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Biosorption of Reactive Red 120 dye from aqueous solution using *Saccharomyces cerevisiae*: RSM analysis, isotherms and kinetic studies

Aliasghar Navaei[a], MohsenYazdani[b,c], Hossein Alidadi[d], Mahmoud Dankoob[a], Ziaeddin Bonyadi[d,*], Aliakbar Dehghan[d], Anis Hosseini[e]

[a]*Department of Environmental Health Engineering, Student Research Committee, School of Health, Mashhad University of Medical Science, Mashhad, Iran, emails: A.navaei2016@gmail.com (A. Navaei), Dankoobm1@mums.ac.ir (M. Dankoob)*
[b]*Department of Environmental health Engineering, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran, email: Yazdani4424@yahoo.com*
[c]*Student Research Committee, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*
[d]*Department of Environmental Health Engineering, Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran, Tel. +98-5138552610; Fax: +98-5138522775; emails: Bonyadiz@mums.ac.ir (Z. Bonyadi), Alidaih@mums.ac.ir (H. Alidadi), Dehgghanaa@mums.ac.ir (A. Dehghan)*
[e]*Department of Mathematics, Payame Noor University, Mashhad, Iran, email: Anishosseini59@gmail.com*

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ABSTRACT

Reactive Red 120 (RR 120) dye is widely used for textile dyeing in many countries. Most of the dye can cause skin reactions such as allergy, dermatitis and skin irritation, and are therefore considered as hazardous materials and toxic compounds for humans. Harvested cells of *Saccharomyces cerevisiae* were locally obtained from an Iranian Research Organization for Science and Technology. To provide an optimum condition for RR 120 removal by the response surface methodology, input factors contained the initial concentration of RR 120 5–50 mg L^{-1}, dose of *S. cerevisiae* 3–10 g L^{-1}, pH 3–10 and contact time 10–180 min. After completing each run, the suspensions were centrifuged at 10,000 rpm for 7 min. Finally, the absorbance of sample was read using UV-visible spectrophotometer at the wavelength of 511 nm. Based on the results, the obtained values from the adsorption of RR 120 were variables ranging from 23 to 96. The highest adsorption rate of RR 120 (99.97%) was obtained at RR 120 concentration of 16.25 mg L^{-1}, yeast dose of 8.25 g L^{-1}, pH 4.75 and contact time of 52.5 min. The dye removal efficiency was better in acidic pH. The Langmuir model was better described in the equilibrium biosorption data. The pseudo-second-order model was the suitable model to fit the experimental data.

Keywords: Saccharomyces cerevisiae; Reactive Red 120; Biosorption; Isotherm; Kinetic; RSM

1. Introduction

Environmental cleanup is mainly focused on the removal of contaminants from polluted industrial wastewater, which destroys the ecosystem. In particular, the textile industry includes many types of processing. Textile dyes can be considered as the emergent contaminants in water and can contribute the mutagenicity of representative environmental samples [1]. In the world, there are 10,000 types of dyestuff and about 7×10^5 tons of these are created annually [2]. Generally, synthetic dyes include anionic (direct, acid and reactive dyes), cationic (basic) and non-ionic (disperse) types. 20%–30% of commercial dyes were used to include anionic types (direct, acid and reactive). Reactive dyes are

* Corresponding author.

