



## Adsorption of reactive orange 13 onto jackfruit seed flakes in aqueous solution



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### ARTICLE INFO

#### Article history:

Received 30 May 2014

Received in revised form 8 September 2014

Accepted 10 September 2014

Available online 16 September 2014

### ABSTRACT

The adsorption of reactive orange 13 (RO13) onto jackfruit seed flakes was investigated in aqueous solution at different pHs, initial concentration of dye solutions, ionic strengths and temperatures, respectively. The adsorbent and dye adsorption were characterized by diffuse reflectance electronic absorption and Fourier transformation infrared (FTIR) spectra. The adsorption of RO13 increased largely with decreasing solution pH or with increasing initial dye concentration. Pseudo first-, second-order, intraparticle, and film diffusion kinetic models were used to evaluate experimental data obtained from batch studies, and thereby elucidate the kinetics and mechanism of adsorption process. The results showed that the adsorption of RO13 follows pseudo second-order kinetics very well. The intraparticle diffusion and film diffusion are the rate limiting steps. The equilibrium adsorption data were analyzed by Temkin, Freundlich and Langmuir isotherm models, respectively. The best fit to the data was obtained from the Langmuir model. The monolayer adsorption capacity of jackfruit seed flakes was found to be 64.10  $\mu\text{mol/g}$  at pH 2. The values of activation and thermodynamic parameters were calculated and obtained results revealed that the present adsorption is a spontaneous and endothermic physisorption process.

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### 1. Introduction

With economic and technological development, water pollution is a common problem in worldwide. Water pollution has become more and more serious, especially regarding dye ions. Dye ions, mainly from dyeing and textile industries have become serious threats to human beings and the aquatic ecosystem, due to their toxicity and persistence after being released into the natural water [1,2]. Therefore, discharge regulations are progressively becoming more stringent. Many recent studies have been focused on the development of efficient processes for the recovery of these organic contaminants from the effluents of textile industries [3–5]. Usually conventional techniques such as precipitation, coagulation and flocculation have been used in wastewater treatment although these techniques are not very efficient for removing several common dyes, especially from dilute solutions [3]. Photo-oxidation has also been proposed for the treatment of dye-containing effluents [4,5], however, this process is relatively expensive and not

appropriate for the treatment of large flows. More recently, biological degradation has been cited as an alternative process for the decolorization of the reactive dyes [6].

On the other hand, adsorption processes remain the most common useful techniques for the decontamination of the effluents of textile and dyeing industries. Many studies have been made on the possibility of adsorbents using chitosan [7–10] mineral sorbents [11], activated carbons [12–14], peat [15,16], chitin [17–20], rice husk [21], soy meal hull [22], and agro wastes [23–25]. However, the adsorption capacity of the adsorbents is not very large, to improve adsorption performance new adsorbents are still under development.

Recently, carbonized jackfruit peel has been used as an adsorbent to remove metal ions from aqueous solution [26]. The possibility of using jackfruit seed flakes as a low-cost adsorbent to remove organic dyes from water and wastewater has not been reported yet. For this reason, it seemed worthwhile to study the kinetics, mechanism, equilibrium and thermodynamics involved in adsorption of organic dye onto jackfruit seed flakes, which would give an insight to use it as a low-cost adsorbent to remove organic dyes from aqueous solution. This work deals with the adsorption

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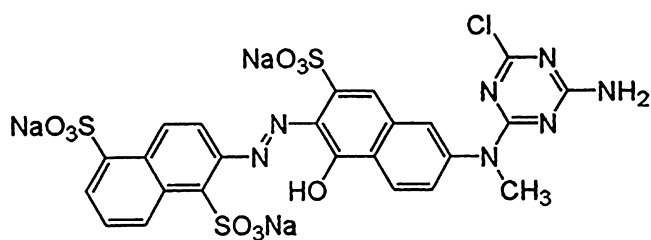


Fig. 1. The chemical structure of reactive orange 13 (RO13).

characteristics of reactive orange 13 (RO13, Fig. 1) onto a low-cost adsorbent jackfruit seed flakes in aqueous solution. The influences of various aspects including solution pH, initial concentration of dye solutions, solution temperatures and ionic strengths were investigated in batch mode. Various models were applied to examine the adsorption kinetics, mechanism and equilibrium adsorption behavior of RO13 onto jackfruit seed flakes. Thermodynamic parameters were also evaluated.

## 2. Materials and methods

### 2.1. Materials

Jackfruit seed was collected from local market. It was washed several times with deionized water to remove dust like impurities. It was then oven dried at 65 °C for 24 h. The dried sample was pulverized and stored in a plastic bottle for later use. No other chemical or physical treatments were used prior to adsorption experiments. The size distribution of jackfruit seed flakes was determined using a laser scattering particle size analyzer (LDSA-2400A, Tonichi Computer Applications, Japan) equipped with a dry dispersing apparatus (PD-10S, Tonichi Computer Applications, Japan). The sample showed a bimodal particle size distribution with peaks appeared at around 20 and 125  $\mu\text{m}$  in frequency, respectively. Moreover, the optical microscopic photograph demonstrated that the sample is a composed of relatively small and large particles.

