



Biosorptive Elimination of Malachite Green from Water Medium by *Prunus laurocerasus* L

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Abstract

In the present study, the waste leaf biomass *Prunus laurocerasus* L. was used as a novel potential biosorbent for biosorptive malachite green elimination from water medium. Biosorption study was conducted under the variation in several experimental conditions like initial malachite green concentration, biosorbent dosage, pH, and contact time for the purpose of the optimization of the treatment operation. Maximum removal performance was achieved at initial malachite green concentration of 15 mg/L, biosorbent dosage of 10 mg, pH of 8, and contact time of 360 min. Isotherm, kinetic, and thermodynamic studies were performed to gain a more in-depth insight into the biosorption process. Dubinin–Radushkevich (D-R) model was in good agreement with the biosorption isotherm data. The biosorption kinetic data followed the pseudo-second-order (P-S-O) model. The intra-particle diffusion (I-P D) model showed that there were diverse mechanisms affecting the elimination process. Thermodynamic study indicated that the biosorption operation was spontaneous, favorable, and physical in nature. FTIR and SEM analysis results disclosed that different binding groups on biosorbent heterogeneous surface were involved in malachite green biosorption. Malachite green removal capacity of the biosorbent was determined as 83.654 mg/g. Compared to other biosorbents for malachite green removal, its biosorption ability was quite high. These results highlighted the potential of the biosorbent as a favorable choice for the effective malachite green removal from water phase.

Keywords Malachite green · Biosorption · *Prunus laurocerasus* L. · Biosorbent · Aqueous phase

1 Introduction

We use products with dazzling colors in an innumerable variety in almost every aspect of our lives, from food to medicine, from clothes to cosmetics. Today, in order to meet this large-scale dye demand in a mass and inexpensive way, the production of synthetic dyes has increased tremendously. These synthetic dyes are broadly utilized in numerous industrial areas such as cosmetics, paper, pharmaceuticals, food, and textiles [1]. However, these industries require enormous amounts of water for production and therefore produce significant amounts of contaminated water containing large quantities of synthetic dyes [2]. The discharge of untreated wastewater into natural aquatic ecosystem not only causes visual pollution, but synthetic dyes also block sunlight from penetrating into deeper layers of the water body, inhibit

photosynthetic biological processes, and reduce the oxygen content of the water source [3]. In addition, they have very serious effects on living beings, such as toxicity, carcinogenicity, and mutagenicity [1, 3–5]. Therefore, synthetic dyes are considered as potential organic pollutants that have very negative effects not only on aquatic biota but also on all ecosystems of the world.

In order to eliminate this issue, which is quite alarming in terms of living and environmental health, industrial wastewater containing these colored pollutants must be purified by an appropriate treatment method before being discharged into natural environment [6]. However, synthetic dyes are persistent pollutants that resist both biotic and abiotic environmental factors due to their complex molecular structures [7]. Numerous technologies like biological degradation, membrane separation, coagulation, ion exchange, photocatalytic degradation, ozonation, and biosorption have been developed to deal with these stubborn pollutants [8]. Among different techniques examined so far, in terms of low cost, simplicity, wide application

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area, efficiency, and environmental sustainability, the biosorption appears to be the strongest of all [1, 4, 9–11].

Plant waste biomasses are abundant, readily available, and either low cost or completely free materials [12]. They have very favorable physicochemical properties for the biosorption of synthetic dyes. For a sustainable environment, it is very important to convert these biological materials from waste into a valuable product such as biosorbent within the scope of circular bioeconomy [13]. Therefore, the application of plant-based waste biomass for the synthetic dyes removal from wastewater medium has recently become very popular among scientists [14–16].

In this context, *Prunus laurocerasus* L. was discussed in this study. *P. laurocerasus* L. is a hardy plant species belonging to the *Rosaceae* family. It is widely cultivated in temperate regions worldwide for various purposes such as food, decorative, barrier, medicine, and landscaping [17–19]. In this research, from a different perspective, the waste leaf biomass *P. laurocerasus* L. was used as a new potential biosorbent for biosorptive elimination of malachite green from water medium. The widespread availability of this plant waste and its rich bioactive content [20, 21] are the motivation for the study. If the biomaterial, which has been found to have antioxidant and antimicrobial effects [21–24], also exhibits good biosorbent properties, this indicates that it will be used as a versatile and valuable material in terms of water treatment.