formed by the combination of azo-based chromophores with various types of reactive groups e.g., vinyl sulfone, chlorotriazine, trichloropyrimidine and difluoro chloropyrimidine. Reactive dye is a dye that can react directly with the fabric, which means that a chemical reaction transpires between the dyes and the molecules of the fabric, effectively making the dyes as part of the fabric [3]. Reactive Red 120 (RR 120) and Reactive Blue Bezaktiv 150 (RBB 150) are one of the oldest synthetic dyes that are frequently employed in many industrial sectors especially in dyeing clothes. However, dyeing processes based on the use of reactive dyes generate a massive amount of unfixed dyes and the wastewater as by-product of this process may interfere with the ecosystem through the effluent discharges. Surveys show that nearly 20% of total global production is lost during the dyeing process and disposed in wastewater [3]. In addition, these can cause a serious hazard to aquatic ecosystems. Treatment of reactive dyes is partially hard because they are not removed by conventional treatment systems [4]. Techniques have been proposed to treat effluent contaminated with dyes, such as flocculation, ozonation and photodegradation. However, the high costs of these treatments underscore the need for alternative methods. Biological treatment involving dye-degrading microorganisms has been studied and proposed as an alternative [5–7]. Still, degradation often requires a long time before achieving satisfactory results and can sometimes result in by-products that are even more toxic than the dye itself [8]. The effluent treatment itself is not enough to confirm the effectiveness of the techniques; therefore, post-treatment toxicity evaluation is recommended [9,10]. The removal of dyes by microorganisms (yeast, bacteria and/or fungi) depends on the chemical and physical properties of both of them. The yeasts have many benefits compared to filamentous fungi and bacteria. Yeasts can acceptably remove reactive dyes because of their unicellular nature and high growth rate. The growth of yeast cells were usually carried out into inexpensive culture media. The growth media of yeasts can provide an easily available source of biomass. These media are suitable for bioremediation of wastes at lower pH values. Yeasts adapt highly in different extreme conditions of pH, temperature and availability of nutrient, and therefore can grow high in concentrations of pollutant. In this regard, *Saccharomyces cerevisiae* can metabolize and biosorb dye compounds [11–13]. *S. cerevisiae*, popularly called Baker's yeast, is present in different technological activities and produces high yields of biomass for use on an industrial scale. Moreover, this microorganism is inexpensive, safe, easily grown and readily available [7]. These microorganisms can be produced in large quantities and used as a by-product in some industries. *S. cerevisiae* can adsorb and or degrade azo dyes into aromatic amines with side groups (–SO_3, –OH, –COOH, –Cl) [14]. McMullan et al. [14] reviewed the main mechanisms for dyestuffs removal by diverse categories of microorganisms from bacterial and fungal domains. Vatandoostarani et al. [15] and Jadhav et al. [11] performed similar studies. In the current study, the removal of RR 120 by the *S. cerevisiae* yeast was considered due to advantages such as safety, low cost, simplicity, widespread distribution, non-pathogenic, rapid growth of cells and easy cultivation. The multivariate statistical methods have to be employed for optimizing the influential factors. Response surface methodology (RSM) is a combination of statistical and mathematical methods that uses the polynomial equation to fit the experimental data [16]. This model is especially practical when some responses are affected by different input variables. It will help the researchers to use a novel method with the minimum number of experiments [17,18]. The technique of experimental design is a useful tool that uses statistical models to optimize the interaction between different parameters. Using the RSM, we can study the interaction between two or more parameters [19].

The aim of this work was designed to optimize the biosorption of RR 120 from aqueous solutions by *S. cerevisiae* using RSM and to evaluate adsorption capacity with different kinetic and isotherms models.

2. Materials and methods

2.1. Materials

All chemicals used in the experiments were reagent grade. All solutions were prepared with distilled water. The anionic dye, RR 120 was provided by Sigma-Aldrich chemicals (St. Louis, MO, USA). *S. cerevisiae* (PTCC 5052) was bought from Iranian Research Organization for Science and Technology. For preparing *S. cerevisiae* at the concentration of 5 g L^{-1}, 5 g of yeast was added into 1,000 mL of toxic substance solution. All chemicals applied in the experiments were of reagent grade. All solutions were prepared with distilled water. RR 120 was provide from Sigma-Aldrich company (USA). The chemical structure and some properties of the RR 120 dye are offered in Fig. 1 and Table 1.

2.2. Treatment procedure

In this study, 100 mL of the reaction mixture was provided at different experimental parameters such as the contact time 10–180 min, initial RR 120 concentration 5–50 mg L^{-1}, yeast dose 3–10 g L^{-1}, and pH 3–10. All experiments were performed in a series of 250 mL conical flasks, and agitated at the fixed speed of 120 rpm and room temperature 28°C ± 2°C. Kinetic and isotherm models of adsorption was obtained using various factors, including RR 120 10–50 mg L^{-1}, yeast 10 g L^{-1}, contact time 95 min, and pH 6.5.

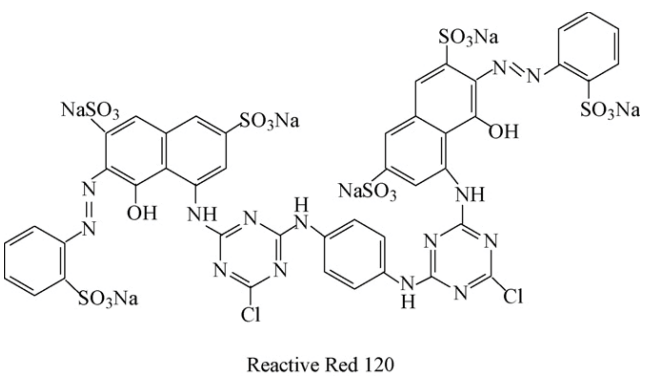

Fig. 1. Chemical structure of the Reactive Red 120.

