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Research Article

Removal of Acidic Dyes from Aqueous Media Using *Citrullus Lanatus* Peels: An Agrowaste-Based Adsorbent for Environmental Safety

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In this work, removal of fluorescein and eosin dyes using common agrowaste, i.e., peels of water melon (*Citrullus lanatus*) (WMP), has been studied in the batch mode. The sorbent material (WMP) was characterized by using scanning electron microscopy, Fourier transform infrared spectroscopy, thermogravimetric analysis, and elemental analysis. The sorbent was chemically modified by subjecting it to 0.1 N HNO_3 and 0.1 N NaOH solutions. Different parameters such as sorbent dose, pH, temperature, and agitation speed were optimized to investigate the sorbent efficiency for fluorescein and eosin dyes. Among three forms (raw, base-treated, and acid-treated), the base-treated form exhibited higher removal efficiency, followed by acid-treated and then the raw form. Generally, range for the removal of fluorescein and eosin was found to be 48.06–88.08% and 48.47–79.31%, respectively. Mathematical modeling of sorption data by Langmuir and Freundlich sorption isotherms and thermodynamic investigations were carried out to check the suitability of these agrowaste materials on bulk scale. The promising results concluded that peel of water melon (common agrowaste) can be potentially utilized for the removal of toxins.

1. Introduction

Since several years, environment has ever been victim of man-made activities, such as burning domestic garbage, contributing domestic sludge, human waste, discharging different types of smokes by burning fuels, and automobile exhaust. Moreover, chemicals are being used as reactants, intermediates, or catalysts and are discharged as effluents into different water bodies. Subsequently, these are escaped into agricultural soils upon irrigation. Ultimately, these reaches human body, as human beings are a big consumer. Such transfer of chemicals from industrial units to human body is a serious threat to quality of life. Hence, green environment has become the keyword for assuring better quality of life. Among different chemicals used in different industrial processes, one of the major classes is dyes. Dyes are used for coloring different materials like leather tanning, textile, food materials, paints, and paintings. Textile industrial effluent is reported to be rich in dyes, and in this way, dyes are the major source of water pollution [1].

Pakistan is an agricultural country, and production of fruits is an important part of its agriculture sector. The opted sorbent, i.e., water melon peel, is the agrowaste of water melon fruits. It is produced in great quantity during summer season. During summer, the temperature rises up to 50°C in several regions of the country, and hence, the consumption of these fruits also increases. This results in the accumulation of its peel in the form of agrowaste.

Different methods are available to remove the toxin from water; however, adsorption especially biosorption has got great attention in last few decades as a green technique. Moreover, the said method is highly economical and result oriented [2–4]. Biosorption, by using biomasses, involves physical or chemical binding. This phenomenon is

cost-effective and has much lesser health hazards in comparison to other techniques [2, 5]. Following-up the utilization of these dyes in industries and inexpensive availability of water melon peels, in this work, adsorption of two widely used acid dyes, i.e., eosin and fluorescein, has been studied and optimized. They are commonly employed for staining biological strains and in fluorescent materials. But their excessive discharge in wastewater leads to various health hazards and ecological disorders. So their removal in an ecofriendly way is explored here.

2. Materials and Methods

2.1. Collection and Preparation of Sorbents. Selection of water melon peel as the sorbent material was made on the basis of its abundant availability, underestimation, and eventually discarding nature just as the agrowaste material. Peel of water melon was collected from discarded wastes at different fruit shops, present in different locations of Lahore city. After collection, the sorbent material was repeatedly washed with tap water to remove water soluble impurities, dust, soil, etc., followed by extensive washing with deionized water and drying in sunlight till the removal of residual drops of water. Finally, dried and cleaned sorbent samples were spread on filter paper sheets and placed under shade till complete drying. Then, it was ground and sieved to achieve a homogeneous size. The homogenized material was stored in zipper bags, at ambient conditions for further use.

2.2. Characterization. Characterization of the above collected sorbent was carried out by using CHN analysis (Exeter CE-440 Elemental Analyzer), scanning electron microscope (JEOL model 2300 scanning electron microscope), thermogravimetric analysis (PerkinElmer Diamond Series unit, USA), and FTIR (PerkinElmer 1600) spectrophotometer.

2.3. Pretreatments of Biomasses. Water melon peel (1.0 g) was chemically treated with 100 mL of 0.1 N NaOH and 0.1 N HNO_3 separately, by shaking for 2 h. Chemically treated biomass was further washed with distilled water to remove any residual traces of acid/base. The pretreated sorbent was dried in an electric oven at 30°C, ground (by pestle-mortar), and stored in jars with air-tight lids.