Malachite green is widely used in aquaculture, agriculture, fishery, food, textile, health, and other sectors due to its particularly strong coloring and anti-parasitic properties [25]. However, it has been widely reported that this synthetic dye has mutagenic, teratogenic, carcinogenic, and toxic effects on humans and other organisms even at very low concentrations [26–28]. Although the use of malachite green has been banned in many countries due to these harmful effects, it continues to be used due to its cheapness, effectiveness, and the lack of an equivalent environmentally and life-friendly alternative [25, 27, 29]. Therefore, the effective removal of malachite green from aquatic environment is of vital importance for the protection of human and other organisms' health.

The treatment study was conducted under the variation in several experimental conditions like initial malachite green concentration, biosorbent dosage, pH, and contact time for the purpose of the optimization of the synthetic dye treatment process. Isotherm, kinetic, and thermodynamic studies were performed to gain a more in-depth insight into the biosorption process. The physiochemical properties of the biosorbent were tested using FTIR and SEM techniques. Finally, a literature comparison of the biosorbent was made in terms of malachite green biosorption ability.

2 Materials and Methods

2.1 Biosorbent Preparation

The plant-based waste biomass (*P. laurocerasus* L.) was supplied from Samsun province of Türkiye. It was first thoroughly cleaned with ultrapure water (Merck Direct-Q 3 UV) and then subjected to oven (Mikrotest MST 120D) drying for 24 h. The biomass was then passed through grinder (Waring) and sieved using sieve (0.5 mm, Loyka). 1 g of raw powdered biomass was added into sodium hydroxide solution (100 mL, 0.3 mol/L), and the mix was agitated at room temperature for 24 h with the help of a hot plate magnetic stirrer (Stuart SB162) for the modification process. Then, the biomass was separated from liquid phase and washed until pH value was neutral. Final material obtained was dried again and stored under appropriate conditions to be used as a biosorbent in the treatment experiments.

2.2 Malachite Green Solution Preparation

Malachite green (Carlo Erba) was provided from a local medical company (Samsun province of Türkiye). The desired initial concentration of the synthetic dye was obtained by diluting the stock malachite green solution (1000 mg/L). pH of solution was set by adding NaOH and/or HCl (0.1 mol/L, Merck, supplied by the same company as above). pH value of medium was determined with a pH meter (Hach HQ40d). A standard curve was created by measuring the absorbance of malachite green (617 nm) using a spectrophotometer (Thermo Genesys 10 S) to determine malachite green concentration in test medium.

2.3 Biosorption Study

The treatment study was conducted at ambient temperature (23 °C) under different operating conditions in 100-mL conical flasks containing malachite green solution. Different amounts of biosorbent were added to the synthetic dye solution, which was prepared at different malachite green concentrations according to the experimental conditions, and the mixture was agitated for a certain period of time. When the specified experimental time was reached, a certain amount of liquid phase sample was separated from mixture. Malachite green concentration in test solution was calculated by spectrophotometer. Malachite green removal capacity (q_t , q_e , mg/g) (Eqs. (1) and (2)) and treatment yield (R_e , %) (Eq. (3)) of the biosorbent were determined using the equations in Table 1.

Table 1 Equations related to synthetic dye removal capacity and treatment efficiency of biosorbent

Eq. No	Eq
(1)	$q_t = \frac{(C_0 - C_t)V}{m}$
(2)	$q_e = \frac{(C_0 - C_e)V}{m}$
(3)	$R_e = \frac{C_0 - C_t}{C_0} \times 100$

C_0 : initial synthetic dye concentration in solution (mg/L)
 C_t : synthetic dye concentration at a time t in solution (mg/L)
 C_e : equilibrium synthetic dye concentration in solution (mg/L)
 V : synthetic dye solution volume (L)
 m : biosorbent mass (g)

2.4 Study of Optimization

The biosorption study was conducted under the variation in different experimental conditions including initial malachite green concentration, contact time, biosorbent amount, and pH for the purpose of optimization of malachite green treatment process. While evaluating the impact of a parameter on biosorption, experiments were conducted by keeping the other operational parameters constant, and thus, optimum operating conditions were obtained.

2.5 Isotherm Study

The relationship between the amount of malachite green retained on biosorbent (q_e) and the malachite green concentration remaining in aqueous medium (C_e) in equilibrium at a constant temperature value was analyzed with Freundlich (Eq. (4)), Langmuir (Eq. (5)), and D-R (Eq. (6)) models (Table 2).