Table 1
General characteristics of Reactive Red 120

Name of dyes	Procion Red HE-3B
Chemical formula	$C_{44}H_{24}Cl_2N_{14}O_{20}S_6Na_6$
Molar mass	1,470
Color index name	Reactive Red 120
λ_{max} (nm)	511

2.3. Kinetic and Equilibrium Study

The adsorption kinetics were carried out using parameters such as the RR 120 concentration of 10, 20, 30, 40 and 50 mg L^{-1}, the yeast of 10 g L^{-1}, with the pH of 6.5 and contact time of 10, 20, 30, 50, 75, 90, 120 and 240 min. Further, a study of adsorption isotherm was conducted with experimental factors, that is, the RR 120 concentration of 10, 20, 30, 40 and 50 mg L^{-1}, the yeast of 10 g L^{-1}, with the pH of 6.5, and contact time of 10, 20, 30, 50, 75, 90, 120 and 240 min. The experiments were conducted at the constant agitation speed of 160 rpm and room temperature.

2.4. Analytical methods

After completing the process of biosorption, the reaction solutions were centrifuged at 10,000 rpm for 7 min to remove the medium. Finally, the value of absorbance was measured by UV-visible spectrophotometer, model T80+ (PG instrument Ltd., Leicester, UK), at the wavelength of 560 nm [20], and the amount of RR 120 in the samples was obtained based on the standard curve. To provide the standard curve, all solutions were made using four standards over the RR 120 range of 5–20 mg L^{-1} which resulted in the standard curve with the linear correlation coefficient (R^2) of 0.999. The removal efficiency (R, %) of RR 120 was calculated using the equations as follows:

$$R(\%) = \left(\frac{(C - C_0)}{C_0}\right) \times 100 \quad (1)$$

where C_0 is the initial concentration of RR 120 mg L^{-1}, C is the concentration of RR 120 in solution after removal (mg L^{-1}).

2.5. Statistical analysis

All statistical analyses were performed with SPSS 16.0. Statistical analysis of the biosorption data was done via one-way analysis of variance (ANOVA) and Tukey's honestly significant difference.

2.6. Experimental design and statistical analysis

The design of the experiment was carried out using RSM. Conventional optimization approach, one-variable-at-a-time, which is applied for observing the effect of experimental variables is time-consuming and expensive. Hence, the multivariate statistical methods have to be employed for optimizing the influential factors. RSM is a combination of statistical and mathematical methods that uses the polynomial equation to fit the experimental data. This model is especially practical when some responses are affected by different input variables. It will help the researchers to use a novel method with the minimum number of experiments [17,21].

As shown in Table 2, four parameters were selected for this study, including the initial RR 120 concentration (mg L^{-1}), contact time (min), *S. cerevisiae* dose (g L^{-1}) and pH which was at the three levels of high (+1), low (–1) and medium (0), respectively. Moreover, assisting points coded +α and –α were considered for model validation based on the models.

In this study, 30 runs were performed using RSM with 16 real points, 8 pivot points and 6 central focal point. The quadratic model for the variables is presented below:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{1 \le i \le j}^{k} \beta_{ij} x_i x_j \quad (2)$$

where Y, β_0, β_i, β_{ii}, β_{ij} and x_i/x_j are the predicted response, the constant coefficient, regression coefficients for linear effects, quadratic coefficients, interaction coefficients and the coded values of the parameters, respectively. The fit of the models was evaluated by determining the coefficients (R^2) and adjusted R^2 (R^2_{adj}) [22].

3. Results and discussion

The Fourier-transform infrared analysis for *S. cerevisiae* before and after the sorption of dye is shown in Fig. 2. As seen in Fig. 2, the peaks at 3,432.45 and 334 cm^{-1} were attributed to stretching vibrations of –OH and C–H groups in the structure of *S. cerevisiae*, respectively.

The peak of N–H groups shifted from 3,322.45 to 3,347.02 cm^{-1} after adsorption, indicating that the dye could reinforce the stretching vibration of hydrogen bonds in proteins.

The *S. cerevisiae* biomass spectrum showed two intense peaks in the 1,656.42 and 1,547.19 cm^{-1} regions, which

Table 2
Experimental ranges and levels of independent parameters according to RSM design

Parameters	Symbol	Levels				
		–α	–1	0	+1	+α
pH	*A*	3	4.75	6.50	8.25	10
Adsorbent dose (g L^{-1})	*B*	3	4.75	6.50	8.25	10
Dye concentration (mg L^{-1})	*C*	5	16.25	27.50	38.75	50
Contact time (min)	*D*	10	52.50	95	137.5	180