2.4. Determination of Dye. Each of the two selected dyes, i.e., fluorescein/eosin, was dissolved (1.0 g each) first in small volume of ethanol and then made up to mark with 1000 mL of distilled water to make the concentration 1000 ppm. From this stock solution, standards were prepared having concentration a range of 10–50 ppm and their absorbance was noted by using CECIL CE-7200 spectrophotometer. The concentration of each dye, before and after addition of each sorbent separately, in the solution was determined through the calibration curve to determine the removal efficiency of each sorbent material for the dye.

2.5. Optimization Study of Batch Sorption. For batch studies, different parameters affecting the efficiency of the sorption process, i.e., pH, sorbent dose, contact time, dye concentration, and temperature, were optimized, separately for native and chemically treated sorbent. To optimize the pH of the batch adsorption experiment, adsorption of dyes on each sorbent material was studied by varying pH from 1 to 7. Higher pH is avoided due to precipitation of dye molecules. During optimization, concentration of each dye was kept fixed at 50 mg/L, concentration of sorbent at 0.2 g/50 mL and at 30°C, and shaking time of 30 min at 100 rpm speed. Amount of sorbent was varied from 0.2 to 2 g/50 mL, in order to find the optimized dose. During optimization of amount of sorbent, concentration of dye was fixed at 50 mg/L, temperature at 30°C and shaking speed 100 rpm for 30 minutes. Optimum pH 4 of each metal ion/dye solution was kept constant. After adding the optimized sorbent dose (0.2 g/50 mL) in aqueous solution of sorbate, dyes (50 mg/L), at pH 4, mixture of sorbent-sorbate was shaken at 30°C and at 100 rpm for 5 to 50 min. Effect of temperature on removal efficiency of the sorbent material for dyes was studied by varying the temperature range from 10°C to 90°C. All other affecting parameters were kept at their optimized levels.

2.6. Sorption Kinetics. Kinetic models (pseudo-first and pseudo-second order) were employed for the interpretation of experimentally obtained data, while thermodynamic parameters, i.e., entropy of adsorption (ΔS°), enthalpy of adsorption (ΔH°), and Gibbs energy (ΔG°), over a range of temperatures were evaluated as reported earlier [6].

2.7. Statistical Analysis. All the results are calculated as mean of a set of experiments with standard deviations. The regression techniques were employed to find the coefficients of thermodynamic, kinetic, and equilibrium models.

3. Results and Discussion

Selection of water melon peel was made on the basis of its abundant availability as the agrowaste material. Its peel is usually discarded after eating. These materials not only create sanitation problems but also contribute offensive odour to environment, if left for sometime in environment. These materials are either dumped in some landfill instantly or incinerated. It is very valuable to use them for some useful purpose, i.e., adsorption, before discarding.

Before studying sorption efficiency of this agrowaste-based sorbent, characterization of this material was carried out to determine its composition, especially the surface structure, as adsorption is a surface phenomenon and nature of sorbate-sorbent binding interaction mainly depends on surface composition of the sorbent material.

3.1. Characterization of Sorbent. Proximate analysis of water melon peels (WMP) was carried out by the reported method [7]. Percentage of fiber, cellulose, hemicelluloses, and lignin was determined, and results are presented in Table 1. It was

Table 1: Physicochemical analysis of sorbent materials.

BWMP	%
Moisture	6.36
Volatile matter	4.71
Ash	88.43
Fixed carbon	0.50
Fiber	32
Lignin	25
Cellulose	21
Hemicellulose	11
Carbon	26.13–29.09
Nitrogen	7.11–7.92
Hydrogen	2.56–4.32

found to be rich in fiber, cellulose, hemicellulose, and lignin. The percentage of C, H, and N in raw sorbent was determined through an elemental analyzer, and results are depicted in Table 1. Fortunately, the opted sorbent materials exhibited the appreciable content of carbon, revealing their significant potential as sorbents.

3.2. FTIR Spectroscopic Analysis. FTIR spectroscopy is considered as the state-of-art technique for characterization of any natural material or synthetic compound regarding determination of functional groups. Functional groups present on the surface of WMP were determined by using the FTIR spectrometer (Figure 1).

Generally, FTIR spectra reveal the presence of amines, alcohol, carboxylic acid, hydroxyl groups, phenol, alkanes, amino acids, alkyl halide, and aromatic compounds in the peel of water melon. A deep band showing strong absorbance can be seen around 3100 cm^{-1}, which may be due to presence of -NH or -OH groups. This band becomes more deep, i.e., showing stronger absorbance, upon treatment with 0.1 N NaOH, which may also be interpreted with the increased concentration of hydroxyl groups upon treatment with base. Region from 1400 to 900 cm^{-1} was found to be rich in peaks, which seemed to be fused in the form of a complex matrix. The peaks at 1230.82 cm^{-1}, 1049.71 cm^{-1}, and 795.97 cm^{-1} represent phenol/tertiary alcohol, C-O stretch, and primary amine, C-N stretch, respectively [8, 9].

