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RESEARCH ARTICLE

INVESTIGATION of REMOVAL of METHYL VIOLET 2B DYE USING TEA WASTE NANOPARTICLES PRODUCED by GREEN SYNTHESIS METHOD

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ABSTRACT

This study investigates the usability of $FeCl_3$ nanoparticles synthesized with tea waste by green synthesis method as an adsorbent in the removal of methyl violet 2B, a widely used cationic dyestuff, from wastewater.
Characterization analyzes of $FeCl_3$ nanoparticles synthesized with tea waste were performed with SEM/EDX and FTIR.
pH, adsorbent dose, initial dyestuff concentration parameters were studied in batch system and optimum conditions were determined. According to the experimental results, the best adsorption efficiency was obtained at the pH of 4.5, adsorbent dose of 1 g/L and initial dyestuff of 50 mg/L.
Equilibrium data obtained using different initial dyestuff concentrations and temperatures were applied to the Freundlich, Langmuir, Dubinin-Radushkevich and Temkin adsorption isotherms. The experimental results best fitted to the Langmuir isotherm. The separation factor (RL) calculated using Langmuir isotherm equations is between 0 and 1 at all temperatures, also showing that adsorption fits the isotherm.
In kinetic studies, experiments were performed at an initial dye concentration of 50 mg/L and the adsorption was found that adsorption was in fiting the pseudo second order kinetic model. Negative ΔG values (-5.703, -5.226, -5.148 kj/mol) determined in thermodynamic studies showed that adsorption was spontaneous and feasible. A negative ΔH value (-13.898 kj/mol) means adsorption is exothermic.
It has been shown that $FeCl_3$ nanoparticles synthesized with tea waste can be used as an effective adsorbent in the removal of methyl violet 2B from aqueous solutions with approximately 80% efficiency.

Keywords: *Methyl violet 2B, Adsorption, Kinetic, Isotherm, Nanoparticle, Green synthesis*

1. INTRODUCTION

As a result of the increase in the needs of people, an increase in production has begun to meet this need. Paints started to be used in many areas and this situation started to create environmental risks. Dyes are divided into three groups according to their chemical structures as anionic, cationic and nonionic. The most harmful dye group is cationic dyes and methyl violet 2B is in this group. This dye can cause various diseases by making a great toxic effect on living things. Considering this dangerous nature of paints, dismantling is required to protect the environment and human health. Methyl violet 2B dyestuff used in the study, dyestuff in textile and printing industry, indicator in the range of pH 0-1.6 in chemistry, fingerprinting in forensic medicine, classification of bacteria in medicine by gram staining technique, treatment of skin injuries and serious burns, prevention and treatment of fungal diseases, antibiotic It has a wide range of uses as an alternative. Methyl violet 2B dyestuff also has some damages like most chemicals. In case of short-term inhalation, such as respiratory tract irritation, vomiting, diarrhea, headache and dizziness in case of long-term exposure, it causes damage to the mucous membranes and digestive system [1]. For these reasons, it should be removed from wastewater. Ultrafiltration, ion exchange and adsorption methods can be used as removal methods. Due to its easy operation and low cost, the most preferred method among these removal methods is the adsorption method. Different adsorbents can be used to reduce sewage pollution [2,3].

Nanotechnology has emerged as one of the basic concepts supported by technological developments and advanced research in various scientific fields. The properties of nanoparticles such as shape and size are due to the different methods used in the synthesis phase. Green synthesis is a method in which plant extracts or biomolecules are used as reducing and stabilizing agents to synthesize nanoparticles without the need for external stabilizers, which further reduces environmental waste. Plant biomass/extract has several inert advantages over other microscopic organisms in the synthesis of nanoparticles from various biological materials. In addition to the synthesis method, the techniques used are also an important element that ensures nanoparticles are in the nanoscale range. In addition to these, nanoparticles composed of various particles can have different catalytic, magnetic, optical properties compared to nanoparticles composed of a single type of particle. Since approximately 40-50% of nanoparticle atoms are on the surface, its reactivity is high. These features increase the importance of nanoparticles compared to other materials [4,5]. Nanoparticles are frequently used in adsorption due to their high adsorption capacity and small size [6,7]. Due to its low cost, it was focused on researching plant extracts. [8]. The main aim of this study is to investigate the effectiveness of $FeCl_3$ nanoparticles synthesized with tea waste in the effective removal of methyl violet 2B dye. In this study, pH, adsorbent dose, initial dyestuff concentration tests were performed and optimum conditions were found. In order to understand the adsorption mechanism, isotherm, kinetic and thermodynamic studies were carried out and results were obtained for the removal of methyl violet 2B dyestuff of $FeCl_3$ nanoparticles synthesized with tea waste. Similar studies are given in Table 1.

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Table 1. Similar studies.

