Journal of BioSustainability
ISSN 3063-2129(Online)
Journal homepage: https://ejournal.upi.edu/index.php/JoBS/

Potential of Papaya Seed (*Carica Papaya* L) Biosorbent for Textile Dyes Absorption

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ABSTRACT

Biosorbents are biological materials used to remove pollutants from solutions passively. Papaya seeds are believed to be a biosorbent candidate because they contain SiO_2, which has the potential to act as an adsorbent. Papaya seed adsorbent was made by adding H2SO4 as an activator and using Wantex red as the tested dye. This research aims to determine the potential concentration of papaya seeds as a biosorbent. The analysis used is qualitative, quantitative, and a significance test analysis. The method in this research uses 0.5 g (1%); 1.5g (3%); 2.5g (5%); 3.5 g (7%) of papaya seed biosorbent dissolved in Wantex red dye solution and analyzed using a UV-Vis spectrophotometer. The qualitative color results show contrasting color differences where the most transparent color is the dye added with 1.5 g and 2.5 papaya seed biosorbent, and the UV-Vis spectrophotometer absorbance results show that the best biosorbent mass is 1.5 g and 2.5 g with the highest absorbance power, namely 0.024 mg/g and 0.009 mg/g.

ARTICLE INFO

Article History:
Submitted/Received 03 May 2025
First Revised 12 May 2025
Accepted 20 May 2025
First Available online 30 Jun 2025
Publication Date 30 Jun 2025

Keyword:
Biosorbent,
Papaya seed,
Wantex Red

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1. INTRODUCTION

Papaya plants (*Carica papaya*) are widely grown in tropical areas for fruit consumption, including in Indonesia. Papaya plants have many health benefits, and even papaya seeds are rich in nutrients (Kusumawardani *et al*., 2018). Papaya seeds contain secondary metabolites such as alkaloids, saponins, and terpenoids, often used as traditional medicine. In addition, the silicon dioxide compound (SiO_2) in papaya seeds makes it potentially a natural adsorbent, as research has shown that this compound can absorb unnecessary substances or dirt (Pavan, F.A., 2014). In addition to silicon content, papaya seeds contain carbohydrates, which are considered essential to adsorbents, especially biosorbents (Paramesti, 2014).

Biosorbents are biological materials used to remove pollutants from solutions passively. Biosorbents include biomaterials such as agricultural waste, algae, bacteria, and industrial waste. Biosorbents come from renewable sources, are cheap, biodegradable, and do not produce secondary contaminants after use (Vijayaraghavan, 2008). The ability of biosorbents to absorb heavy metal ions and phosphorus (Aini, *et al*., 2022). Heavy metal ions and phosphorus are often found in textile wastewater from the dyeing process because both are insoluble in water and difficult to decompose by local microorganisms at the disposal site. Dyes are colored organic or inorganic compounds usually used to color textiles, food, medicines, cosmetics, and others (T. Pangesti, *et al*., 2013). Based on the description above, papaya seeds, which have the potential as biosorbents, can also adsorb dyes in solutions (Siswari, *et al*., 2017). Therefore, an experiment was carried out to determine the optimal percentage of papaya seeds as a biosorbent in absorbing dyes in solutions.

2. METHODS

2.1 Preparation and Activation of Papaya Seed Biosorbent

Papaya (*Carica papaya*) seeds were initially collected, thoroughly washed with distilled water to remove adhering pulp and impurities, and dried under sunlight, followed by oven drying to eliminate moisture content. The dried seeds were then ground into fine powder using a household blender. To enhance their adsorption properties, the powdered seeds were subjected to chemical activation using sulfuric acid (H_2SO_4) at a concentration of 10% (v/v), following the method outlined by Foo and Hameed (2012). Acid activation is a standard method to increase biosorbent surface area, porosity, and functional group density, thereby improving adsorption capacity.

The acid-treated material was left to soak and react for several hours, after which it was repeatedly rinsed with distilled water until a neutral pH was achieved, indicating the removal of residual acid. The material was then oven-dried at 110°C for 14 hours to stabilize the structure and reduce moisture, consistent with the procedures described in studies such as Bhatnagar and Sillanpää (2010). Following drying, the biosorbent was sieved using a 60-mesh sieve to ensure particle size uniformity, which is crucial for reproducibility in adsorption experiments and influences surface contact with adsorbates (Ioannidou & Zabaniotou, 2007).

