye's adsorption in the series from (10–30°C). The adsorption efficiency of the SAFB and ACTIVE-SAFB rise when the temperature increases from 10–30°C. It is finding that the greater temperature solution is to the advantage of adsorption and that the adsorption is an endothermic presses.[14,15] The thermos-dynamic factors, that is to say (ΔH), (ΔG), and (ΔS) were estimated by equations (3 and 4).

$$\ln Xm = \frac{-\Delta H}{RT} + constant \quad (3)$$

$$\Delta G = -RT \ln K \quad (4)$$

Table 2 and Figure 5 shows influence of temperature of the maximum adsorbed amount of adsorption of RG onto SAFB and ACTIVE-SAFB. Table 3 appear the calculated values of the thermos-dynamic parameter for the dye adsorption onto SAFB and ACTIVE-SAFB.

Table 4: Kinetics model the adsorption of reactive green dye.

SAFB					
First model					
Slope 0.0164	Intercept 0.1839	k_1 $(min)^{-1}$ 0.0164	$q_{e\ (mg/g)}$ 1.20189	R^2 0.9797	
Second model					
Slope -0.0719	Intercept 2.3039	q_e $(min)^{-1}$ -13.9082	k_2 $(g.mg.min^{-1})$ 0.001614	H 0.31212	R^2 0.703
ACTIVE-SAFB					
First model					
Slope 0.01157	Intercept 0.1248	k_1 $(min)^{-1}$ -0.1157	$q_{e\ (mg/g)}$ 1.132922	R^2 0.99097	
Second model					
Slope -0.06195	Intercept 4.5587	k_1 $(min)^{-1}$ 0.00129	$q_{e\ (mg/g)}$ 12.6904	H 0.207827	$R^2$0.69943

The value enthalpy indicates an endo-thermic adsorption system. One probable explanation of the endo-thermic of adsorption is that RG and the SAFB and ACTIVE-SAFB are both solvated in water. For the dye to be adsorbed, they have to lose part of their shell hydration. The dehydration methods of the dye and the adsorbent SAFB and ACTIVE-SAFB require energy. So, the de-hydration ways supersede the exothermicity of the adsorption ways. The values of entropy is positive, in addition to the tiny negative values of ΔG have too been considered as the con-sequence of the diffusion of the RG in to the chemical SAFB and ACTIVE-SAFB of the adsorbent.[11-14]

Adsorption Kinetic Models

The kinetic of the adsorption way that describe the studied data were utilized well of adsorption for RG onto SAFB and ACTIVE-SAFB. The reaction models of kinetic were utilized to analyze the experimental result. The reaction (k) for removal RG from the solution *via* SAFB and ACTIVE-SAFB calculated utilizing first and second-pseudo-order equations. The Lagergren equation was utilized to describe pseudo-first-order rate the investigation data. The linear form of the Lagergren equation is:

$$\ln(q_e - q_t) = \ln q_e - k_1 t \quad (5)$$

q_e (mgg-1) represented the adsorption equilibrium, efficiency and qt (mgg^{-1}) refer to the amount of RG adsorbed at time. k_1 Values of RG-SAFB method can be calculated from draw slope of the ln (q_e-q_t) against t, Figure (6a). The kinetic adsorption factors from Figure (6b) are indicated in Table 4. The adsorption result too analysis counterfeit a second-order model.[12-14]

CONCLUSION

SAFB is considered an environmentally friendly adsorbent of reactive green (RG) dye from an aqueous solution. Adsorption capacity increased from 10.121 to 38.412 and 20.111 to 110.11 mg/g of SAFB and ACTIVE-SAFB at the same order as the temperature solution was raised from 10–30°C and the adsorption process has nearly reached equilibrium in 2 hours. The investigational result is fitted well to model first order.

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