IHJPAS. 36(1)2023

Ibn Al-Haitham Journal for Pure and Applied Sciences

Journal homepage: jih.uobaghdad.edu.iq

Study the Interaction Adsorptive Behavior of Sunset Yellow Dye and Loratadine Drug: Kinetics and Thermodynamics Study

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Article history: Received 8 Augest 2022, Accepted 27 September 2022, Published in January 2023.

doi.org/10.30526/36.1.2974

Abstract

The performance of drug treatment and assessments of different drugs' side effects both can be affected by the interaction between food additives and drugs. Organic compounds such as food colorants dyes are utilized as additives in a wide range of foods. In this study, the adsorption interaction behavior between the colorant food dye sunset yellow (SY) and the drug loratadine was examined. The adsorption procedure is conducted at different drug dosages, various SY dye concentrations, and different temperature (288-318K). The equilibrium data were explained by using Freundlich and Langmuir adsorption isotherms, but Langmuir offering the best fit model. Kinetics adsorptive behavior of sunset yellow on loratadine matched pseudo-second order kinetics. Thermodynamics study show that the process is exothermic, spontaneous and the disorder at the solid-solution interface was proven from the negative entropy (-140.556 J/ K.mol) of adsorption process.

Key words: Sunset Yellow, Loratadine, Adsorption, Kinetics, Thermodynamics.

1. Introduction

The performance of pharmacological treatment and evaluation of many drugs' adverse reactions can both be influenced by the interaction between food additives and drugs. Some pharmaceuticals cannot be taken with particular foods because they include chemical components such as dyes, which can induce a reaction that alters the drug's effect. It also can cause or exacerbate negative effects [1].

Nowadays, the majority of food dyes are synthesized and derived from petroleum and coal tar. In reality, consumption of artificial food dyes has risen by 500% in the previous 50 years, with children being the main consumers [2].

Food coloring dyes may be harmful and have no important nutrients, and can cause a number of diseases, such as cancer and allergies [3]. Synthetic dyes are bioaccumulate so they have adverse environmental effects, carcinogenic effects, causing metabolic disorders and genetic problems especially if they are used in large quantities. [4]. Children who consume too many food dyes may suffer a number of negative effects, including allergies, hyperactivity, and attention deficit disorders [5]. The health consequences of these dyes are negligible because they are regarded as safe when used in accordance with authorized production techniques.

Since each government regulates all types and levels of food dyes that are authorized, the investigations were shown that some dyes are used at quantities over the limit permissible, exposing consumers at significant risks [6].

Sunset yellow (SY) is a synthesized compound contains azo groups (**Figure 1**). It is soluble in water, slightly soluble in ethanol, have IUPAC name disodium, 6-hydroxy-5-(4-sulfonatophenyl) diazenyl) naphthalene-2-sulfonate [7]. Many production processes, like those in the food, pharmaceuticals, cosmetic, textile, and leather trades, utilize sunset yellow as a colorants material. When these azo dyes are used frequently, it could really lead to many health risks such allergic reactions, chromosomal abnormalities, and hyperactivity in children [8].

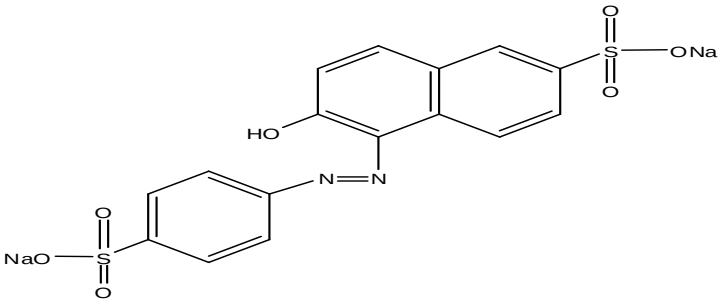

Figure 1. Structure of sunset yellow

Contrarily, drugs administered as pharmaceuticals are often aromatic hydrocarbons compounds that have an effect on the whole organism. Generally, the therapeutic effects of these drugs seen with daily use may be enhanced in an overdose [9].