2.6 Kinetic Study

The relationship between the synthetic dye removal ability of biosorbent (q_t) and the process time (t , min) was examined with pseudo-first-order (P-F-O) (Eq. (7)), P-S-O (Eq. (8)), and I-P D (Eq. (9)) models (Table 3).

2.7 Thermodynamic Study

The thermodynamic study was executed using the parameter of free energy change (ΔG° , kJ/mol) [30] (Eq. (10) (Table 3) for the synthetic dye biosorption.

2.8 Statistical Analysis

The performance of all the models in representing the experimental biosorption data was assessed with determination

Table 2 Biosorption isotherm equations

Eq. No	Eq	Ref.
(4)	Freundlich isotherm $q_e = K_F C_e^{\frac{1}{n_F}}$	[6]
(5)	Langmuir isotherm $q_e = \frac{q_m K_L C_e}{1 + K_L C_e}$	[6]
(6)	Dubinin–Radushkevich (D-R) isotherm $q_e = q_m e^{-B\epsilon^2}$	[6]

K_F : a parameter about synthetic dye biosorption capacity of biosorbent for the Freundlich isotherm

n_F : a parameter about biosorption intensity for the Freundlich isotherm

q_m : maximum synthetic dye biosorption capacity of biosorbent (mg/g)

K_L : a parameter about biosorption capacity of biosorbent for the Langmuir isotherm (L/mg)

B : a parameter about biosorption free energy ($\text{mol}^2 \text{K}^2/\text{J}^2$)

ϵ : Polanyi biosorption potential (J/mol/K)

coefficient (R^2) (Eq. (11)), adjusted R^2 (R^2_{adj}) (Eq. (12)), and root mean square error ($RMSE$) (Eq. (13)) (Table 4) using SigmaPlot program (Systat software).

2.9 Characterization Study

The physiochemical properties of the material before and after malachite green treatment were analyzed by FTIR and SEM techniques. The functional group profile of the biosorbent was examined using an FTIR spectrometer (PerkinElmer Spectrum 400). FTIR spectrum of the biosorbent was recorded in $4000\text{--}400 \text{ cm}^{-1}$ range. The morphological features of the material were studied by SEM (Zeiss Evo Ls 10) at a magnification range of 100–5000 times.

Table 3 Biosorption kinetic and thermodynamic equations

Eq. No	Eq	Ref.
(7)	Pseudo-first-order (P-F-O) model: $q_t = q_e (1 - e^{-k_1 t})$	[12]
(8)	Pseudo-second-order (P-S-O) model: $q_t = \frac{k_2 q_e^2 t}{1 + k_2 q_e t}$	[12]
(9)	Intra-particle diffusion (I-P D) model: $q_t = C + k_p \sqrt{t}$	[12]
(10)	$\Delta G^\circ = -RT \ln K_D = \Delta H^\circ - T \Delta S^\circ$	[12]

k_1 : P-F-O rate constant (min^{-1})

k_2 : P-S-O rate constant (g/mg/min)

C : a parameter about boundary layer thickness (mg/g)

k_p : I-P D rate constant ($\text{mg/g/min}^{1/2}$)

R : gas constant (J/mol/K)

T : temperature (K)

K_D : equilibrium constant (dimensionless)

Table 4 Statistical parameters used in evaluation of biosorption data

Eq. No	Parameter	Reference
(11)	$R^2 = 1 - \frac{\sum_{i=1}^n (x-y)^2}{\sum_{i=1}^n (x-\bar{x})^2}$	[12]
(12)	$R^2_{adj} = 1 - \frac{(1-R^2)(n-1)}{n-p-1}$	[12]
(13)	$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (x-y)^2}$	[12]