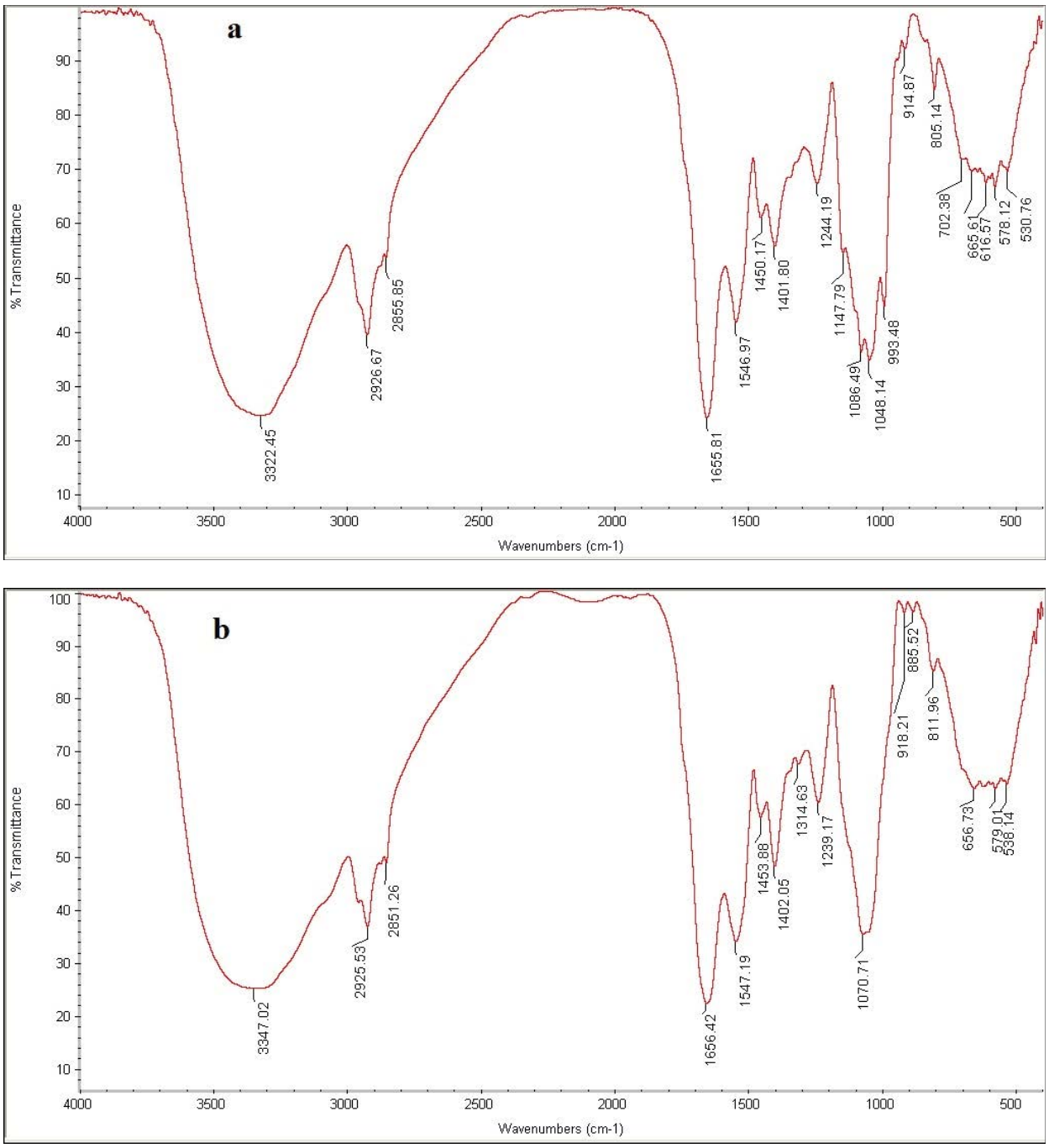

Fig. 2. FTIR analysis for *S. cerevisiae* (a) before and (b) after the adsorption of dye.

represent the binding of the amide group R–NH–C–O–CH_3. The band at 1,453 cm^{-1} is the stretching of the –C–NH bond, probably by an amine group belonging to a chitin of the yeast cell wall. The peak in the 1,239 cm^{-1} region shows the vibration of the –C=O bond, which is another linking group in the chitin structure. The band at 1,070 cm^{-1} had high intensity, indicating the presence of the –C–O bond. This chemical group is present in the sugars of the yeast cell wall. The 656 cm^{-1} region demonstrated reasonable intensity, indicating the presence of the –C–N–C group found in proteins on the yeast cell wall [7].

In this study, the impact of different factors, including RR 120 concentration, *S. cerevisiae* concentration, reaction time and pH was investigated on the removal of RR 120. The summary of the results of the study are showed in Table 3.

Table 3 shows the regression results of quadratic model for the removal of RR 120. Fig. 3 illustrates the relation between the predicted and actual removal of RR 120.