3.3. Scanning Electron Microscopy. Scanning electron microscopic analysis of raw WMP was made to determine the surface texture and morphological characteristics (Figure 2). From apparent view, irregular-shaped pores are present in SEM graphs for WMP, however, seem to be uniformly distributed on the entire surface and smooth. Due to the presence of irregular-shaped pores, WMP would have a strong binding ability.

3.4. Thermogravimetric Analysis. Thermogravimetric analysis is an effective tool to examine the pattern of chemical changes in the lingocellulosic matrix. WMP was subjected to it over a wide temperature range of 25–1000°C (Figure 3). As shown in Figure 3, initial decrease in weight was noted below 200°C and may be attributed to loss of light volatiles, mainly

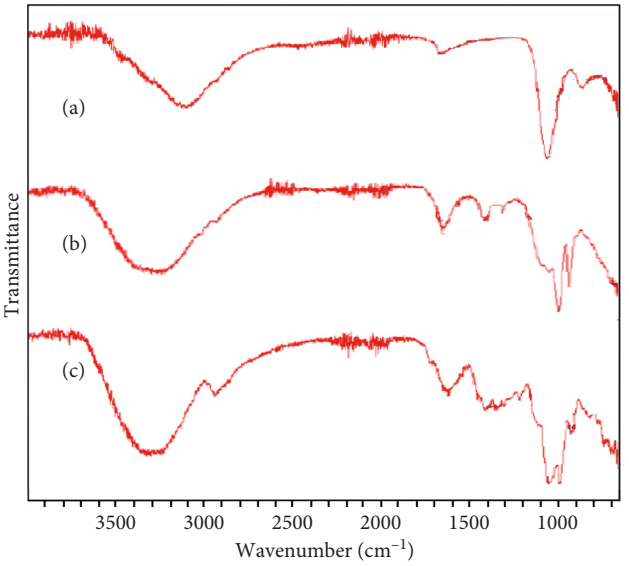

Figure 1: FTIR spectrum of (a) raw WMP, (b) acid-treated WMP, and (c) base-treated WMP.

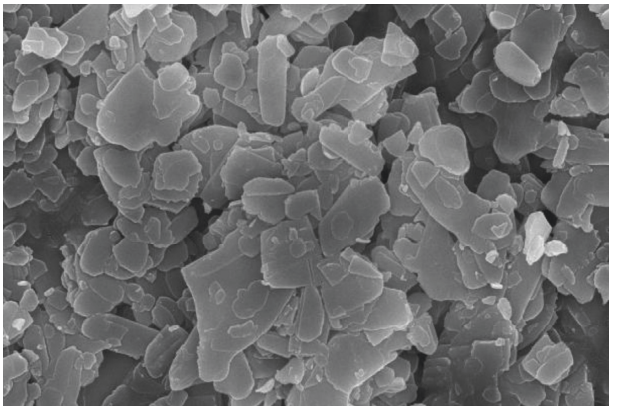

Figure 2: SEM micrograph of WMP.

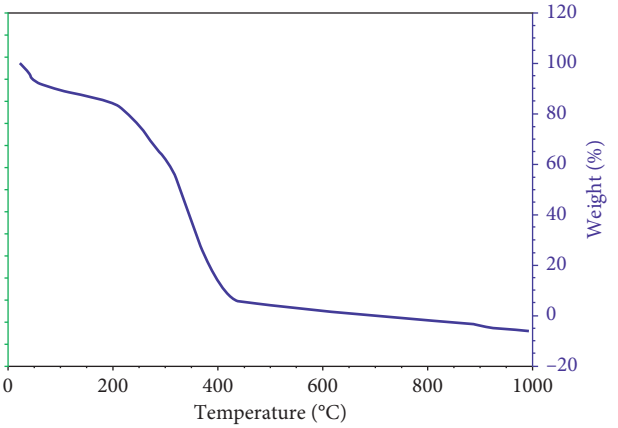

Figure 3: TGA curve (WMP).

water. The second weight loss is mainly observed between 200 and 400°C and may be related to breakdown of lignin and cellulose. Above 500°C, a continuous weight loss was

noticed, which may be attributed to slow decomposition of the remaining heavy components, which may consist of stable micronutrients like metal oxide [7, 10].

3.5. Optimization of Parameters. Adsorption is a surface phenomenon and is based on physicochemical interaction between sorbate and sorbent materials. To achieve the maximum adsorption, parameters like sorbent dose, pH, time of contact, temperature, dye concentration, and agitation speed were optimized. To possibly enhance the removal efficiency of these sorbents, it was separately subjected to acid treatment and base treatment. Then, its removal efficiency in its raw form, acid-treated form, and base-treated form for the removal of dyes was investigated.