Dye	Adsorbents	Processing conditions	Efficiency	References
Methyl violet	Fe_3O_4-Clinoptilolite	pH: 7 Time: 150 min Ad. dosage: 2 g/L Temperature(°K): 298	% 92-% 97	[9]
Methyl violet	Acorn inner shells - Fe_3O_4	pH: 6 Time: 180 min Ad. dosage:1 g/L Temperature(°K): 298	% 95	[10]
Methyl violet	Chitosan coated Clinoptilolite	pH: 6 Time: 60 min Ad. dosage: 5 g/L Temperature(°K): 298	% 93-% 98	[11]
Methyl violet	Ground olive kernel	pH: 7 Time: 90 min Ad. dosage: 0.25 mg/L Temperature(°K): 300	% 96	[12]
Methyl violet	Apricot kernel husk modified with tartaric acid	pH: 4 Time: 120 min Ad. dosage: 1 g/L Temperature(°K): 298	% 79	[13]

In this study, the adsorption efficiency of $FeCl_3$ nanoparticles synthesized with tea waste with methyl violet 2B aqueous solution was investigated. The reason why methyl violet 2B dyestuff is preferred is that it has a toxic effect on the environment and living things. In the study, firstly, tea extract was obtained by using the green synthesis method and synthesized with $FeCl_3$, and then the characterization and adsorption potential of these nanoparticles were investigated. This study provided an innovation to the literature in terms of the use of $FeCl_3$ nanoparticles synthesized using green synthesis method in the adsorption of methyl violet 2B solution. In the study, both detailed characterization analyses and the use of the nanoparticle synthesized in the adsorption stages have contributed to the literature.

2. MATERIAL and METHOD

2.1. Material

The methyl violet 2B ($C_{24}H_{28}CIN_3$) chemical (CAS: 8004-87-3) used to prepare the stock solution was obtained from HiMedia Lab. Iron (III) chloride ($FeCl_3$ 95%) chemical and sodium hydroxide (NaOH 99%) chemical were obtained from Tekkim Lab. Information on the characterization of $FeCl_3$ nanoparticles synthesized with tea waste has been reported using FTIR (Bruker Model: Tensor II, 4000-400 cm-1), SEM/EDX (TESCAN MIRA3 XMU), UV-Spectrophotometer (Hach DR3900) devices.

2.2. Preparation of Tea Extract

In this study, black tea extract was used at a concentration of 60 g/L. To prepare black tea extract at the indicated concentration 60 g of black tea was weighed, 1000 mL of distilled water was added and mixed for 1 hour at 80 °C and precipitated at room temperature. The precipitate and the tea extract were separated from each other with the help of a filter.

2.3. Synthesis of $FeCl_3$ Nanoparticles

$FeCl_3$ nanoparticles synthesized using tea waste were obtained by green synthesis method. 0.1 M anhydrous $FeCl_3$ solution was dissolved in a 3:2 ratio of 100 mL of pure water-tea extract mixture and stirred at 80°C for 30 minutes. pH adjustment was made with NH_4OH. After pH adjustment, the temperature was kept constant and stirred on a magnetic stirrer for 2 hours. Later then the solution was allowed to settle at room temperature and the precipitate was washed with ethanol followed by distilled water. The washed precipitate was dried in a vacuum oven at 90°C for 12 hours.

2.4. Characterization of $FeCl_3$ Nanoparticles

Scanning Electron Microscopy - Energy Dispersive X-Ray Spectrometer (SEM/EDX, TESCAN MIRA3 XMU) and Fourier transform infrared (FTIR, Bruker Model: TensorII) were used for the characterization of $FeCl_3$ nanoparticles synthesized using tea waste.

2.5. Adsorption Experiments

Experiments were carried out in a batch system on the removal of methyl violet 2B dyestuff with $FeCl_3$ nanoparticles synthesized using tea waste. For adsorption experiments, 1000 mg/L stock methyl violet 2B solution was prepared. The stock solution was diluted and a dyestuff solution was prepared at a concentration of 50 mg/L. pH, adsorbent dose, initial dyestuff concentration tests were carried out and optimum conditions were determined. NaOH (0.1 M) and HCl (0.1 M) were used for pH adjustment. In order to determine the removal, dye concentrations were determined using a UV spectrophotometer at a wavelength of 575 nm.
The removal equations for the adsorption experiments are given in equations 1 and 2. [14].

$$\mathrm{qe} = \frac{(\mathrm{Co}-\mathrm{Ce})\mathrm{V}}{\mathrm{m}} \qquad (1)$$

$$\mathrm{Removal}(\%) = \frac{(\mathrm{Co}-\mathrm{Ce})}{\mathrm{Co}}\mathrm{x}100 \qquad (2)$$

3. RESULTS and DISCUSSION

3.1. Charactarization of $FeCl_3$ nanoparticles

3.1.1. SEM/EDX results

500, 5000, 1000 and 2000 kx SEM images of $FeCl_3$ nanoparticles synthesized by green synthesis method using tea waste before adsorption and after adsorption are given in Figure 1.