Antihistamine drugs like loratadine (**Figure 2**) are used to treat the allergy symptoms. It is usually used to treat the hives, a rash, itchy eyes, runny nose, nasal congestion, and nasal congestion [10]. Due to its poor ability to dissolve, loratadine has a rate-limiting step in the absorption process. Loratadine has a low variable oral absorption considering that it is practically insoluble in water [11].

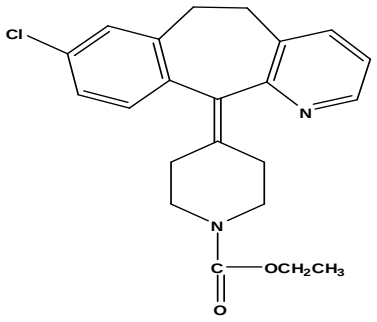

Figure 2. Loratadine chemical structure

The hazards of interactions between food dye and insoluble or weakly soluble drugs in water have not yet been studied. If the additives in food like colorant dyes adsorb on such drugs, it cause an interaction that may decrease the efficiency of the treatments in curing diseases and increasing their biocompatibility within the body.

Taking into account the health risks that food dyes cause to humans, the objective for carrying out this investigation is to study that how food dye sunset yellow and the drug loratadine interact during the adsorption process. To illustrate the equilibrium in processes, various adsorption isotherms will be employed such as the Langmuir and Freundlich models. Kinetics and thermodynamics parameters of the process will be used to assess the feasibility of the adsorption process

2. Materials and Experiments

Loratadine was provided by a state company in Samarra for the production of pharmaceuticals and medical equipment. Sunset yellow dye was supplied from locally Market. 1 g of the dye was accurately dissolved in one liter of distilled water to obtain 1000gL^{-1} of sunset yellow stock solution. Shimadzu double-beam UV-Vis spectrophotometer was used to determine the absorbance of different concentrations (10-60 mg/L) of sunset yellow dye which were prepared by diluting the appropriate dye stock solution in accordance with the calibration curve and adsorption process requirements. At a wavelength of 480 nm, sunset yellow's maximum absorption was detected as in **Figure (3)**.

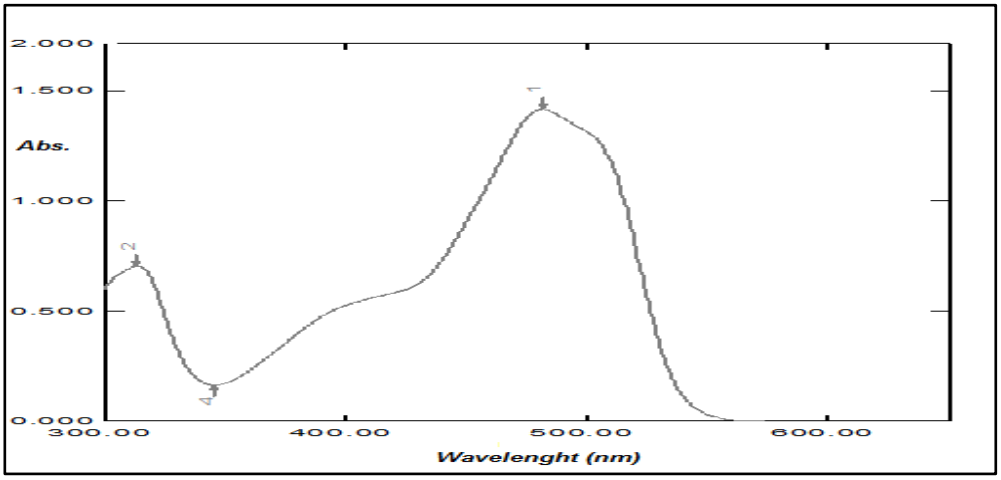

Figure 3. The UV-Visible spectra of sunset yellow dye.

For building the calibration curve of sunset yellow dye, a range of concentrations of sunset yellow dye (10–60 mg/L) were made from stock solution, and the absorbance for each concentration was observed as shown in figure (4) at its optimum wavelength (480 nm).