The quadratic model is explained in Eq. (2) in terms of coded variables of the removal of RR 120

$$Y = +90.30 - 6A + 20.22B - 16C + 8.34D - 1.53AB - 0.4AC + 3.52AD + 16.76BC - 0.04BD + 1.49CD + 2.6A^2 - 6.89B^2 - 3.5C^24 - 15.84D^2 \quad (3)$$

Regarding Eq. (2), each model has a variable part and a fixed part RR 120 can be seen in the equation, the rate of biosorption has been 90.30% that is impacted by various parameters.The main effect of *A*, *B*, *C* and *D* have the coefficients of –6, +20.22, –16 and +8.34, respectively.

The main effect is related to the code of *B*, which has been shown with the coefficient of +20.22. The maximum interaction impact belongs to the *BC* with the coefficient of 16.76, and the highest square effects of the variables belong to the B^2 with the coefficient of +6.89.

Based on the results of Table 3, the highest and lowest adsorption of RR 120 was 99.97% and 15.23%, respectively. Findings (Fig. 3) showed that the observed values of the adsorption of RR 120 were in the range of 15.23%–99.97%, which was not different from the values predicted by the model RSM. The results of this research using Eq. (2) determined that the process of treatment was able to adsorb 90.30% of RR 120 from aquatic solutions. This process underwent the main, interaction and square effects. Each of these effects has coefficients with negative or positive signs that reflect negative or positive effects are on adsorption rate. Table 4 displays ANOVA of the quadratic model for the adsorption efficiency of RR 120. The best model to fit the experimental data with independent variables was the quadratic model. ANOVA was used to determine the significance of the model (*P*-values < 0.05). Overall, the results displays that this process was significance (*P*-values < 0.05). Findings indicated in Table 4 revealed that R^2, and justified R^2 were 0.93 and 0.86, respectively.

3.1. Effect of independent parameters on RR 120 adsorption

The effect of contact time and initial dye concentration on RR 120 removal are indicated in Fig. 4. The results of Fig. 4 indicate that there is an indirect relationship between the

Table 3
Experimental design and response values at different runs of RR 120 removal

Run	Dye concentration (mg L^{-1})	pH	Adsorbent dose (g L^{-1})	Contact time (min)	Removal (%)
1	16.25	4.75	4.75	137.50	87.47
2	27.50	6.50	6.50	95.00	93.45
3	16.25	8.25	4.75	137.50	93.03
4	27.50	3.00	6.50	95.00	96.09
5	27.50	6.50	6.50	95.00	93.45
6	38.75	8.25	8.25	52.50	58.61
7	38.75	4.75	8.25	137.50	92.98
8	27.50	10.00	6.50	95.00	53.42
9	16.25	4.75	8.25	137.50	85.97
10	38.75	8.25	8.25	137.50	91.03
11	5.00	6.50	6.50	95.00	85.92
12	38.75	8.25	4.75	137.50	16.34
13	27.50	6.50	6.50	180.00	43.61
14	16.25	4.75	4.75	52.50	78.42
15	38.75	4.75	4.75	52.50	16.29
16	38.75	4.75	4.75	137.50	19.073
17	38.75	8.25	4.75	52.50	15.36
18	27.50	6.50	6.50	10.00	11.12
19	16.25	8.25	8.25	137.50	93.24
20	38.75	4.75	8.25	52.50	78.33
21	27.50	6.50	10.00	95.00	99.11
22	27.50	6.50	6.50	95.00	92.93
23	27.50	6.50	3.00	95.00	15.23
24	50.00	6.50	6.50	95.00	56.42
25	16.25	8.25	4.75	52.50	66.60
26	16.25	4.75	8.25	52.50	99.97
27	27.50	6.50	6.50	95.00	92.93
28	27.50	6.50	6.50	95.00	76.01
29	16.25	8.25	8.25	52.50	71.04
30	27.50	6.50	6.50	95.00	93.00