2.2 Batch Adsorption Experiment

The prepared biosorbent was weighed into different dosages—**0.5 g (1%), 1.5 g (3%), 2.5 g (5%), and 3.5 g (7%)**—and each was added into a fixed volume of textile dye solution. These dosage variations were chosen to evaluate the effect of biosorbent mass on dye removal efficiency, a key parameter in adsorption studies (Crini & Badot, 2008). The mixture was agitated under controlled conditions to allow sufficient contact time for adsorption. After the

DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
e-ISSN 3063-2129

adsorption process, the solution was filtered using cotton wool to separate the solid biosorbent from the liquid phase, and the resulting filtrate was collected for analysis.

2.3 Analytical Measurements

The concentration of dye remaining in the filtrate was determined by measuring its absorbance using a UV-Vis spectrophotometer at a specific wavelength corresponding to the maximum absorbance of the dye used (λ_max). The percentage removal efficiency was calculated based on the difference in absorbance before and after treatment, following the Beer–Lambert law. This method is widely accepted in adsorption studies for its sensitivity and precision in monitoring changes in dye concentration (Katheresan *et al*., 2018).

2.4 Statistical Analysis

All experiments were conducted in triplicate to ensure reliability and accuracy. The results were statistically analyzed using **Duncan's multiple range test (DMRT)** via IBM SPSS statistical software. DMRT was employed to compare the mean differences among treatments at a significant level (usually $p < 0.05$), enabling the identification of statistically significant variations in dye removal efficiency across different biosorbent dosages (Gomez & Gomez, 1984).

3. RESULTS AND DISCUSSION

Qualitative and quantitative results were obtained in testing the absorbance power of papaya seeds on textile dyes, and parametric testing was conducted using SPSS. Qualitative testing was carried out by directly looking at the papaya seed absorbance results' color, which can be seen in **Table 1**. Quantitative results were obtained by looking at the absorbance power of papaya seeds using a UV-Vis Spectrophotometer, which can be seen in **Table 2**. The results of the Duncan parametric test to know the level of significance can be seen in **Table 3.**

3.1. Qualitative Test of the Effect of Biosorbent Mass on Textile Dyes

The results of qualitative tests on the effect of biosorbent mass on textile dyes are shown in **Table 1**.

Table 1. Qualitative Test Results of Papaya Seed Biosorbent on Textile Dyes

	CONCENTRATION OF PAPAYA SEED			
Repetition	**0.5 g (1%)**	**1.5 g (3%)**	**2.5 g (5%)**	**3.5 g (7%)**
1	++++	+	+	++
2	++++	+	+	++
3	++++	++	+	+++

Note: ++++ = deep red; +++= faded red; ++=deep pink; +=faded pink

Table 1 shows that the concentration of textile dye decreases with increasing biosorbent mass. This occurs because increasing the amount of biosorbent increases the number of active sites on the biosorbent surface (Mondal, 2011). Furthermore, the increased surface area of the biosorbent causes more ions to be absorbed on the biosorbent surface (Ashraf, 2010). However, under certain conditions, the absorption percentage will remain constant or even decrease due to saturation of the biosorbent, known as the overdensity effect. This is evident in the 3.5 gram mass of biosorbent (7%), which experienced an increase in color (deep pink). This indicates a decrease in the adsorption percentage due to overlapping during

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p-ISSN 2655-9757

the adsorption process, due to the density of the biosorbent particles. This density results in a smaller surface area of the biosorbent, thus reducing the active sites of the biosorbent.

The 2.5 gram (5%) biosorbent mass was the optimal mass because at that point, a balance was reached between the textile dye absorbed by the papaya seed biosorbent and the remaining textile dye in the solution. This was evident from the resulting color, which was more faded than at other concentrations. This indicates that this papaya seed powder biosorbent concentration had maximally bound the textile dye.

3.2 Quantitative Test of the Effect of Biosorbent Mass Using UV-Vis

The results of the quantitative test of the effect of biosorbent mass using UV-Vis are shown in **Table 2**.