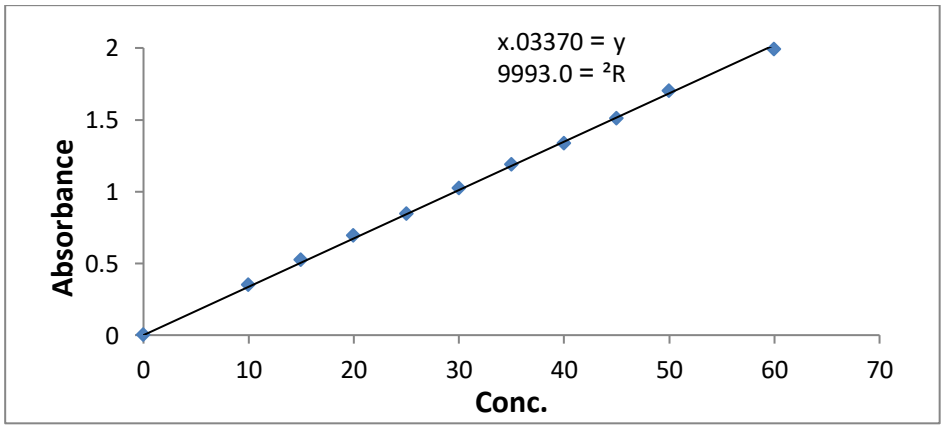

Figure 4. Calibration curve of sunset yellow

To investigate that how process is influenced by different factors, such as SY concentration, loratadine amount, contact time, and temperature, batch adsorption studies have been carried out. The quantity of SY adsorbed on the loratadine drug's surface was calculated using the formula below:

$$q_e = \frac{(C_0 - C_e)\,V}{w} \qquad (1)$$

Where V represents for the volume of the solution (L), the mass of the drug w is (g), and C_0 and C_e are the concentrations of SY (mg/L) at initial and equilibrium, respectively.

For a 30 mg/L of SY dye solution, the effects of many adsorbent dosages (0.05, 0.1, 0.15, 0.2, and 0.25 g) in 50 mL of dye were investigated. The thermostatic shaker bath's agitation speed was set at 200 rpm for all the experimental steps, and the temperature was kept constant at 298 K.

To evaluate the effect of contact time on the adsorption process of SY, 0.1g of loratadine drug was added to 50 mL of SY solution (30 mg/L) in 250 mL flasks. 5mL of the sample was drawn out every 10 minutes, and until equilibrium is achieved, the concentration was determined. The adsorption process was studied at temperatures in the range 288–318 K to examine the effect of temperature on the process.

3. Results and Discussion:

Effect of Drug Dosage

Because it directly influences an adsorbent's capacity at a specific initial concentration of adsorbate, the dosage of an adsorbent is a significant factor to be studied. A series of adsorption experiments were conducted with various adsorbent doses from (0.05g - 0.25g) in 50 ml of initial concentration 30 mg/ L SY dye and at constant contact time to examine the effects of drug dosage on the adsorption of SY.

Figure (5) reveals that using 0.1g of loratadine increases the amount of SY adsorbed with drug dosage enhancement to its maximum value.

In fact, the dye adsorption remained approximately constant as the dose of the drug was increased, and then it decreased as the dosage was increased. Additional dye was adsorbed when the dosage of the drug was increased until equilibrium was reached. This due to the competition between adsorbent molecules for adsorption as well as the influence of the variation in SY molecules concentration and drug quantity [12]. The use of this adsorbent dose was confirmed in all experiments.