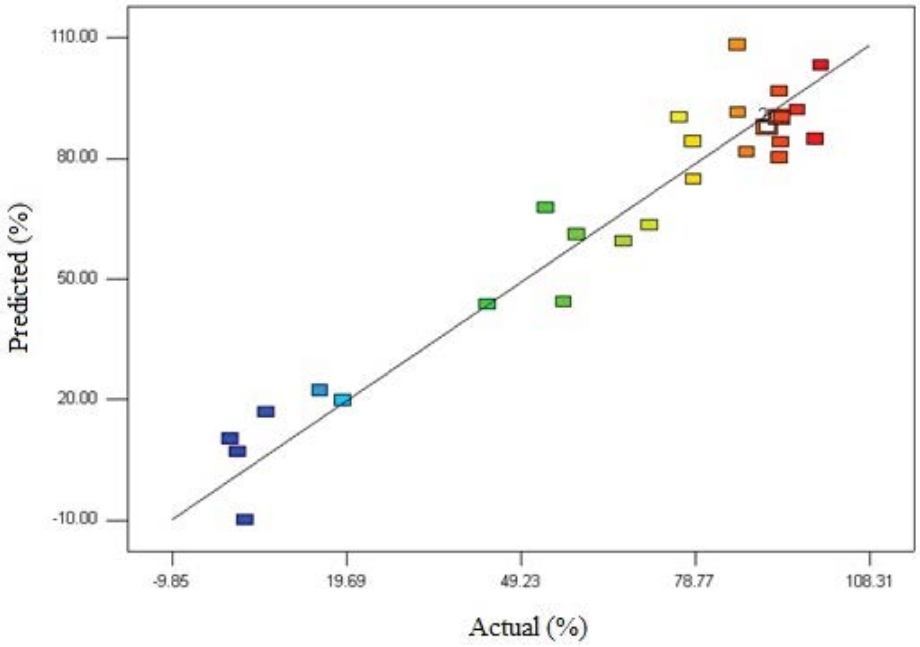

Fig. 3. Actual and predicted removal of Reactive Red 120.

Table 4
ANOVA of the quadratic model for the removal efficiency of RR120

Source of variation	Sum of squares	Degree of freedom	Mean square	*F*-value	*P*-value
Model	30,774.64	14	2,198.19	14.42	<0.0001
x_1	6,143.82	1	6,143.82	40.29	<0.0001
x_2	887.03	1	887.03	5.82	0.0291
x_3	9,815.91	1	9,815.91	64.37	<0.0001
x_4	1,668.96	1	1,668.96	10.95	0.0048
x_1x_3	4,492.37	1	4,492.37	29.46	<0.0001
X_3^2	1,300.35	1	1,300.35	8.53	0.0106
X_4^2	6,879.83	1	6,879.83	45.12	<0.0001
Lack of fit	2,041.68	10	204.17	4.16	0.0647
Pure error	245.61	5	49.12		
Corr. total	33,061.93	29			

R^2 = 0.9308, Adj-R^2 = 0.8662, Pred-R^2 = 0.6336

adsorption of RR 120 and its initial concentration. From the results, the adsorption initially increases due to the increase in the driving force of the concentration gradient [2,23] and then gradually decreases along with the elevation of the RR 120 concentration. This can be attributed to the fact that the biosorption capacity is influenced by the increase in the concentration of RR 120 which reduces the biosorption capacity owing to the saturating sorption sites of the cell wall of yeast [24]. Based on Fig. 4, there is a direct correlation between the adsorption rate of RR 120 and the contact time. The change in the adsorption rate can be due to the reason that initially all the adsorbent sites are vacant and solute concentration gradient is very high. Later, the lower adsorption rate is due to a decrease in the number of vacant sites of adsorbent and dye concentrations. The decreased adsorption rate, particularly, towards the end of contact time, indicates the possible monolayer formation of RR 120 on the adsorbent surface [25,26]. This may be attributed to the lack of available active sites required for further uptake after attaining the equilibrium. Fig. 4 exhibits the effect of pH and adsorbent dosage on RR 120 removal. Results (Fig. 5) display an increase in the uptake percentage of RR 120 with the increase in the concentration of *S. cerevisiae*. The main variable describing this performance is that at initial adsorbent concentration, adsorption sites remain unsaturated during the adsorption reaction, whereas the number of sites available for adsorption increases by enhancing the adsorbent concentration due to the augmentation of available surface area. The

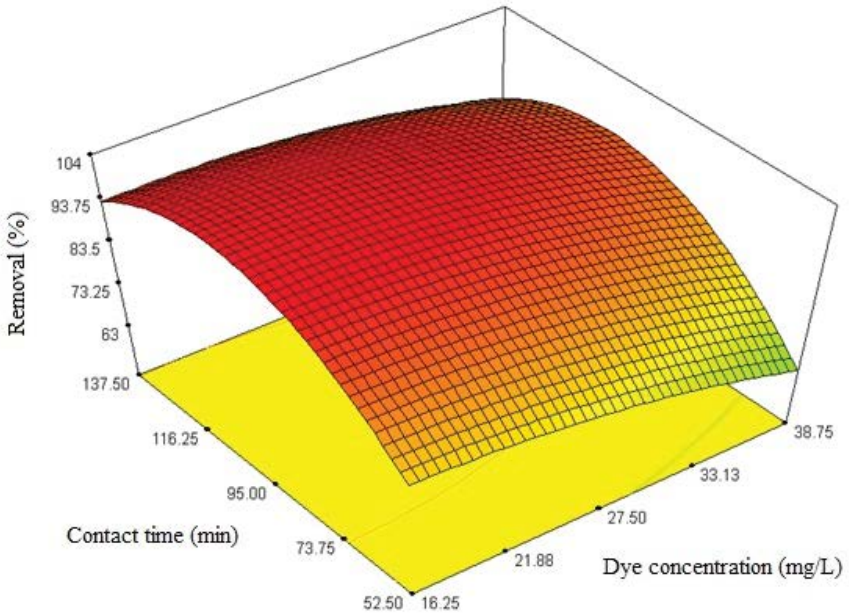

Fig. 4. Effect of contact time and initial color concentration on the removal of RR 120 at the pH of 6.5 and the yeast dose of 6.5 g L^{-1}.