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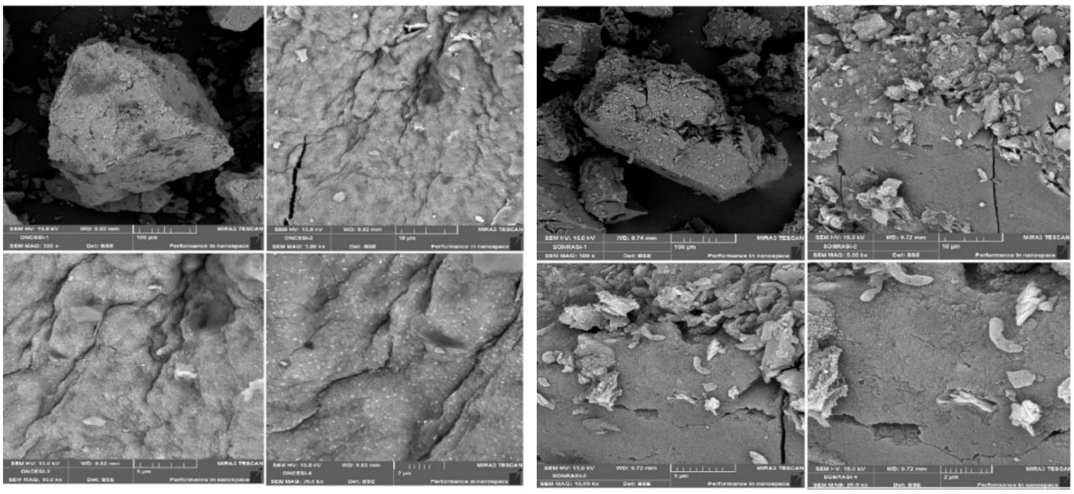

(a) (b)

Figure 1. SEM images of $FeCl_3$ nanoparticles synthesized with tea waste (a)before adsorption, (b)after adsorption.

As seen from the pre-adsorption SEM images $FeCl_3$ nanoparticles synthesized using tea waste have a porous and nano-sized structure. The white dots seen in Figure 1a are proof that the nanoparticle contains iron. If these white dots are not visible in Figure 1b This is the proof that the nanoparticle is adsorbed with the dye.

EDX analyzes were performed using the backscattered electron detector (BSE) of the SEM (TESCAN MIRA3 XMU). Elemental analysis results of $FeCl_3$ nanoparticles synthesized using tea waste before adsorption are given in Table 2. Figure 2 shows the EDX image of $FeCl_3$ nanoparticles synthesized using tea waste before and after adsorption.

Table 2. Elemental analysis results of $FeCl_3$ nanoparticles synthesized using tea waste before adsorption.

Element	Weight(%)	Atomic(%)
C	34.23	48.30
O	32.40	34.33
Na	10.16	7.49
Cl	15.11	7.22
K	1.60	0.69
Fe	6.51	1.97

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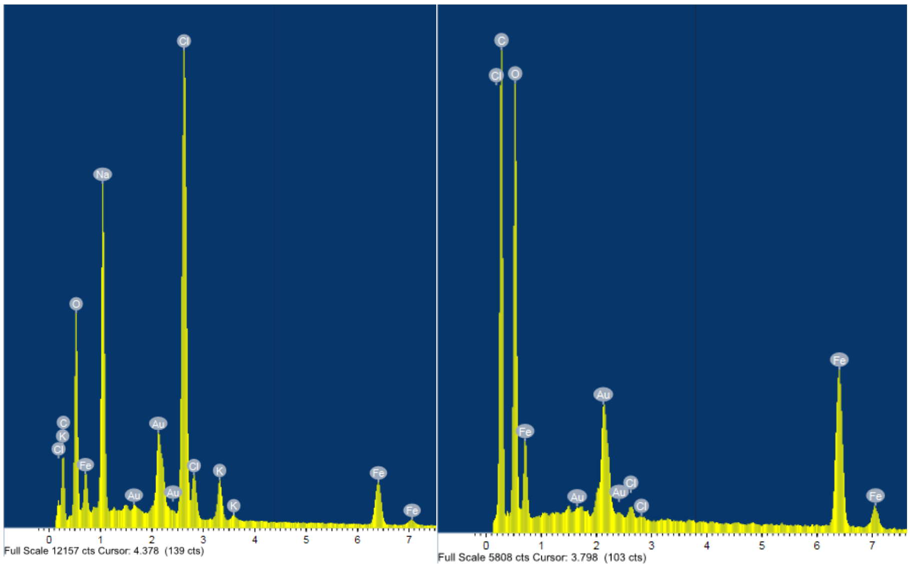

a b

Figure 2. EDX image of $FeCl_3$ nanoparticles synthesized using tea waste (a)before adsorption, (b)after adsorption.