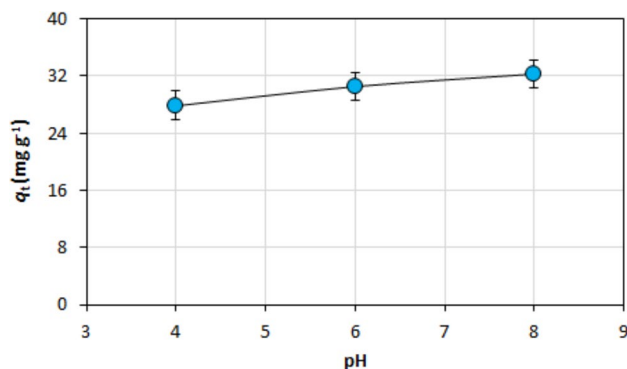
n : number of tests

x : experimental values

y : predicted values

$\bar{x}$: mean of actual values

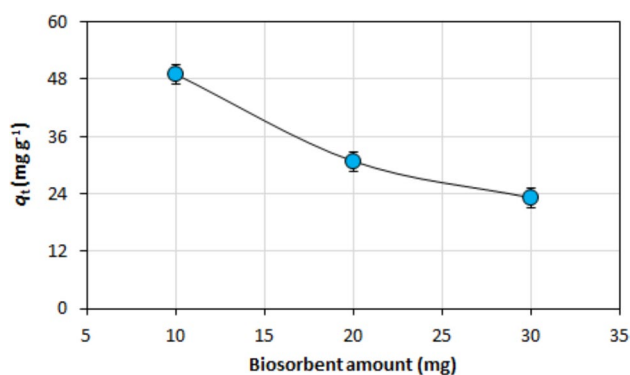
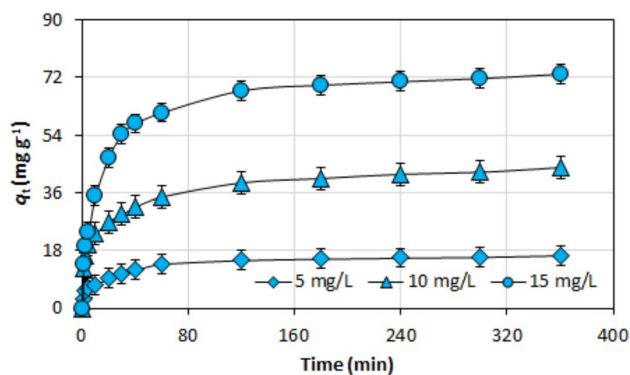
p : number of independent variables

**Fig. 1** Effect of pH on biosorption of synthetic dye

3 Results and Discussion

3.1 Operational Parameters Optimization

The impact of pH on malachite green biosorption was tested by changing pH from 4 to 8. Figure 1 presents pH effect on malachite green treatment. The synthetic dye removal ability of the material enhanced with increasing pH. The functional groups on the biosorbent were more protonated at low solution pH. Thus, positive charges surrounded the surface of the biosorbent. Since malachite green is a cationic synthetic dye, the competition between malachite green molecules and protons for functional groups on biosorbent limited the retention of malachite green on the surface. As pH increased, active groups became deprotonated and negatively charged [6, 31, 32]. Thus, these groups created high electrostatic attraction fields for the cationic synthetic dye molecules, thus increasing the biosorption yield [12, 31]. As a result,

**Fig. 2** Effect of biosorbent amount on synthetic dye biosorption**Fig. 3** Effect of contact time and initial synthetic dye concentration on biosorption capacity of biosorbent

optimum pH for malachite green biosorption was determined as 8.

The impact of biosorbent amount on synthetic dye removal by the biosorbent was examined in the range of 10–30 mg. The impact of biosorbent amount on malachite green treatment is displayed in Fig. 2. Malachite green biosorption ability decreased with the increase in material amount. As it increased, the number of active sites to retain the molecules of malachite green increased. However, since the synthetic dye concentration did not change in aqueous medium, the functional groups were not completely occupied by malachite green molecules, resulting in lower removal capacity at higher biosorbent amounts [16, 33, 34]. The overlapping of material particles might be another reason for this situation [7, 16, 35]. Thus, the optimum biosorbent amount for biosorption process was found to be 10 mg.

The impact of process time on malachite green biosorption was studied in the range of 0–360 min. The results are given in Fig. 3. The biosorption of synthetic dye enhanced with increasing contact time and equilibrium position was reached within 360 min. Initially, malachite green biosorption increased gradually due to the availability of numerous

Table 5 Biosorption isotherm analysis results

Model	Synthetic dye concentration (mg/L)	Parameter				
Freundlich		K_F	n_F	R^2	R^2_{adj}	$RMSE$
		3.242	1.958	0.951	0.902	8.829
Langmuir	5	$q_m(\text{mg/g})$	K_L	R^2	R^2_{adj}	$RMSE$
	10	83.654	0.792	0.937	0.873	10.073
	15		0.655			
D-R		$q_m(\text{mg/g})$	$E(\text{kJ/mol})$	R^2	R^2_{adj}	$RMSE$
		82.994	0.315	0.996	0.991	2.689

suitable binding sites on biosorbent for retention of the synthetic dye molecules [6, 33]. However, after a certain contact time, the vacant functional groups were almost completely filled by malachite green molecules, and biosorption reached equilibrium position [6, 36]. Thus, the optimum contact time for malachite green treatment was determined as 360 min.