Table 2. Quantitative Test Results of Papaya Seed Biosorbent on Textile Dyes

		CONCENTRATION OF PAPAYA SEED			
Repetition	**Control**	**0.5 g (1%)**	**1.5 g (3%)**	**2.5 g (5%)**	**3.5 g (7%)**
1	1.963	0.276	0,085	0,268	0,029
2		0.535	0,000	0,034	0,550
3		0.468	-0,012	-0,004	0,042
Average		0.462	0,024	**0,009**	0,207

UV-Vis spectrophotometer is a measurement based on the absorption of ultraviolet and visible light by samples at specific wavelengths. Ultraviolet and visible light rays have a certain amount of energy to excite valence electrons to higher energy levels. The UV-Vis spectrum is used as a quantitative analysis for inorganic and complex molecules in solution. The concentration of analytes in solution can be determined by measuring the absorbance value at specific wavelengths using the Lambert-Beer law (Dachriyanus, 2004). Table 2 shows that a 0.5-gram biosorbent has an absorbance capacity of 0.462 Nm, while the adsorption capacities of 1.5-gram, 2.5-gram, and 3.5-gram biosorbents are 0.024 Nm, 0.009 Nm, and 0.207 Nm, respectively. The best textile dye adsorption capacity was achieved using a 2.5-gram biosorbent with an adsorption capacity of 0.009 Nm.

3.3 Duncan's Parametric Test

The statistical results of the Duncan test, shown in Figure 1, show that the papaya seed biosorbent significantly affected the solution's textile dye (wants). The 1.5 g (3%) and 2.5 g (5%) treatments significantly reduced the dye (wantex) in the solution. In other words, the 1.5 g and 2.5 g papaya seed biosorbents absorbed the most dye from 100 ml of solution.

Duncan[a]

Perlakuan	N	Subset for alpha = 0.05 1	2	3
P_1.5	3	.02433		
P_2.5	3	.09933		
P_3.5	3	.20700	.20700	
P_0.5	3		.42633	
Standar	3			1.96300
Sig.		.216	.128	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Figure 1. Result of Duncan's Parametric Test

The utilization of Carica papaya seeds as a biosorbent for removing synthetic dyes from aqueous solutions has gained increasing attention due to their availability, low cost, and eco-friendly nature. Several studies have demonstrated the capability of papaya seed-derived

DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
e-ISSN 3063-2129

biosorbents to effectively adsorb dye molecules through mechanisms such as electrostatic interaction, pore diffusion, and surface complexation (Demiral & Güngör, 2016; Salleh *et al*., 2011).

Experimental results in the present study confirm the potential of papaya seeds as a biosorbent, as evidenced by the significant removal of textile dyes under various biosorbent mass conditions. However, an important observation was that the relationship between the amount of biosorbent and the adsorption efficiency is not strictly linear. For instance, increasing the biosorbent mass from 1.5 g (3%) to 2.5 g (5%) improved dye removal. Still, a further increase to 3.5 g (7%) resulted in a decline in the adsorption capacity.

This phenomenon may be attributed to several factors. First, increased biosorbent mass can lead to particle agglomeration, reducing the effective surface area for dye adsorption. When particles cluster together, the number of active binding sites accessible to the dye molecules decreases (Ahmad *et al*., 2015). Second, a higher biosorbent mass in a fixed volume of solution may also hinder adequate mixing and reduce the contact between dye molecules and biosorbent particles, especially if the stirring or shaking speed remains constant. This reduction in mixing efficiency can limit the diffusion of dye molecules into the internal pores of the biosorbent.

Another plausible explanation involves the overlapping or crowding of active sites. As the concentration of the adsorbent increases, the available dye molecules may become insufficient to saturate all the adsorption sites, leading to a decrease in adsorption per unit mass. This phenomenon is supported by studies showing that beyond a specific adsorbent dosage, the equilibrium of the adsorption process is disturbed due to adsorbate-adsorbent interactions becoming less effective (Crini *et al*., 2019; Malik, 2004).

In conclusion, while papaya seed biosorbents exhibit promising performance for dye removal from wastewater, their efficiency depends on their physicochemical properties and operational parameters such as adsorbent dosage, mixing speed, and contact time. Optimization of these parameters is crucial to ensure maximum adsorption capacity and cost-effective application in real-world wastewater treatment systems.

4. CONCLUSION

Based on the research, it can be concluded that the concentration of papaya seed biosorbent affects the adsorption of textile dyes. The best absorbance power is found when adding papaya seed biosorbent at a concentration of 3% (1.5 g) and 5% (2.5g), with the highest absorbance power of 0.024 Nm and 0.009 Nm.

5. ACKNOWLEDGMENT

The authors would like to sincerely thank the Biology Program, Universitas Pendidikan Indonesia, for the valuable support and facilities provided throughout this research. The resources and guidance made available by the department played a crucial role in successfully completing this study.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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DOI: http://dx.doi.org/10. 17509/xxxx.xxxx
e-ISSN 3063-2129