3.5.1. Sorbent Dose. Sorption efficiency of the opted sorbent (WMP) was studied against all the opted sorbates, i.e., eosin and fluorescein, one by one, by varying the sorbent dose over the range of 0.2 to 2.0 g, in their raw form, acid-treated form, and base-treated form. As adsorption is an equilibrium-based phenomenon, maximum sorption is achieved at certain sorbent dose, at which sorbate equilibrates well between aqueous solution and sorbent surface. More amount of adsorbents adsorb more amounts of dyes, but decrease in adsorption after reaching a maximum value may be due to coagulation of adsorbent particles. Sorbent dose of WMP in its raw form, acid-treated form, and base-treated form was optimized for the maximum removal of dyes from aqueous solutions.

Maximum removal of fluorescein achieved was 78.2% by B-(WMP) at 0.6 g/50 mL optimized dose compared with A-(WMP) and raw WMP. Optimized sorbent dose for the maximum removal efficiency of eosin was between 1.0 g/50 mL to 1.2 g/50 mL and was also exhibited by B-(WMP) (79.31%) (Table 2). Overall, removal efficiency for both the explored dyes was quite appreciable, as shown in Figure 4, with base-treated WMP [11].

3.5.2. Contact Time. Contact time of dye solution and sorbent has been reported to be very a useful parameter in sorption studies. Contact time between all forms of raw, acid-treated, and base-treated WMP was, separately, varied over a range of 5–50 minutes, and results are presented in Table 3. Generally, the base-treated form exhibited the highest (80.42%) removal efficiency, followed by acid-treated (69.15%) and raw forms (55.67%), fluorescein. Same trend has been noted for the eosin dye (Table 3). This observation suggests increase in pore size, pore area, and pore volume on the sorbent surface upon treatment with base in comparison to the raw sorbent, revealing the same trend as clear from Figure 5, as was noted for optimization of the sorbent dose.

3.5.3. Effect of Agitation Speed. Agitation speed has also been reported as the important parameter, affecting sorption of different sorbates. Sorbate materials are sorbed at a particular agitation speed, while at a certain speed, they get desorbed. Agitation increases the available surface area for sorbates and distributes the sorbate effectively in solutions. Agitation speed varies, depending on the nature of sorbate and sorbent. To achieve the optimum agitation speed, a range of 75–200 rpm was chosen, and results are presented in Table 4. Maximum removal (88.08%) was accomplished at an agitation speed of 125–150 rpm. For the base-treated sorbent form, equilibrium was found to be established at a relatively lower speed (Figure 6).

3.5.4. Temperature. Temperature significantly affects the magnitude and rate of adsorption. Sorbate-sorbent interaction was investigated by varying the temperature of solution over a range of 283–363 K, and results are presented in Table 5. For fluorescein, maximum removal was achieved with base-treated WMP at 323 K, while eosin removal was achieved at 303 K, as shown in Figure 7.

3.5.5. Effect of pH. pH change strongly affects the process of chelation, precipitation, and solubility. Solutions for dyes were prepared in aqueous buffers, having a pH range of 1–7. Trend of sorption remained the same, as discussed above. Base-treated water melon peels had shown more adsorption, as indicated in Figure 8, because of protonation of adsorbent binding sites, which can interact more with acidic dyes, like fluorescein and eosin in acidic conditions, as shown in Figure 9. Moreover, these dyes are more ionized, and their solubility is more in acidic conditions. As both these facts help, overall, B-(WMP) exhibited the highest removal efficiency of 86.33% and 79.41% for fluorescein and eosin, respectively (Table 6).

3.6. Mathematical Modeling

3.6.1. Isothermal Studies. An adsorption isotherm has a key role in surface chemistry and provides useful information for regarding sorption under optimized conditions. In this study, Langmuir and Freundlich were employed to fit the equilibrium data. Among all the opted raw as well as chemically treated, the base-treated form showed maximum sorption for dyes, and hence, isothermal studies were done on the base-treated form B-(WMP) by applying optimized conditions of sorbent dose, contact time, pH, agitation speed, and temperature (Tables 7 and 8) [12].

In case of the Langmuir model, the isotherm correlation coefficient (R) values for B-(WMP) is near to unity. On the basis of R values, it was assumed that the Langmuir isotherm could describe the sorption process in good way. Moreover, the maximum sorption capacity "q_m" was highest for it [13].