The effect of initial malachite green concentration on the biosorption capacity was explored by varying malachite green concentration from 5 to 15 mg/L. Figure 3 shows impact of initial malachite green concentration on biosorption. The biosorption yield increased with enhancing malachite green concentration. Higher driving force created by the increasing concentration gradient with enhancing malachite green concentration provided more mass transfer of malachite green molecules to the biosorbent binding sites [7, 37, 38]. Thus, the optimum initial synthetic dye concentration for biosorption process was determined as 15 mg/L.

3.2 Biosorption Isotherm

Freundlich, Langmuir, and D-R models were employed in analysis of isotherm data of malachite green biosorption process. The results of biosorption isotherm analysis are

shown in Table 5. Performance of models in representing the biosorption data was assessed with R^2 , R^2_{adj} , and $RMSE$. The statistical parameters indicated that D-R model was in good agreement with malachite green biosorption data. In addition, B parameter of D-R model is employed to calculate a significant parameter known as mean free energy (E) (Eq. (14)).

$$E = \frac{1}{\sqrt{2B}} \quad (14)$$

The value of E for malachite green removal was determined as 0.315 kJ/mol. It was less than 8 kJ/mol. This showed that malachite green biosorption was multi-layer physical process [39–41].

For the synthetic dye biosorption, n_F parameter (Freundlich isotherm) was determined as 1.958. It was in the range of 1–10. This result showed a favorable process [36]. K_L parameter (Langmuir isotherm) is used to compute the separation factor (R_L) (Eq. (15)).

$$R_L = \frac{1}{1 + K_L C_0} \quad (15)$$

Table 6 Biosorption kinetic analysis results

Model	Synthetic dye concentration (mg/L)	Parameter				
P-F-O		$q_e(\text{mg/g})$	$k_1(\text{min}^{-1})$	R^2	R^2_{adj}	$RMSE$
	5	15.279	0.055	0.888	0.878	1.638
	10	37.918	0.108	0.740	0.717	5.623
P-S-O	15	68.185	0.066	0.944	0.939	5.290
		$q_e(\text{mg/g})$	$k_2(\text{g/mg/min})$	R^2	R^2_{adj}	$RMSE$
	5	16.311	0.00552	0.958	0.954	1.010
I-P D	10	40.889	0.00377	0.891	0.881	3.648
	15	73.428	0.00134	0.987	0.986	2.550
		$C(\text{mg/g})$	$k_p(\text{mg/g/min}^{1/2})$	R^2	R^2_{adj}	$RMSE$
	5	5.516	0.691	0.843	0.829	1.940
	10	17.730	1.592	0.883	0.873	3.768
	15	25.883	3.037	0.785	0.766	10.351

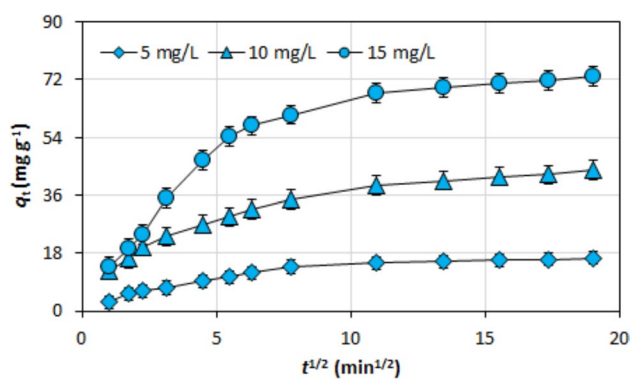


Fig. 4 Plots of intra-particle diffusion model

The separation factor value for malachite green biosorption was determined in the range of 0.559–0.792. These values between 0 and 1 showed that malachite green biosorption was a feasible process [15].