The EDX analysis results given in Table 2 show that the elemental and quantitative weight composition of $FeCl_3$ nanoparticles synthesized using tea waste before adsorption It has been shown that it consists of 34.23% C, 32.40% O, 10.16% Na, 15.11% Cl, 1.60% K, 6.51% Fe elements. The EDX analysis results given in Table 3 show that the elemental and quantitative weight composition of $FeCl_3$ nanoparticles synthesized using tea waste after adsorption It showed that it consists of 45.99% C, 38.30% O, 0.27% Cl, 15.44% Fe elements. The presence of K in the nanoparticles before adsorption indicates that this may be due to the tea extract. The absence of some elements in the nanoparticles after adsorption can be explained by the fact that these elements have passed into the water. In addition, the increase in element C after adsorption is due to the adsorption of dye molecules with $FeCl_3$ nanoparticles synthesized using tea waste. Elemental analysis results of $FeCl_3$ nanoparticles synthesized using tea waste after adsorption are given in Table 3.

Table 3. Elemental analysis results of $FeCl_3$ nanoparticles synthesized using tea waste before adsorption.

Element	Weight(%)	Atomic(%)
C	34.23	48.30
O	32.40	34.33
Na	10.16	7.49
Cl	15.11	7.22
K	1.60	0.69

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Fe	6.51	1.97

3.1.2. FTIR analysis results
FTIR is used to understand the bonding of compounds in the substance and to determine adsorption and desorption [15]. Spectra Bruker Model: It was taken between 400-4000 cm^{-1} using Tensor FTIR Spectrum Device.

In Figure 3 The peaks around 2958 cm^{-1} and 2898 cm^{-1} may be due to the presence of CH_3 groups that cause C-H stretching [16]. The peaks at 2264 cm^{-1} and 2303 cm^{-1} can be attributed to stretching of the single bond CH group [5]. The adsorption band around 1728 cm^{-1}, 1634 cm^{-1}, 1581 cm^{-1}, 1544 cm^{-1}, 1497 cm^{-1} can correspond to C=C double bond stretching vibrations. The peaks formed in the fingerprint region, ie the band around 1342 cm^{-1}, 1205 cm^{-1}, 1169 cm^{-1}, 1040 cm^{-1} and 1034 cm^{-1}, may correspond to C-N stretching and bending vibrations [16].

The spectrum obtained after the adsorption of $FeCl_3$ nanoparticles synthesized using tea waste with methyl violet 2B solution showed spectral properties at 1582 cm^{-1}, which is proof that adsorbents are adsorbed with dye [17]. FTIR analysis result of $FeCl_3$ nanoparticle synthesized using tea waste is given in Figure 3.

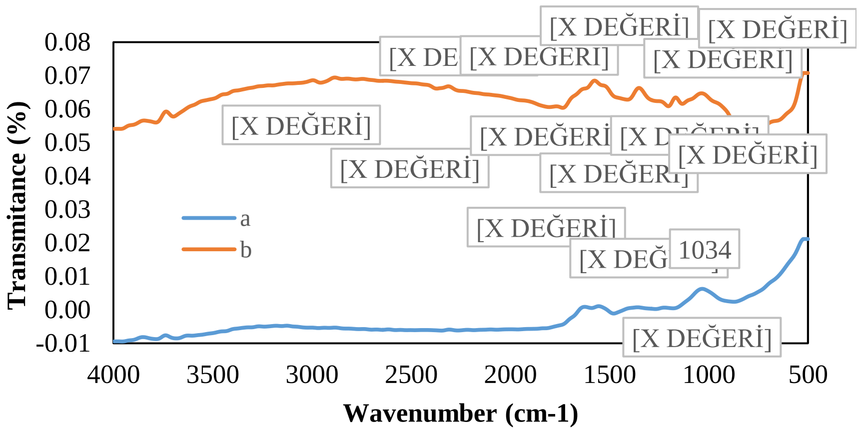

Figure 3. FTIR spectrum of $FeCl_3$ nanoparticles synthesized using tea waste a) Before adsorption of $FeCl_3$ nanoparticles synthesized using tea waste with methyl violet 2B b) After adsorption of $FeCl_3$ nanoparticles synthesized using tea waste with methyl violet 2B.

3.2. Adsorption Studies

3.2.1. Effect of pH
In order to observe the adsorption of methyl violet 2B solution with $FeCl_3$ nanoparticles synthesized using tea waste, pH values were changed and ambient conditions were kept constant (100 mL working volume, 50 mg/L dye concentration, 30°C temperature, 125 rpm stirring speed, 2 hours waiting time,

1 g/L adsorbent dosage). Different pH adjustments were made and it was observed that the solution was more efficient at low pH, but the optimum pH was determined as 4.5 due to the loss of the produced material in acidic conditions. pH adjustments were made with HCl¬ and NaOH. The effect of pH on the adsorption is given in Figure 4.