According to the Langmuir adsorption isotherm, monolayer adsorption occurred. Langmuir isotherm equation is represented by the following equation:

$$\frac{1}{q} = \frac{1}{(q_m b)C_e} + \frac{1}{q_m}, \quad (1)$$

where q_m is the monolayer (maximum) adsorption capacity (mg/g), C_e (mg·L^{-1}) is the concentration of dye at

Table 2: Sorption efficiency of WMP sorbent at different doses.

Sorbent dose (g)	Fluorescein			Eosin		
	Raw WMP	A-(WMP)	B-(WMP)	Raw WMP	A-(WMP)	B-(WMP)
0.2	45.43	62.26	70.29	51.16	65.37	77.17
0.4	46.71	63.79	75.46	51.13	64.35	78.35
0.6	50.42	65.57	78.2	51.36	65.37	78.46
0.8	52.89	67.26	76.2	52.74	66.95	79.00
1.0	54.73	69.45	76.31	52.52	66.13	79.31
1.2	56.71	68.67	75.68	53.75	66.77	78.68
1.4	58.51	67.9	74.23	52.26	67.26	77.23
1.6	56.88	66.68	73.16	54.45	66.15	77.16
1.8	55.52	65.38	72.36	53.55	66.26	77.17
2.0	54.01	65.3	71.29	51.16	65.37	78.35

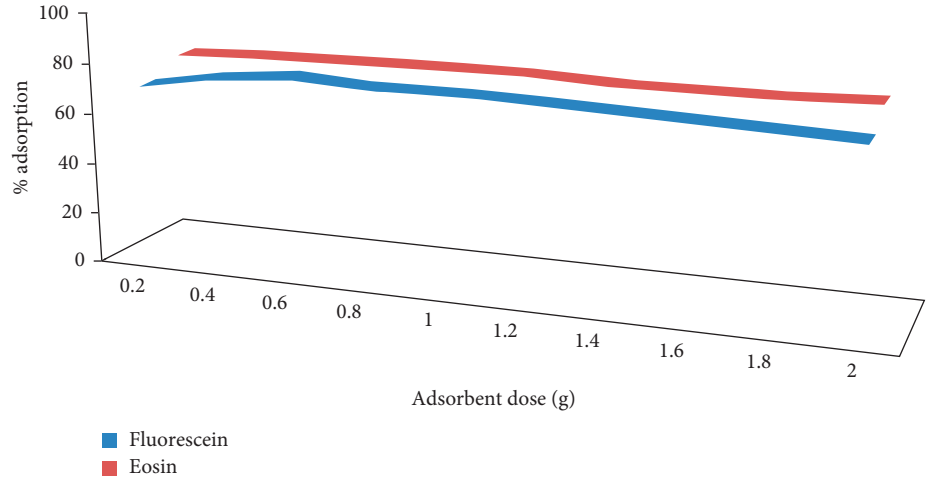

Figure 4: Comparative sorption efficiency of base-treated WMP at different doses for removing fluorescein and eosin dyes.

Table 3: Sorption efficiency of the sorbent material (WMP) over a different range of contact time.

Contact time (min)	Fluorescein			Eosin		
	Raw WMP	A-(WMP)	B-(WMP)	Raw WMP	A-(WMP)	B-(WMP)
5	53.01	66.15	79.57	51.16	65.37	77.17
10	53.16	67.59	79.71	51.13	64.35	78.35
15	53.74	68.48	79.73	51.36	65.37	78.46
20	54.39	69.01	80.42	52.74	66.95	79.00
25	54.26	69.15	79.99	52.52	66.13	79.31
30	55.00	68.63	78.54	53.75	66.77	78.68
35	55.67	68.96	78.89	52.26	67.26	77.23
40	54.87	67.88	78.48	54.45	66.15	77.16
45	54.28	66.85	78.15	53.55	66.26	76.36
50	53.82	66.28	77.13	53.27	66.28	75.29

equilibrium, and R_L is a separation factor. It describes the nature of the adsorption process. It is represented by the following equation:

$$R_L = \frac{1}{(1 + bC_0)}. \quad (2)$$

If value of R_L is greater than 1, the unfavorable adsorption occurs. If R_L is between 0 and 1, then isotherm is favorable. The value of $R_L = 1$ indicates linear adsorption. In the present study, the value of R_L is between 0 and 1.