3.3 Biosorption Kinetic

P-F-O, P-S-O, and I-P D models were employed to analyze malachite green biosorption kinetic data. The results of kinetic analysis are displayed in Table 6. Performance of the kinetic models in representing the biosorption kinetic data was assessed with R^2 , R^2_{adj} , and $RMSE$. The statistical parameters indicated that the experimental kinetic data

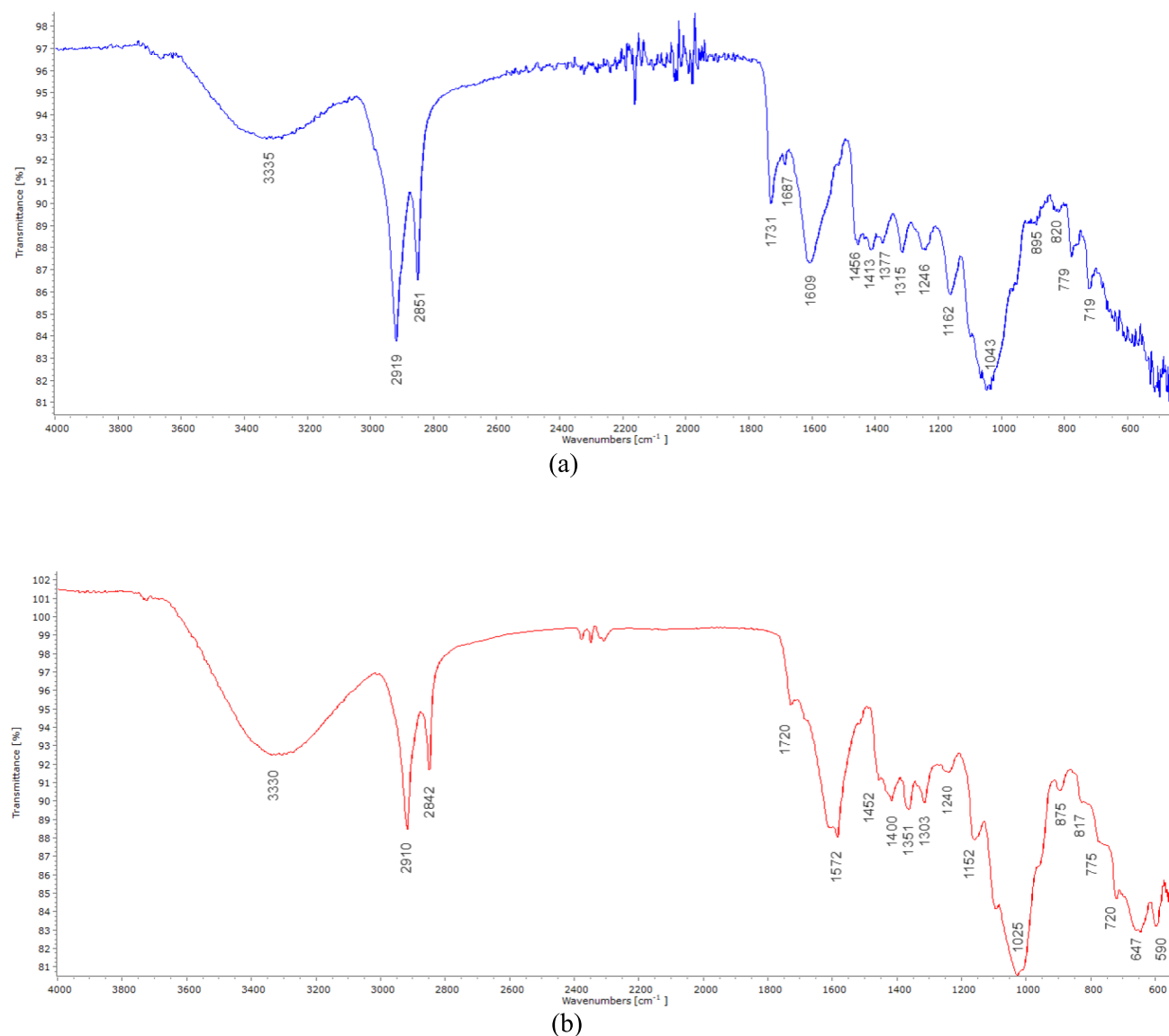


Fig. 5 Fourier transform infrared spectra of biosorbent before **a** and after **b** biosorption of synthetic dye