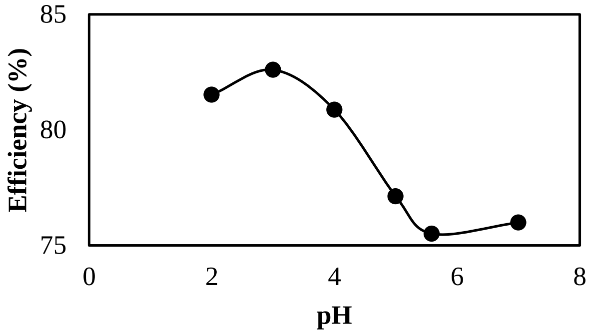

Figure 4. Effect of pH on adsorption efficiency.

3.2.2. Adsorbent dosage effect

To examine the effect of $FeCl_3$ nanoparticles synthesized using tea waste on methyl violet 2B dyestuff, the dye concentration was kept constant (50 mg/L) at a stirring speed of 125 rpm at 0.5-1-2-4-6 g/L adsorbent dosages, 100 mL working volume, pH 4.5 at 30 °C and time held constant (2 hours).When the graph below is examined, the removal efficiency is 92% at 2 g/L adsorbent dosage, while the efficiency is 82% at 1 g/L adsorbent dosage. Effect of adsorbent dosage on the adsorption is given in Figure 5.

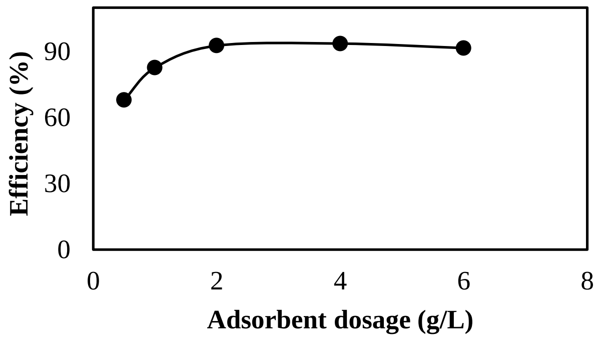

Figure 5. Effect of adsorbent dosage on adsorption efficiency.

3.2.3. Initial dye effect

Methyl violet 2B solutions were prepared at 20, 40, 60, 80 and 100 mg/L concentrations by keeping the experimental conditions constant (125 rpm stirring speed, 30 °C temperature, 1 g/L adsorbent dosage, pH 4.5, 100 mL working volume, 2 hours waiting time). In the Figure below, it was observed that the percentage yield increased as dye concentration increased, while a decrease in yield was observed after a certain concentration. The adsorption reached equilibrium at initial concentration of 50 mg/L, and thus the optimum concentration was determined as 50 mg/L The effect of dye concentration on the adsorption is given in Figure 6.

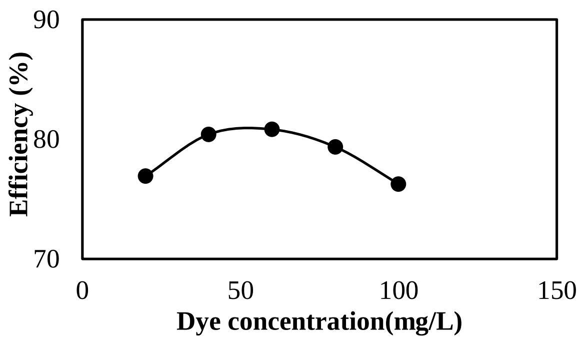

Figure 6. Effect of dye concentration on the adsorption efficiency.

3.3. Adsorption Kinetic

The velocity graphs of $FeCl_3$ nanoparticles synthesized with tea waste were analyzed in 4 different models as pseudo first order, pseudo second order, intraparticle diffusion and Elovich model. These models are it was investigated at optimum pH (4.5), 50 mg/L initial pollutant concentration, 1 g/L adsorbent dosage, 100 mL working volume, 240 min contact time and 125 rpm mixing speed. Graphs of kinetics were drawn and desired values were obtained from these graphs.

A plot of t/qt versus t was drawn to determine the pseudo second-order kinetic model. The R^2 value was found to be 1. However, it is seen that the adsorption capacity obtained experimentally and the calculated from the kinetic equation are very close to each other. Therefore, as a result of the data obtained, the removal of methyl violet 2B dye with FeCl3 nanoparticles synthesized using tea waste was found to be compatible with the pseudo second order kinetic model. The plots for the Pseudo first-order (a) and Pseudo second-order, (b) Intraparticle diffusion model (c) and Elovich model (d) are given in Figure 7. The data of methyl violet 2B adsorption with $FeCl_3$ nanoparticle synthesized using tea waste are given in Table 4.