Heterogeneous surface sorption is well explained on the basis of the Freundlich model and favors multilayered physisorption process. The Freundlich isotherm is represented as

$$\log q_e = \log K_F + \frac{1}{n} \log C_e, \quad (3)$$

where q_e (mg·g^{-1}) is the adsorption capacity of the adsorbent at equilibrium and C_e (mg·L^{-1}) is the equilibrium dye concentration. Adsorption capacity is described by "K_F," and "n" represents adsorption intensity. Both are Freundlich

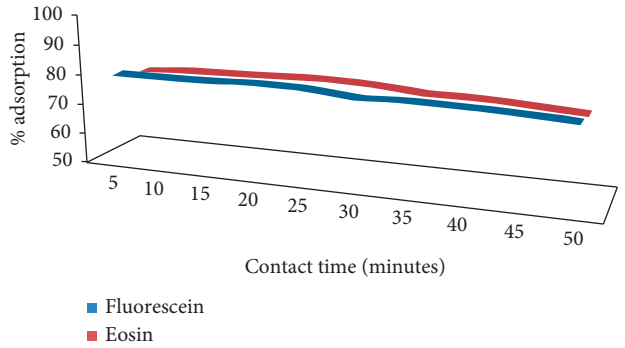

Figure 5: Comparative sorption efficiency of the base-treated WMP at different time intervals for removing fluorescein and eosin dyes.

Table 4: Sorption efficiency of the sorbent material (WMP) at different agitation speeds.

Agitation speed (rpm)	Fluorescein			Eosin		
	Raw WMP	A-(WMP)	B-(WMP)	Raw WMP	A-(WMP)	B-(WMP)
75	42.61	65.61	87.04	40.39	60.39	85.01
100	44.73	67.73	88.08	44.64	62.64	85.76
125	46.85	69.85	84.37	47.45	64.45	85.1
150	49.86	68.86	83.31	50.02	62.02	84.58
175	50.73	67.73	61.54	53.41	60.41	42.87
200	48.51	66.51	42.05	52.63	59.63	40.14

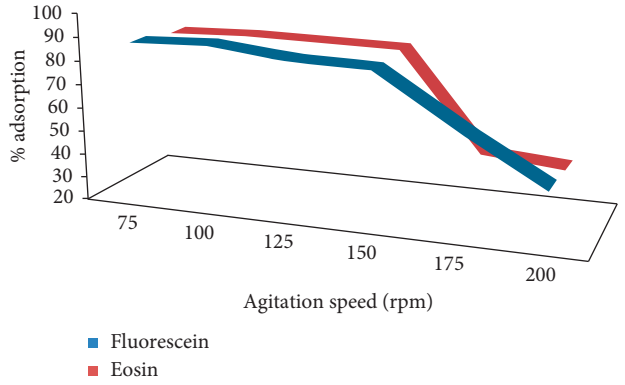

Figure 6: Comparative sorption efficiency of the base-treated WMP at different agitation speeds for removing fluorescein and eosin dyes.

Table 5: Adsorption rate of the sorbent material (WMP) at varying temperatures.

Temperature (K)	Fluorescein			Eosin		
	Raw WMP	A-(WMP)	B-(WMP)	Raw WMP	A-(WMP)	B-(WMP)
283	58.4	58.73	68.58	61.81	70.45	72.41
293	60.58	67.65	70.49	62.75	72.64	79.05
303	62.79	68.45	72.76	63.14	72.92	80.89
313	64.83	68.58	74.87	64.74	73.66	79.08
323	64.8	70.81	75.68	63.89	73.03	78.72
333	64.03	69.6	74.55	62.07	72.28	79.51
343	63.72	68.79	73.47	61.68	70.63	78.37
353	63.33	66.32	72.89	61.13	69.89	77.76
363	62.12	65.89	72.34	60.46	69.04	76.89

parameters. As presented in Table 8, the "n" value under this study is in the range of 0–6. Base-treated water melon peel B-(WMP) showed highest values of "K_F" for dyes (Table 8).

3.6.2. Kinetic Studies. Kinetic models are quite useful for understanding reaction rate, mechanism, and its applicability on commercial scale. In this regard, experimental

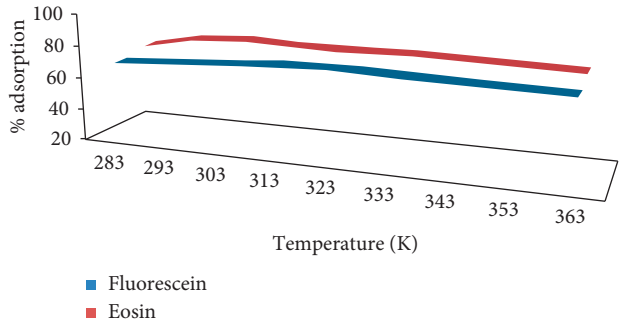

Figure 7: Comparative sorption efficiency of base-treated WMP at different temperatures for removing fluorescein and eosin dyes.