presence of relatively higher concentration of adsorbent in the solution leading to diminished distances between the adsorbent particles, thus making many binding sites unoccupied [27,28]. In addition, the inter-particles interactions like accumulation, overcrowding and overlapping create at high adsorbent concentrations. This can lead to decrease in available total surface area [29]. The results of this study (Fig. 5) show that with the increase in the solution pH from 4.75 to 8.25, the adsorption of RR 120 decreases. The solution pH can alter the ionization degree and the surface charge of materials [30]. The cell wall of yeast contains the various compositions such as polysaccharides (i.e., chitin and chitosan), proteins, lipids and melanin as well as different functional groups (such as, amino, carboxyl, thiol and phosphate groups) [31]. Functional groups play an important role in adsorbing the dye molecules. Compared with other groups, amine groups are more active in adsorbing contaminants due to creating positive charges on yeast. Carboxyl and phosphonate groups and phosphonate, on the other hand, bring negative charges on the yeast. The pH of solution can change the ionic form of the dye and the surface electrical charge of yeast. At lower pH values, yeast biomass is positively charged leading to the protonation of amine groups, which are desirable to the adsorption of the negative charged dye [32,33]. On the other hand, the sulfonate group ($–SO_3H$) in the molecular structure of the RR 120 can be converted in aqueous medium into active negative sulfonate group ($–SO_3^-$). Consequently, a strong electrostatic (columbic) attraction between positively charged protonated amino group of *S. cerevisiae* with negatively charged sulfonate group of RR120, thus increases dyes adsorption [34]. As shown from the findings of Fig. 5, as the pH was reduced, the RR 120 biosorption on the cell wall of yeast enhanced. RR 120 is known as an acidic dye and is composed of six sulfonate, two hydroxyl and six secondary amino groups [27,35]. The pKa value of the sulfonate groups of the dye molecule is 2.1. At the working experimental conditions, this functional group is easily separated and therefore, net negative charges are created in the dye molecules [35,36]. Thus, the positive sites of cell well such as protonated form of amino groups (i.e., $–NH_3$) can have a main role in the RR 120 biosorption using *S. cerevisiae*. The binding sites increase by increasing pH, and hence the adsorption of RR 120 enhances [37,38]. The study of Drufovka et al. [39] confirmed that microorganisms could be having high removal efficiency at low pH. Aksu et al. [40] used *S. cerevisiae* to remove reactive dye where at a low pH, the removal efficiency of the reactive dye was significantly high.

3.2. Biosorption kinetics

The parameters of the kinetic model and regression correlation coefficient are presented in Table 5. In this study, the effect of adsorbent dose on the adsorption capacity (mg g^{-1}) was studied and the value of adsorption capacity was calculated by the kinetic reaction models, that is, the pseudo-first-order and pseudo-second-order models [41,42].

The pseudo-first-order model is expressed as Eq. (2):

$$\log\left(q_e - q_t\right) = \log q_e - \frac{k_1}{2.303}t \tag{4}$$

where k_1 (min^{-1}), q_e (mg g^{-1}) and q_t (mg g^{-1}) are the pseudo-first-order kinetic constant, adsorbed RR 120 per mass of *S. cerevisiae* at equilibrium, and the amount of adsorbed RR 120 per mass of the yeast at any time t (min), respectively.

The pseudo-second-order model is described as follows:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e}t \tag{5}$$