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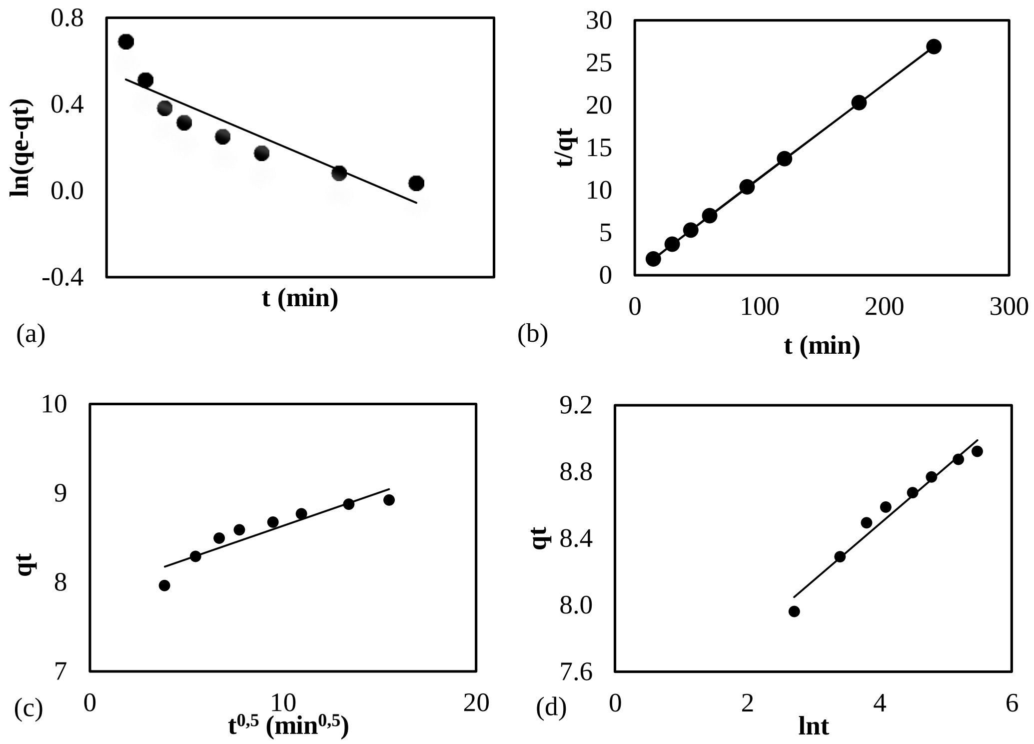

Figure 7. The plots for the (a) Pseudo first-order and (b) Pseudo second-order velocity graph, (c) Intraparticle diffusion model and (d) Elovich model.

Table 4. Kinetic data of methyl violet 2B adsorption with $FeCl_3$ nanoparticle synthesized using tea waste.

Pseudo first-order		**Pseudo second-order**		**Intraparticle diffusion model**		**Elovich**	
R^2	0.8161	R^2	1.0	R^2	0.865	R^2	0.9684
k_1 (min^{-1})	0.0001	k_2 ((mg/g).min))	0.0402	C	7.8852	β	1.187
$qe_{(cal)}$ (mg/g)	1.738	$qe_{(cal)}$ (mg/g)	9.009	K_2	0.0757	α	2.949
$qe_{(exp)}$ (mg/g)	9.058	$qe_{(exp)}$ (mg/g)	9.058				

3.4. Adsorption Isotherms

The Langmuir isotherm is a homogeneous, monolayer and physical isotherm [18]. Adsorption isotherms are used to determine the adsorption capacity. Curves that relate the solute concentration (Ce) remaining in the solution after being adsorbed at equilibrium and the amount of substance adsorbed per unit weight of the adsorbent at equilibrium (qe) [19].

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The dye adsorption of $FeCl_3$ nanoparticle synthesized with tea waste was investigated by Freundlich, Langmuir, Dubinin-Radushkevich and Temkin isotherms in the Figures below. These isotherms were investigated at different temperatures (20-30-40 °C), optimum pH (pH 4.5), 100 mL working volume, different dye concentrations (25-50-100-200 mg/L), 1440 min contact time and 125 rpm stirring speed. The curves given below are plotted with data obtained at 20°C.

When the correlation numbers of the Langmuir isotherm model at 20-40 °C temperatures given in Table 5 are examined, it is seen that the adsorption of $FeCl_3$ nanoparticles synthesized using tea waste is compatible with this isotherm model. The RL value, which is the separation factor defined by Webber and Chakkravorti based on the Langmuir equation, is an important parameter that indicates whether adsorption will occur or not. A low RL value is more suitable for the adsorption process [20]. Looking at Table 5, the low RL values and correlation number prove that this adsorption is compatible with the Langmuir isotherm model. Linear isotherm graphs of adsorption of methyl violet 2B from aqueous solution by $FeCl_3$ nanoparticle synthesized using tea waste Langmuir(a), Freundlich(b), Temkin(c) and Dubinin-Radushkevich(d) are given in figure 8.