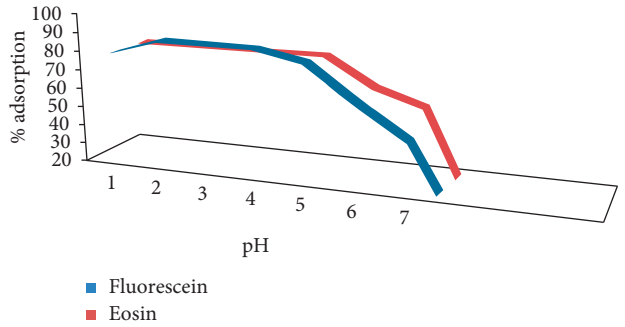

Figure 8: Comparative sorption efficiency of the base-treated WMP at different pH values for removing fluorescein and eosin dyes.

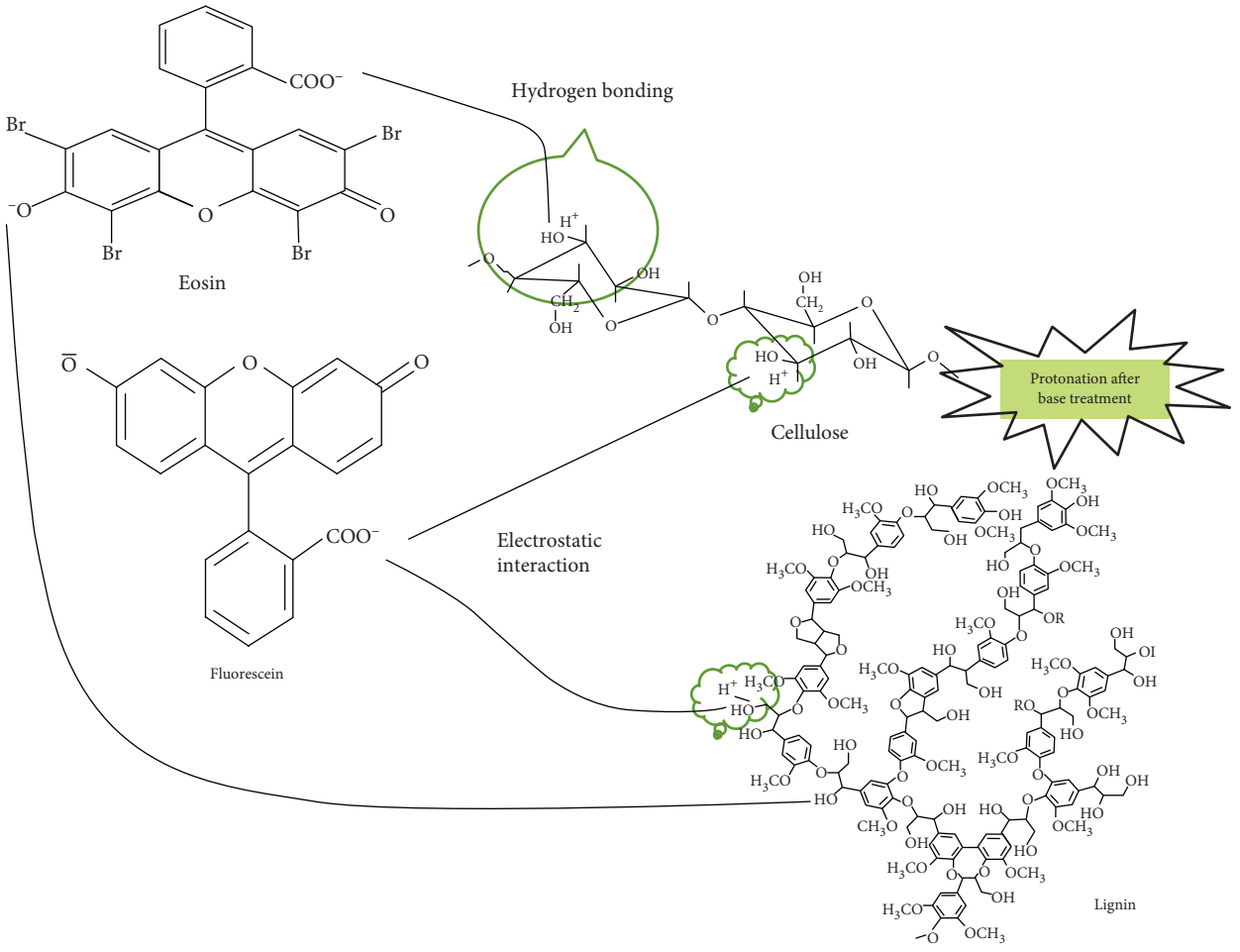

Figure 9: Interaction of acidic dyes with the lingocellulosic material of *Citrullus lanatus* peels.