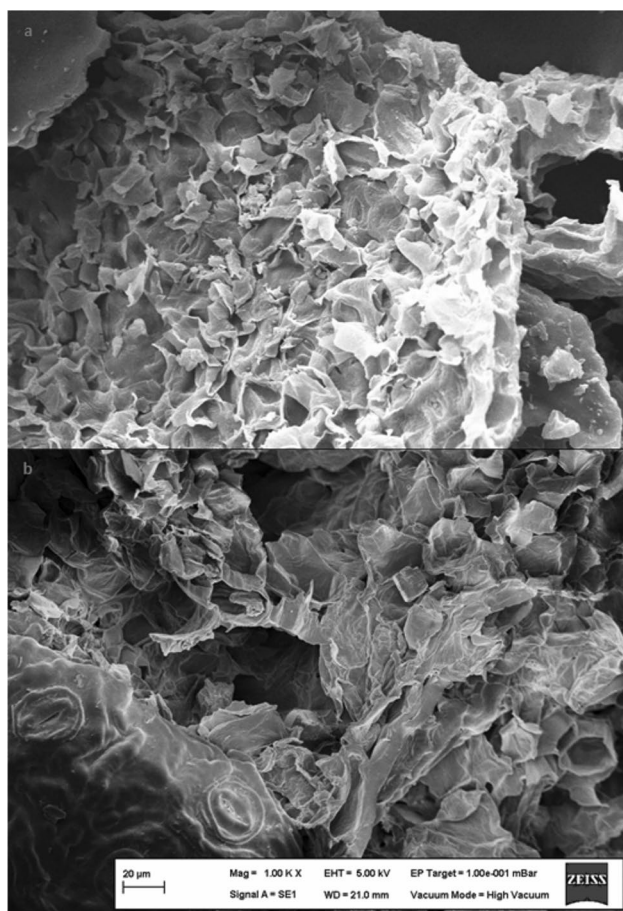


Fig. 6 Scanning electron microscope pictures of biosorbent surface before **a** and after **b** synthetic dye biosorption

followed P-S-O model. This result showed that malachite green biosorption onto the biosorbent was mainly dependent on chemical interactions [14, 15]. In addition, the impact of I-P D phase on malachite green biosorption was studied by I-P D model. Figure 4 displays I-P D model plots. The plots did not pass via the origin point. The result revealed that there were multiple mechanisms affecting malachite green biosorption process [14, 39].

3.4 Biosorption Thermodynamic

Thermodynamic analysis was conducted using ΔG° parameter. The values of ΔG° were found to be in the range of $-5.456 \sim -3.747$ kJ/mol for malachite green removal process. The negative values of ΔG° indicated that malachite green biosorption was favorable and spontaneous process [14]. In addition, the negative values of ΔG° ($-20 \sim 0$ kJ/mol) showed a physical mechanism for malachite green biosorption [30, 42].

3.5 Biosorption Characterization

The physiochemical features of biosorbent before and after malachite green treatment were analyzed using FTIR and SEM techniques. The functional group profile of biosorbent was examined using FTIR spectrometer. Figure 5 shows FTIR spectra of biosorbent before and after the biosorption process. For Fig. 5a, broad band at 3335 cm^{-1} was associated with O-H group. Sharp bands at 2919 and 2851 cm^{-1} were attributed to C-H group [8]. The bands at 1731 , 1687 , and

Table 7 Malachite green biosorption performances of different biosorbents

Biosorbent	Biosorption performance (mg/g)	Reference
Acid-modified pomegranate peel	2.95	[1]
Date seeds	43.478	[4]
<i>Newbouldia laevis</i> husk	35.78	[36]
<i>Newbouldia laevis</i> husk-based nanocomposite	69.97	[36]
Baru fruit endocarp	57.85	[16]
Diatom biosilica	40.71	[3]
Coir pith-based activated carbon (CPAC)	4.4	[28]
CPAC/chitosan/SDS composite	4.8	[28]
Chitosan-zinc oxide composite	11	[51]
Polylactic acid (PLA)	58.8	[52]
PLA/polyaniline composite (PLA/PANI)	54.3	[52]
PLA/PANI/carbon fibers composite (PLA/PANI/CFs)	60.1	[52]
Magnetic ragweed biomass	34.1	[53]
Bamboo leaves (BL)	80.034	[54]
H ₂ SO ₄ -treated BL	107.237	[54]
H ₃ PO ₄ -treated BL	151.735	[54]
<i>P. laurocerasus</i> L. waste leaf biomass	83.654	Current study