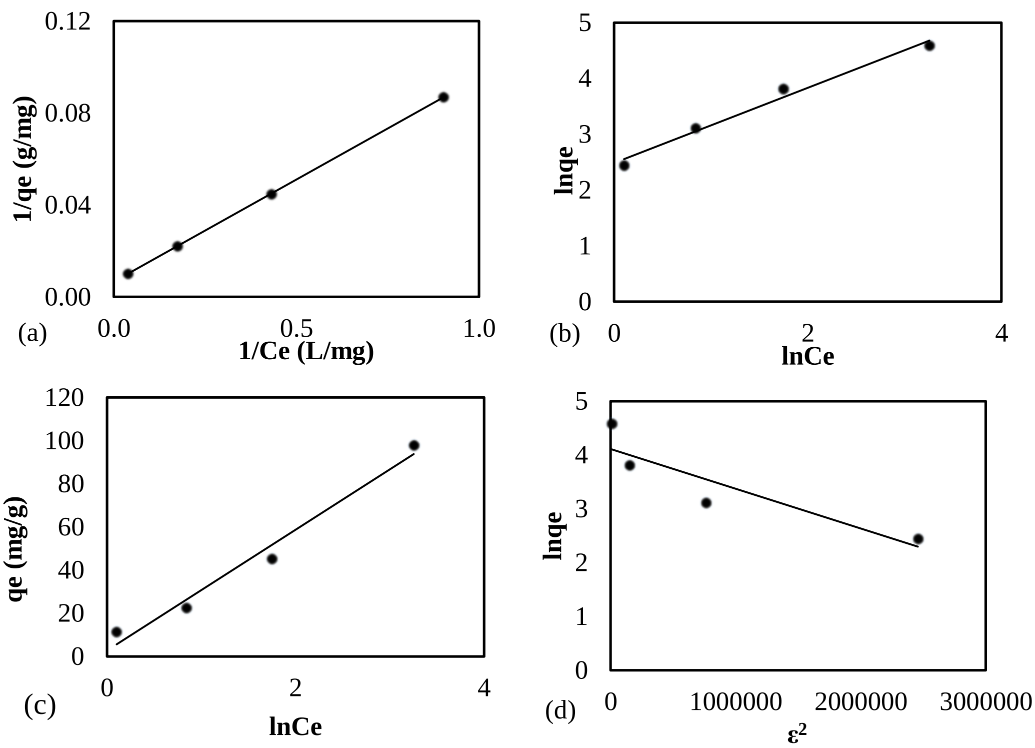

Figure 8. Linear isotherm plots of adsorption of methyl violet 2B from aqueous solution by $FeCl_3$ nanoparticle synthesized using tea waste (a) Langmuir, (b) Freundlich, (c) Temkin and (d) Dubinin-Radushkevich.

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Freundlich isotherm is considered a multilayered process in which the amount of solute absorbed per unit mass of adsorbent gradually increases [21]. When looking at temperatures of 20-40 °C in Table 5, it is seen that the value of n is between 1 and 10. This shows a suitable sorption process [22]. Adsorption of $FeCl_3$ nanoparticles synthesized using tea waste may also be suitable for Freundlich isotherm.

It is accepted that the adsorption energy decreases linearly in the Temkin isotherm model as the active centers on the surface of the adsorbent are filled [23].

Dubinin-Radushkevich isotherm is used to understand whether the adsorption takes place with Gaussian energy over a heterogeneous surface [22]. The isotherm data of methyl violet 2B adsorption with $FeCl_3$ nanoparticle synthesized using tea waste are given in Table 5.

Table 5. Isotherm data of methyl violet 2B adsorption with $FeCl_3$ nanoparticle synthesized using tea waste.

Isotherm model	**Temperature (°C)**		
	20	**30**	**40**
Langmuir			
q_m (mg/g)	149.254	200.0	166.67
K_L (L/mg)	0.076	0.0437	0.049
R_L	0.344	0.477	0.449
R^2	1.0	0.9871	0.9752
Freundlich			
n	1.487	1.412	1.45
K_F	12.03	10.14	9.569
R^2	0.9819	0.982	0.9794
Temkin			
B	28.013	29.171	27.87
A	1.09	0.88	0.82
b_T (J/mol)	0.086	0.086	0.093
R^2	0.9754	0.9656	0.9459
Dubinin- Radushkevich			
q_m(mg/g)	61,06	64	63.18
K_D (mol^2/kJ^2)	22.225	8.718	8.718
E (kj/mol)	$2.67*10^{-4}$	$2.89*10^{-4}$	$2,89*10^{-4}$
R^2	0.8113	0.8563	0.8609