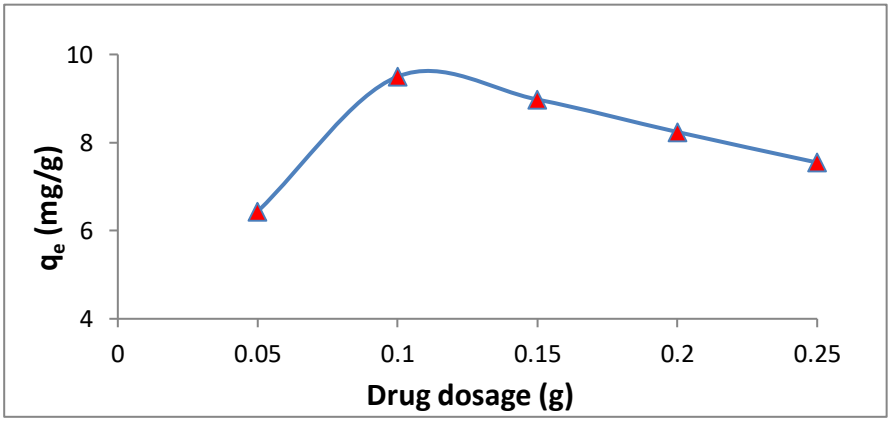

Figure 5. Effect of drug quantity on the amount of sunset yellow absorbed

Effect of initial concentration and contact time

The impact of contact time on dye adsorption was assessed throughout a variety of times and initial dye concentrations, ranging from 10 to 50 mg L^{-1}, as shown in **Figure (6)**. It was revealed that the adsorption process began rapidly and slowed down after the initial contact time. To attain equilibrium in the adsorption of SY on the drug, it required 50 min to reach equilibrium then the amount of dye adsorption did not significantly alter over time. This is possible because vacant surface sites are available during the initial stages of adsorption, but after some time passes, the vacant sites become filled by dye molecules [13]. The relating plot **Figure (6)** illustrates how the amount of SY adsorbed depends on changing initial SY concentration and rises with initial SY concentration enhancement.

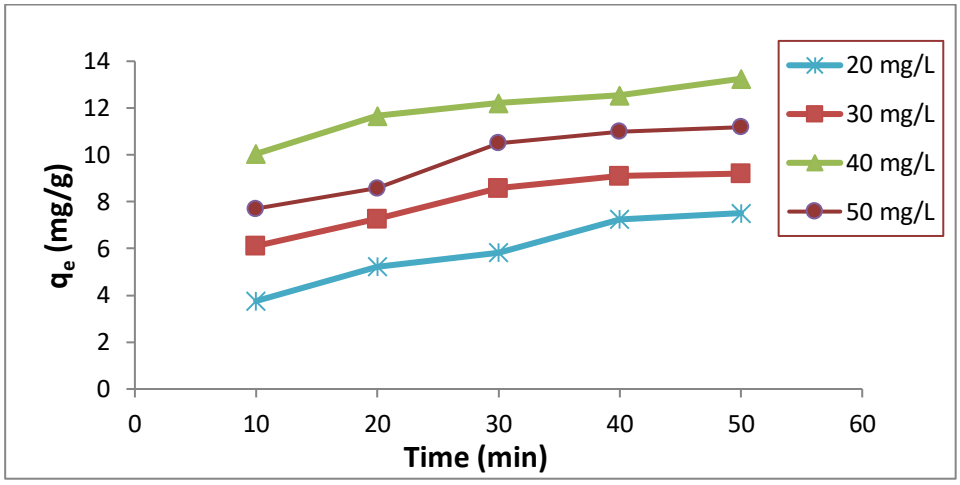

Figure 6. Contact time and initial SY concentration's effect on the adsorption process.

Adsorption Isotherm

Understanding the interaction between the amounts adsorbed of the food colorant sunset yellow on the surface of the drug at equilibrium is facilitated by adsorption isotherms. The relationship between amount adsorbed and dye concentration at equilibrium illustrates in **Figure (7)**. This figure shows the curve has an S-shape because of the small initial slope followed by a fast rise. Based on this specific isotherm, the affinity of the adsorptive surface is enhance with higher initial concentration and decreases with it droplets [14].