The reactive orange 13 (RO13) was obtained from Sigma-Aldrich Germany and was used without further purification. The chemical structure of RO13 is shown in Fig. 1. The other reagents used in this study were of pure analytical grade. Deionized water was prepared by passing distilled water through a deionizing column (Barnstead, Syboron Corporation, Boston, USA).

### 2.2. Spectroscopic measurements

The diffuse reflectance electronic absorption spectra of the solid RO13, jackfruit seed flakes, and jackfruit seed flake-RO13 complex mixed with KBr were recorded by a Varian, Cary 5000 UV-visible-NIR spectrometer (Varian Inc., USA) in the wavelength region of 200–800 nm. The Fourier transformation infrared (FTIR) spectra of above samples were recorded in the frequency range 400–4000  $\text{cm}^{-1}$  using FTIR spectrometer (IRPrestige-21 FTIR Spectrophotometer, Shimadzu, Japan).

### 2.3. Batch adsorption experiments

In order to estimate the adsorption characteristics of RO13 onto jackfruit seed flakes, batch adsorption studies were carried out in 125 mL stoppered bottles containing a fixed amount (0.1 g) of adsorbent with 25 mL of 80  $\mu\text{mol/L}$  dye solution. The initial pH of the solution was adjusted with 1 M HCl or 1 M NaOH solution by using a pH meter (HANNA instruments microprocessor pH meter). The stoppered bottles were agitated in a thermostated shaker at

room temperature ( $30 \pm 0.2$  °C) with a speed of 120 r/min until reaching equilibrium. Each bottle was capped to avoid evaporation at high temperature. Samples were withdrawn at desired time intervals for analyzing the concentration of RO13 in solution. The samples were centrifuged at a speed of 4000 r/min for 5 min. The concentration of RO13 in the supernatant was determined by spectrophotometric method using a Shimadzu UV-1601PC spectrophotometer (Shimadzu, Japan) at  $\lambda_{\text{max}}$  value of 487 nm. The  $\lambda_{\text{max}}$  (487 nm) of RO13 solution was found to be constant at the pH ranges between 2 and 8. The apparent molar absorptivity of RO13 was estimated to be  $13 \times 10^3$  L/mol/cm at 487 nm and pH 2–8.

The amount of RO13 adsorbed at time  $t$ ,  $q_t$  ( $\mu\text{mol/g}$ ) was determined by

$$q_t = \frac{V(C_0 - C_t)}{m} \quad (1)$$

where  $C_0$  ( $\mu\text{mol/L}$ ) and  $C_t$  ( $\mu\text{mol/L}$ ) are the liquid-phase concentrations of RO13 at initial and at any time  $t$ , respectively,  $V$  (L) is the volume of RO13 solution and  $m$  (g) is the amount of dry jackfruit seed flakes used.

The amount of RO13 adsorbed at equilibrium time,  $q_e$  ( $\mu\text{mol/g}$ ) was determined by

$$q_e = \frac{V(C_0 - C_e)}{m} \quad (2)$$

where  $C_e$  ( $\mu\text{mol/L}$ ) is the liquid-phase concentrations of RO13 at equilibrium time;  $C_0$ ,  $V$  and  $m$  remain same as described above.

The adsorption kinetics was also performed varying initial concentration of dye solutions (50–700  $\mu\text{mol/L}$ ), ionic strengths (0.01–0.04 mol/L) and temperatures (35, 40 and 45 °C), respectively. The ionic strength of dye solutions was adjusted with 1 M KCl solution. The equilibrium adsorption was done at different temperatures of 30, 35, 40 and 45 °C, and at pH 2 in absence of KCl. The amount of adsorption was determined in the same way as described above.

## 3. Results and discussion

### 3.1. Point of zero charge measurements

The pH at potential of zero charge ( $\text{pH}_{\text{zpc}}$ ) of jackfruit seed flakes was measured using the pH drift method [28]. For the determination of  $\text{pH}_{\text{zpc}}$ , 0.1 M KCl was prepared, and its initial pH was adjusted between 2 and 12 using HCl and NaOH. Then, 50 mL of 0.1 M KCl was taken in 125 mL stoppered bottle and 0.1 g of jackfruit seed flakes was added to each solution. These bottles were kept for 24 h and the final pH of the solutions was measured with a pH meter. Fig. 2 shows the pH drift data, from which  $\text{pH}_{\text{zpc}}$  of the

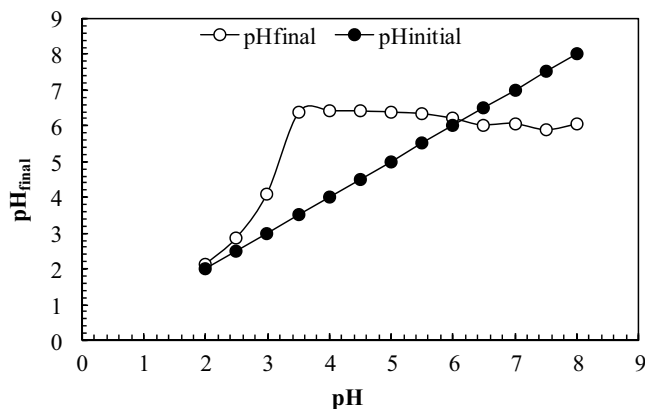


Fig. 2. Determination of  $\text{pH}_{\text{zpc}}$  of jackfruit seed flakes.

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