3.5. Adsorption Thermodynamics

Thermodynamic studies of the adsorption of $FeCl_3$ nanoparticles synthesized with tea waste with methyl violet 2B It was investigated at temperatures of 20-30-40 °C, optimum pH (pH 4.5), 100 mL working volume, adsorbent dosage of 1 g/L, initial dye concentration of 25 mg/L, contact time of

1440 min and stirring speed of 125 rpm. Shape ΔH, ΔS and ΔG data were calculated from the Van't Hoff graph shown in Figure 17 and are given in Table 5. The adsorption process is thermodynamically feasible or not feasible and can be estimated from the sign of the standard free energy change (ΔG). If ΔG < 0 adsorption is always possible and spontaneous, if ΔG > 0. The adsorption process is not convenient and not spontaneous. Looking at Table 5, it is seen that the ΔG value obtained from the Van't Hoff plot is negative, indicating that the adsorption process is spontaneous and feasible. The ΔH value was calculated as -13,898 kj/mol, indicating that the adsorption is exothermic. The ΔS value was calculated as -28.18 kj/mol.K, which indicates a decrease in irregularity at the solid liquid interface [24]. Previous studies have shown that the ΔG° value ranges from -20 to 0 kj/mol for physical adsorption and -80 to -400 kJ/mol for chemical adsorption [25]. The ΔG values at all temperatures are respectively since -5.703, -5.226 and -5.148 kj/mol, we can say that adsorption is physical. A negative ΔG value (-5.703, -5.226, -5.148 kj/mol) indicates that adsorption is spontaneous and feasible, a negative ΔH value (-13.898 kj/mol) indicates adsorption is exothermic. The Van’t Hoff linear graph is given in Figure 9.

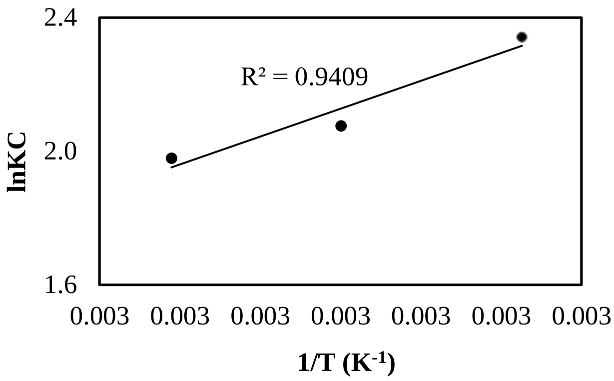

Figure 9. Van’t Hoff linear graph.

4. RESULTS

In this study, $FeCl_3$ nanoparticles were prepared by green synthesis method using tea extract. The adsorption of methyl violet 2B dyestuff with $FeCl_3$ nanoparticles synthesized using tea extract was investigated in batch system. In 2 hours, the adsorption experiments reached equilibrium. The adsorbent dosege was studied in the range of 0.5-6 g/L and the optimum dose was determined as 1 g/L. pH was studied in the range of 2-7 and the optimum pH was determined as 4.5. The initial dyestuff concentration was studied in the range of 20-100 mg/L and the optimum concentration was determined as 50 mg/L. The equilibrium data obtained were applied to the isotherm equations and when the correlation numbers were examined, it was determined that the adsorption was in accordance with the Langmuir isotherm model. In the isotherm studies performed at 20 °C, 30 °C and 40 °C and the q_{max} values were found to be 149.254, 200 and 166.67 mg/g, respectively. The removal efficiency was calculated as 82 % at 30 °C where the highest q_{max} was obtained. According to the Langmuir isotherm, adsorption takes place physically. The separation factor (RL) for the Langmuir isotherm was determined between 0.344-0.349, indicating that the process is suitable for the Langmuir isotherm. The adsorption kinetic equations were examined and it was seen that the adsorption was suitable for the pseudo second order kinetic model since the correlation number was 1. In addition, the relatively small relative error between the qe values obtained from the pseudo second order equation and the experimental qe values also supports this. The pseudo second order kinetic model assumes that the rate of adsorption is determined by the amount of sites remaining on the adsorption surface [26]. In the data obtained from thermodynamic studies, the adsorption enthalpy (ΔH) and Gibbs free energy were found to be -13.898kj/mol and -5.226kj/mol (30 °C), respectively. This shows that the adsorption process is exothermic, spontaneous and feasible. ΔS was found to be -28.18 kj/mol. A negative entropy indicates that the disorder at the solid-liquid interface is reduced. Characterization of $FeCl_3$ nanoparticles synthesized using tea extract was performed using SEM/EDX and FTIR devices. As a result of SEM/EDX analysis, it was observed that $FeCl_3$ nanoparticles synthesized using tea waste were adsorbed with methyl violet 2B dye. According to the results of the FTIR analysis, a peak showing methyl violet 2B was observed, which is proof that $FeCl_3$ nanoparticles synthesized using tea waste were adsorbed with dye. It was found that $FeCl_3$ nanoparticles synthesized with tea extract were effective in removing methyl violet 2B dye solution.

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