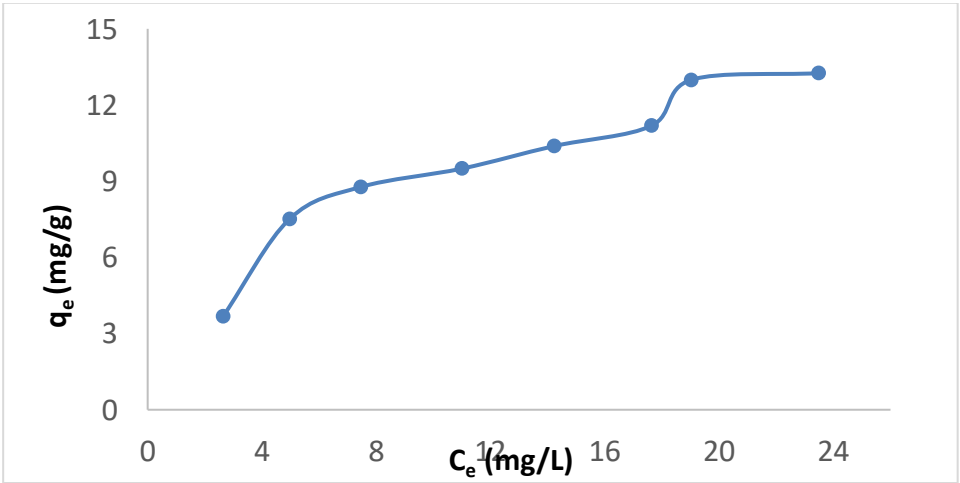

Figure 7. Adsorption isotherm of SY on loratadine at 298K.

The experimental data were tested to match the Freundlich and Langmuir adsorption models. Langmuir model, which affirmatively assume a monolayer, homogeneous and confined adsorption site. It is possible that a minimum threshold after which no further adsorption will take place. The

Langmuir equation is established and given as follows equation (2) for a surface with a small number of similar locations and monolayer saturation [15]:

$$\frac{C_e}{q_e} = \frac{1}{K_L . Q°} + \frac{C_e}{Q°} \qquad (2)$$

Where the Langmuir constants Q° (mg/g) and K_L (L/mg) are represented. K_L is roughly the energy adsorption constant, and Q° is the maximum adsorption capacity. The Langmuir constants Q° and K_L were obtained from the slope and interception of a linear plot of C_e/q_e against C_e, respectively. **Figure (8)** depicts the application of the Langmuir isotherm equation to the experimental data of adsorption SY dye on the drug adsorbent.

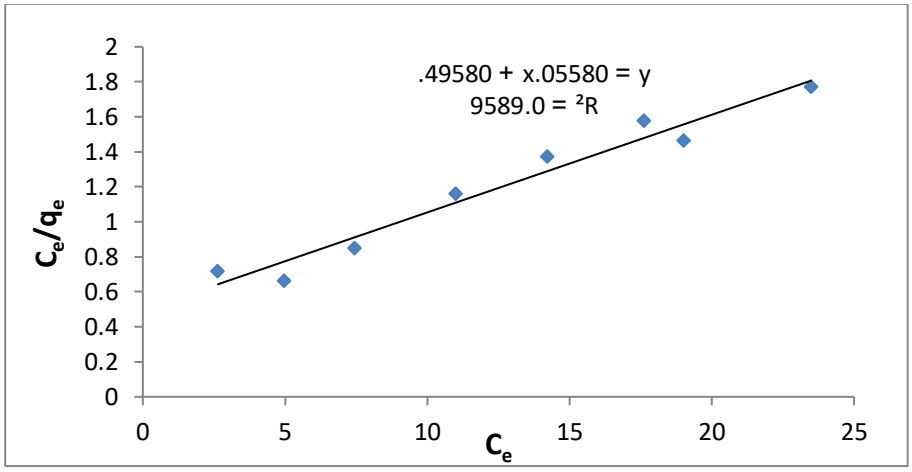

Figure 8. The Langmuir isotherm of SY adsorption of

The Langmuir isotherm is used to construct the Freundlich isotherm [16], which requires a heterogeneous surface with an adsorption capacity and is given by:

$$\ln q_e = \ln K_f + \frac{1}{n} \ln C_e \qquad (3)$$

The efficiency of adsorption is proportional to the dimensionless constant n, and the capacity of adsorption is related to the Freundlich constant (mg/L), or K_f. The value of n denotes how nonlinear the relationship is between the adsorption process and concentration of adsorbate. **Figure (9)** illustrates how the values of K_f and n were calculated from the intercept and slope of the fitted line of $\ln q_e$ against $\ln C_e$, respectively..