1609 cm^{-1} were related to C=O and C=C groups [12]. Small bands at 1456, 1413, 1377, 1315, 1246, and 1162 cm^{-1} were associated with C–O–C, O–H, C–H, C–O, C=C, and C–N groups, respectively [37, 38]. Strong band at 1043 cm^{-1} was related to the group of C–O–C [16]. Small bands at 895, 820, 779, and 719 cm^{-1} were associated with C–O and C–H groups [1, 4, 16, 37]. The changes in FTIR spectrum after the synthetic dye biosorption (Fig. 5b) showed that different binding sites on the material (especially the bands at 3335, 2919, 2851, 1731, 1609, and 1043 cm^{-1}) were involved in malachite green biosorption.

The morphological features of the material surface were studied using SEM. Figure 6 shows SEM pictures of the biosorbent before and after malachite green treatment. As seen from the figure (Fig. 6a), the biosorbent had a curved heterogeneous surface structure containing cavities of various sizes. This showed that it had a suitable structure for the retention of malachite green molecules [43–45]. The changes in SEM picture after malachite green treatment (Fig. 6b) disclosed that malachite green molecules were detained on the material surface.

3.6 Study of Comparison

The biosorbent was compared with other biosorbents in terms of biosorption ability in the present study. As seen from Table 5, malachite green removal power of the biosorbent was determined as 83.654 mg/g. Malachite green biosorption performances of different biosorbents are listed in Table 7. Compared to other biosorbents for malachite green removal, its biosorption ability was quite high. This result highlighted the potential of the biosorbent as a favorable choice for effective malachite green biosorption from aquatic medium.

3.7 Economic Feasibility Of Biosorbent

Cost is a very important parameter for the economical and sustainable use of biosorbent in real-scale treatment applications [46, 47]. Raw material, chemical, energy consumption, and labor (production and application) costs are taken into account in the total cost calculation [48, 49]. Biosorbents are obtained from abundant and largely cost-free biological waste, which means that raw material cost is minimized. *P. laurocerasus* L. waste leaf biomass is a zero-cost biomaterial. Sodium hydroxide (1.2 g) is the only chemical substance used in the process (for biosorbent modification). Sodium hydroxide costs around US\$5/kg. Electricity costs about US\$0.06/kWh. The minimum wage in Türkiye is around US\$550/month. From all of these, the total cost of biosorbent production is estimated to be around US\$1/kg. Under the operating conditions applied in this study, approximately 3.12 g of biosorbent

is required to treat 1 L of wastewater contaminated with malachite green. It is quite cost-effective when compared to commercial activated carbon (US\$13.62/kg), which is the top material in the treatment field [48, 50]. It should be taken into account that this cost will decrease even further in industrial-based production. This cost advantage of the biosorbent is due to its abundant and almost free supply, simplicity of production, and very low chemical and energy requirements for production [49, 50].

4 Conclusions

The waste leaf biomass of *P. laurocerasus* L. plant was successfully applied for malachite green treatment. The maximum synthetic dye biosorption was achieved at pH 8, biosorbent dosage of 10 mg, time of 360 min, and malachite green concentration of 15 mg/L. D-R and P-S-O models were in good agreement with malachite green biosorption data. The biosorption process was thermodynamically spontaneous, favorable, and physical in nature. The characterization analysis indicated that different binding sites on the biosorbent heterogeneous surface were involved in malachite green removal. The comparison study revealed that the material had a very high malachite green removal ability. All these findings demonstrated the potential of biosorbent to be a suitable option for the effective, environmentally sound, and sustainable malachite green treatment from water phase. On the other hand, it should be taken into account that this study was conducted at laboratory scale under limited environmental conditions. However, the nature of real wastewater can be quite complicated. Investigating the biosorption behavior of biosorbent in this environment will provide valuable information about its future field-based use. Again, issues such as optimization of the biosorbent production process, regeneration, and reuse of used material and disposal of final waste also need to be investigated.

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Data Availability All data generated or analyzed during the study are included in the article.

Declarations

Conflict of interest There is no conflict of interest to declare.

Ethical Approval Not applicable.

Use of Generative AI and AI-Assisted Technologies There is no generative AI and AI-assisted technologies usage to declare.

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