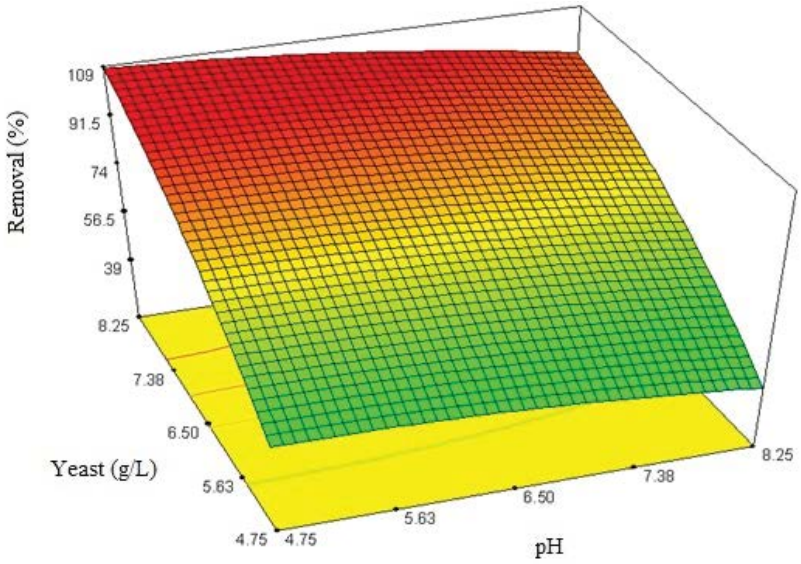

Fig. 5. Effect of pH and adsorbent dosage on the removal of RR 120 at the dye concentration of 27.5 mg L^{-1} and the reaction time of 95 min.

Table 5
Parameters of kinetic model for the adsorption of reactive red 120 onto *S. cerevisiae* (pH = 6.5, adsorption dose = 10g L^{-1})

	Pseudo-first-order			Pseudo-second-order		
Reactive Red 120 concentration (mg L^{-1})	R^2	q_e (mg g^{-1})	k_1 (min^{-1})	R^2	q_e (mg g^{-1})	k_2 (g mg^{-1} min^{-1})
10	0.005	4.487	0.0013	0.9857	1.124	0.028
20	0.0523	2.249	0.0055	0.9875	2.207	0.016
30	0.3286	1.613	0.0175	0.9876	3.253	0.0124
40	0.1195	1.007	0.0089	0.9856	4.325	0.0077
50	0.1564	1.327	0.0094	0.9828	5.691	0.0059

where k_2 (g mg^{-1} min^{-1}) is the rate constant of pseudo-second-order sorption. From Table 5, the pseudo-second-order model for studied concentrations of RR 120 was found more suitable for describing kinetic data according to the correlation coefficient ($R^2 \geq 0.98$) and obtained statistical data compared with pseudo-first-order model [26]. This result in agreement with the dye removal by other adsorbents like modified rice stem [43], multi walled carbon nanotubes [44], canola [45], heat-treated rice husk [46] and modified azolla filicoloides [47].

3.3. Biosorption isotherms

The models of Langmuir and Freundlich isotherm were applied to explain the equilibrium data of biosorption.

The Langmuir isotherm equation is:

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \tag{6}$$

where q_e (mg g^{-1}), q_m (mg g^{-1}), K_L (L mg^{-1}) and C_e (mg L^{-1}) are expressed as the biosorption capacity at the equilibrium state, the maximum biosorption capacity, the Langmuir equilibrium constant and the equilibrium concentration of RR 120, respectively [32].

The linear form of the Freundlich model is showed as follows:

$$q_e = K_F C_e^{\frac{1}{n}} \tag{7}$$

where K_F and n reflect Freundlich constants are describe as the biosorption capacity and biosorption intensity, respectively [48].

Langmuir and Freundlich constants and correlation coefficients are listed in Table 6. As seen in Table 6, the Langmuir isotherm exhibited the best-fit model (R^2 = 0.98) for RR 120 removal, compared to the Freundlich model (R^2 = 0.43). Also, the maximum adsorption capacity of *S. cerevisiae* was obtained to be 23.48 mg g^{-1} based on the Langmuir model. Langmuir and Freundlich isotherms describe the mechanism of monolayer biosorption with homogenous energy and the multilayer biosorption with heterogeneous energy, respectively [49,50].

Table 6
Langmuir and Freundlich constants and correlation coefficients (pH = 6.5, adsorption dose = 10 g L^{-1})

Langmuir parameters				Freundlich parameters		
Q_0 (mg g^{-1})	b (L mg^{-1})	R^2	R_L (dimensionless)	K_F (mg g^{-1})	n	R^2
23.4829	0.028	0.9823	0.8771	420.57	13.96	0.4338

4. Conclusion

In this paper, the biosorption of RR 120 was investigated by *S. cerevisiae*. The maximum adsorption rates have been observed at an acidic pH. The biosorption of RR 120 has a direct relationship with the dose of *S. cerevisiae* and reaction time, and an inverse relationship with pH and initial concentration of RR 120. The biosorption process of RR 120 was indicated to be dependent on pH, initial dye concentration and contact time. The removal efficiency of RR 120 had an increasing rate from 52.5 to 137.5 min followed by equilibrium state. The dye removal efficiency was better in acidic pH. The Langmuir model better described the equilibrium biosorption data. The pseudo-second-order model was the best model to fit the experimental data. The results of this study confirmed that *S. cerevisiae* could be used as a low-cost adsorbent for adsorption of RR 120 from aqueous environments. We can conclude that *S. cerevisiae* has the ability to remove dye with the lowest cost and a high efficiency.

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