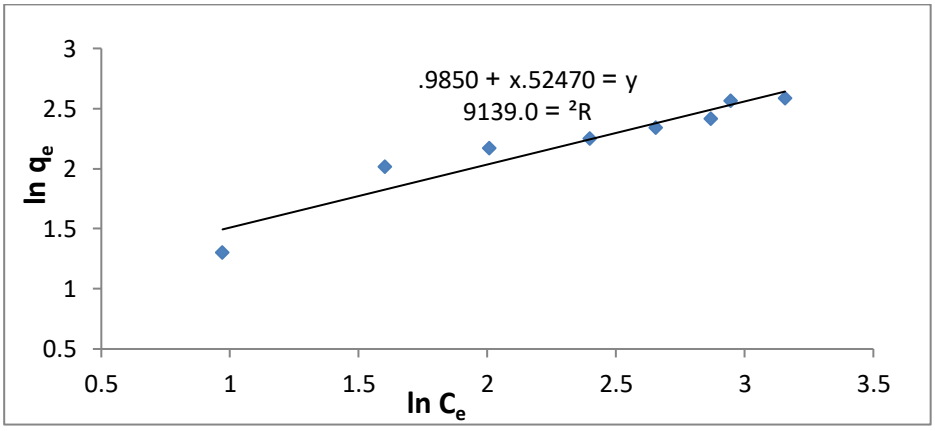

Figure 9. The Freundlich isotherm of SY adsorption

It is clear from the findings in Table 1 and based on the R^2 (regression coefficients), the Langmuir model was higher from that predicted by Freundlich This demonstrated that the results of the SY dye's adsorption onto the drug were well fitted by the Langmuir model. n values greater than unity showed a good synergistic association and a heterogeneous binding arrangement [17]. Furthermore, the Langmuir equation's estimate of maximal monolayer capacity (Q_0) showed a reduction in value with rising temperature, indicating an increase in adsorption capacity at low temperatures.

Table 2. Adsorption isotherm parameters of SY dye on drug.

Isotherm	Langmuir model			Freundlich model		
Temperature (K)	R^2	Q^0 (mg/g)	K_L(Lmg^{-1})	R^2	K_f(Lmg^{-1})	n
288	0. 9874	19.08	0.129	0.9791	3.125	1.946
298	0.9589	17.92	0.112	0.9139	2.667	1.905
308	0.9513	19.34	0.063	0.9468	1.679	1.594
318	0.9764	24.44	0.033	0.988	1.102	1.372

Adsorption Kinetics

The rate constant and mechanisms of SY adsorption on drug surface were determined using two kinetics models. These models are Lagergren-first-order equation and the pseudo-second-order equation which have been used to investigate the adsorption kinetic behavior of SY (30 mg/L) onto drug at temperatures ranged (288-318K). The best-fit was selected based on the results of the linear regression correlation coefficient (R^2).

The linear formula pattern of the pseudo-first order kinetic model is as follows (18):

$$\log(q_e - q_t) = log q_e - (k_1/2.303)\, t \qquad (4)$$

Where k_1 is the rate constant of the pseudo-first order kinetics (min^{-1}), The quantity of SY adsorbed on the drug's surface at equilibrium is termed as q_e, and the quantity at any given time is termed as q_t. The q_e and k_1 are frequently estimated using the intercept and slope of plots of log (q_e - q_t) vs t, respectively. In **Figure 10**, the result of such a plot is shown.