Table 6: Effect of pH on sorption efficiency of the sorbent (WMP).

pH	Fluorescein			Eosin		
	Raw WMP	A-(WMP)	B-(WMP)	Raw WMP	A-(WMP)	B-(WMP)
1	53.45	68.16	78.24	43.48	49.62	78.65
2	54.71	81.02	86.33	45.24	70.67	79.41
3	57.84	81.96	85.79	48.27	75.26	79.02
4	59.91	81.45	85.77	51.05	76.01	78.38
5	61.23	80.42	80.67	54.43	75.42	78.76
6	60.82	42.38	61.72	53.24	60.99	63.65
7	57.91	40.54	45.25	53.35	51.14	55.52

Table 7: Langmuir isotherm parameters of the B-(WMP) sorbent.

		Langmuir isotherm parameters						
B-(WMP)	Dyes	Slope	Intercept	R^2	q_m (mg/g)	b (L/g)	Specific surface area (m^2/g)	R_L
	Fluorescein	7.971	0.052	0.989	20.545	0.007	4.380	0.771
	Eosin	10.101	0.071	0.924	14.613	0.006	3.804	0.739

Table 8: Freundlich isotherm parameters of the B-(WMP) sorbent.

		Freundlich isotherm parameters				
B-(WMP)	Dyes	Slope	Intercept	R^2	K_F ($mg^{1-1/n}\cdot L^{1/n}\cdot g^{-1}$)	n
	Fluorescein	0.390	0.025	0.978	1.040	2.530
	Eosin	0.485	−0.298	0.990	0. 625	2.048

Table 9: Kinetic parameters of B-(WMP) sorbent.

		Pseudo-second-order kinetics parameters						
B-(WMP)	Dyes	Slope	Intercept	R^2	K_F ($mg^{1-1/n}\cdot L^{1/n}\cdot g^{-1}$)	q_o (mg/g)	h	$t_{1/2}$
	Fluorescein	1.214	23.962	0.962	0.045	0.888	0.094	19.145
	Eosin	1.360	16.953	0.957	0.082	0.728	0.044	9.101

Table 10: Thermodynamic parameters of B-(WMP) sorbent.

		Thermodynamic parameters					
B-(WMP)	Sorbates	Slope	Intercept	R^2	ΔH° (kJ/mol)	ΔS° (kJ/mol·K)	ΔG° (kJ/mol)
	Fluorescein	0.003	0.002	0.967	−0.048	0.059	−17.117
	Eosin	0.002	0.003	0.953	−0.051	0.034	−10.466

data of the time-dependent sorption of dyes were fitted to the kinetic models, i.e., pseudo-first-order and pseudo-second-order order models. The coefficient (R^2) values for the pseudo-first-order model were low, which indicates that this model did not fit on the experimental data. Contrast to this observation, it was found that the second-order model provided promising fits for the sorption data; hence, this model was applied to the experimental data under optimized conditions. The values of the regression coefficient (R^2) were in the range 0.957 to 0.962 near to unity (Table 9). The initial sorption rate (h) was determined from "k_2" and "q_e" values which are more for base-treated water melon peel B-(WMP), which means plenty of adsorption site were available for dyes, thus favoring good adsorption [14, 15].

3.6.3. Thermodynamic Studies. Thermodynamic parameters are also very important in order to see spontaneous or nonspontaneous nature of process. Furthermore, these parameters elucidate the spontaneity, feasibility, and heat change of the sorption process. Thermodynamic properties of the sorption process of dyes under this study by base-treated sorbents were evaluated by calculating the Gibbs free energy change (ΔG°), entropy change (ΔS°), and enthalpy change (ΔH°), and results are shown in Table 10. It is well established in the literature that the range of ΔG° values for physisorption is between 20 and 80 kJ/mol while chemisorption is between 80 and 400 kJ/mol [16, 17]. This further indicates that the sorption process under this study seems to be physisorption. Enthalpy change values are also negative, which means that the sorption process is

exothermic in nature, whereas the ΔS° values are positive which confirmed the increased randomness during the sorption process [18].

4. Conclusions

It can be concluded from this study that peel of *Citrullus lanatus* can be effectively used for removal of fluorescein and eosin from wastewater streams of textile industry. The adsorption capacity of this agrowaste peel can be prominently enhanced by chemical modification. Base-treated water melon peels have found to possess more sorption capacity. Kinetic studies favored pseudo-second-order kinetics, which indicate rapid transfer of dyes from solution. Thermodynamic studies revealed the spontaneity and exothermic nature of removal of dyes by this sorbent.

Abbreviations

WMP: Water melon peels
A-(WMP): Acid-treated water melon peels
B-(WMP): Base-treated water melon peels
SEM: Scanning electron microscopy
FTIR: Fourier transform infrared spectroscopy
TGA: Thermogravimetric analysis
HEC: Higher education commission.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this publication.

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Supplementary Materials

Graphical abstract of present work. (*Supplementary Materials*)

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