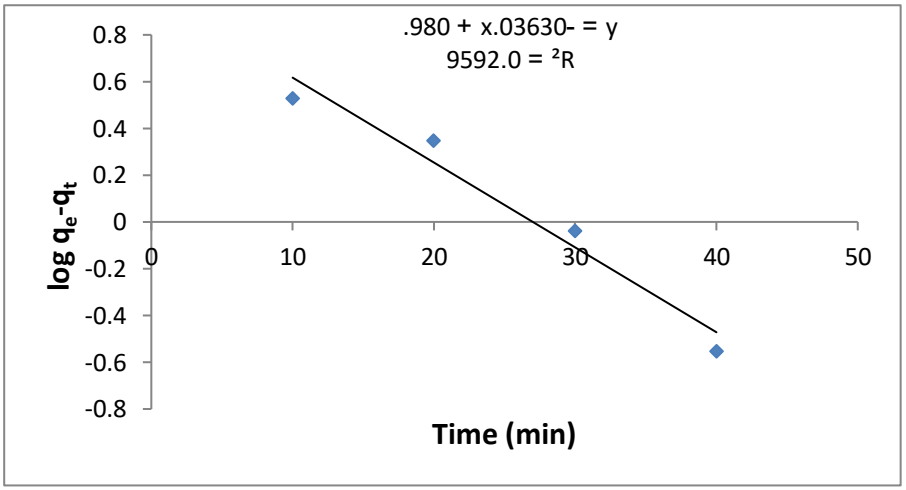

Figure 10. Adsorption kinetics pseudo-first order of SY on drug dye at 298K

The pseudo-second order kinetic model in linear form (19) is as follows:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \left(\frac{1}{q_e}\right) t \qquad (5)$$

Where k_2 is the pseudo-second order kinetics rate constant ($g.mg^{-1}.min^{-1}$). The intercept and slope of plots of t/q_t against t were obtained to calculate k_2 and q_e, as shown in **Figure 11**.

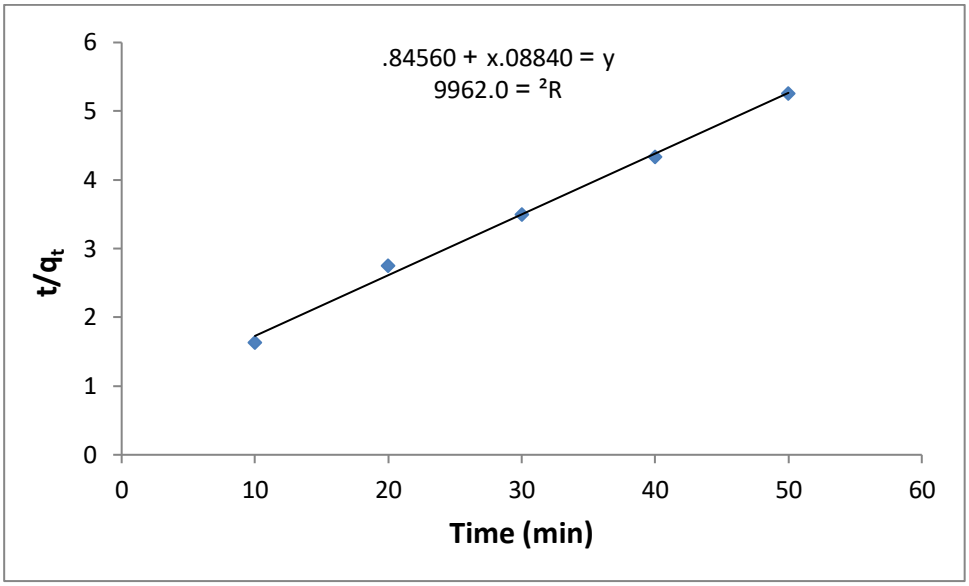

Figure 11. Adsorption kinetics pseudo-second order of SY on drug dye at 298K

As illustrated in **Table 2**, the value (R^2) of the two models are approximately identical, although the pseudo-second order equation's R^2 value is significantly higher. According to this, the pseudo second order kinetic model described the kinetics of the adsorption system more precisely than the pseudo-first order model.

Table 2. Kinetics data of SY dye adsorption on drug.

Kinetics models	Pseudo First order			Pseudo Second order		
Temperature (K)	R^2	k_1 (min^{-1})	$q_{e\ (mg/g)}$	R^2	k_2(g mg^{-1} min^{-1})	$q_{e\ (mg/g)}$
288	0.9428	0.0637	5.193	0.9962	0.0166	10.775
298	0.9592	0.0835	9. 549	0.9962	0.0092	11.312
308	0.9576	0.0852	5.591	0.9956	0.0163	9.310
318	0.9484	0.0817	12.723	0.994	0.0023	13.020

Thermodynamic Study

At four different temperatures in the range of (288- 318 K), adsorption studies were carried out to estimate the thermodynamic properties (free energy function (ΔG°), enthalpy function (ΔH°), and entropy function (ΔS°).

The thermodynamic properties were determined using these equations [20]:

$$\Delta G° = -RT \ln K_L \qquad (6)$$

$$\ln K_c = \frac{\Delta S°}{R} - \frac{\Delta H°}{RT} \qquad (7)$$

Where T is the temperature in kelvin, K_c is the equilibrium constant (L/g), and R is the value of the gas constant in joules (8.314 J/mol K). The van't Hoff plots of ln(K_c) against 1/T were used to

estimate the values of (ΔH°) and (ΔS°). Plotting of this relationship is illustrated in e **Figure (12)** represents this plotted relation and **Table (3)** depicts the thermodynamic parameters derived at various temperatures. The negative values of ΔG° provide as evidence for the feasibility and nature of spontaneous adsorption. The fact that the negative value of ΔG° diminishes as temperature rises suggests adsorption of SY on lotatadine is preferable and more strongly at low temperature.

As shown, the exothermic aspect of the process was proven by the negative value of (ΔH°) (-40.276 kJ/mol). Likewise, practically, (ΔH°) has a value approximately 40 kJ/mol. This indicated that adsorption of SY onto loratadine was a physical process [21].

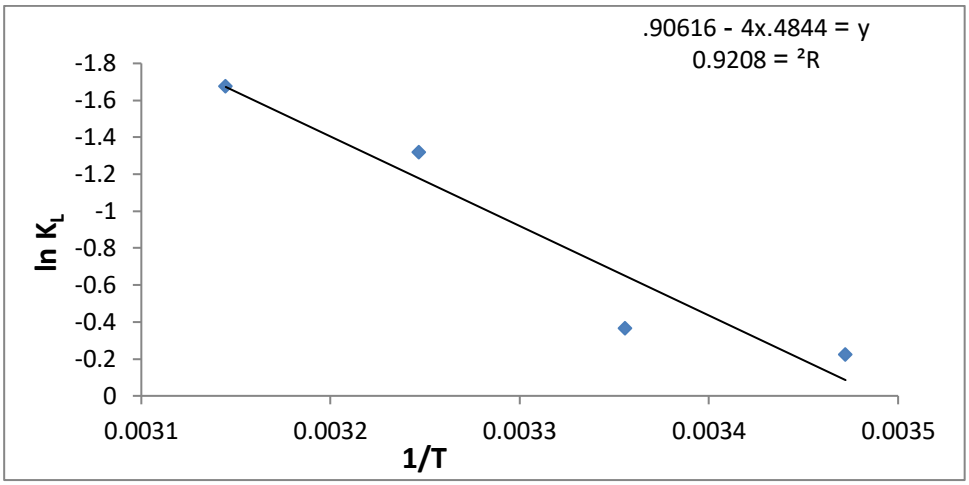

Figure 12. Van't Hoff plots for SY adsorption on loratadine

Entropy (ΔS°) is an indicator of randomness and show how a system's solid/liquid interface varies with temperature. Its negative value (-140.556 J/K mol) indicates the adsorption system tends to make the solid/liquid interface less irregular [22].

Table 3: Thermodynamic properties of the adsorption of SY on drug.

Temp.(K)	ΔG° (kJ/mol)	ΔH°(kJ/mol)	ΔS° (J/K.mol)
288	-0.224	-40.276	-140.556
298	-0.365		
308	-1.319		
318	-1.676		

4. Conclusions

Precautions must be considered prior to clinical instances because of the prevalence of drugs and food colorant dye interactions globally. The interaction in this study was clarified by adsorption of the food additive sunset yellow dye and the drug loratadine. The most effective model for illustrating the adsorption isotherm of SY dye onto the drug loratadine was observed to be the Langmuir isotherm model. The pseudo-second order equation can be used to explain the kinetics of SY adsorption on the drug loratadine, because it closely matched the results of the experiments. Thermodynamic study confirms that the SY adsorption onto loratadine was exothermic and spontaneous. The SY adsorption on loratadine is physisorption, as evidenced by the negative ΔH° value, which is -40.276 kJ/mol.

Conflict of interest

No actual conflict of interest that could have influenced this study.

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