International Journal of Advances in Applied Sciences (IJAAS)
Vol. 14, No. 1, March 2025, pp. 255~267
ISSN: 2252-8814, DOI: 10.11591/ijaas.v14.i1.pp255-267

Bio-adsorbents from banana peel and corncob in reducing Naphthol Yellow S dye

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Article Info

Article history:

Received Jul 7, 2024
Revised Jan 19, 2025
Accepted Jan 26, 2025

Keywords:

Banana peel
Bio adsorbent
Corncob
Dye
Naphthol Yellow S

ABSTRACT

Naphthol Yellow S, a textile dye waste, poses environmental pollution due to its degradable chromophore and auxochrome groups, necessitating processing. The aim was to analyze the adsorption kinetics of banana peel and corncob bioadsorbents to reduce the dye Naphthol Yellow S in wastewater. This research was a true experiment and the object used was an artificial Naphthol Yellow S solution with an initial concentration of 80 ppm applied to the adsorbent mass of 0.1, 0.2, and 0.3 grams and contact time of 3, 6, 9, and 12 hours. Dye levels were measured before and after treatment using a spectrophotometer. The best adsorption test occurred on the banana peel bioadsorbent with an adsorbent mass of 0.3 grams and a stirring time of 3 hours. The adsorption study of banana peel and corncob bioadsorbents showed that the entire adsorption process of Naphthol Yellow S dye followed the Langmuir isothermal adsorption model with R^2 coefficients of 0.9953 and 0.999, respectively, and maximum adsorption capacities of 4.6516 and 5.2825 mg/g, respectively. The activated carbon adsorption kinetics followed the second order, with R^2 values of 0.9737 and 0.9152, respectively. This study concluded that the bioadsorbent of banana peels and corncob was able to reduce the dye Naphthol Yellow S.

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1. INTRODUCTION

Water is the most essential raw element for humans, animals, plants, and microbes, water is the most essential raw element [1]. Almost every important biotic phenomenon is dependent on water availability. Today's society faces a significant water pollution issue because of the rapid advancement of technology [2]. Ecosystems deteriorate when untreated or insufficiently treated residential, industrial, and agricultural wastewater is released [3]. Given that industrial effluents have a far more hazardous nature, this issue is even more serious [4].

Tanneries and the textile sector ranked first and second, respectively, among industries that use large amounts of water [5]. Particularly significant are the textile printing and finishing industries as well as the dyeing sector [6]. Wastewater, which is heavily laden with basic or acidic dyes, salts, and adjuvants, is significantly polluted by these processes [7]. Considerable research has been conducted on the disposal of these dyes, including precipitation [8], ionic exchange [9], membrane filtration [10], electrochemical destruction [11], photodegradation [12], and adsorption [13]. Because of its many adsorbents, ease of design, high efficiency, and capacity to treat dyes in a more concentrated form, adsorption is regarded as a superior technique among these procedures when compared to other treatment methods [14].

Although various sorbents have historically been employed to remove dyes from aqueous solutions, activated carbon has recently gained popularity because of its pore structure, various surface oxygen functional groups, and high adsorption capacity. The type of precursor and activation procedure determine the properties of the activated carbons [15]. Several biomasses have been tested as precursors for the production of activated carbon, including buriti shells (*Mauritia flexuosa L.*) [16], waste tea [17], hazelnut husks [18], coconut shells [19], and Diplotaxis harra [20]. Nevertheless, research in this area has not yielded materials that completely satisfy adsorption activity requirements.

Naphthol Yellow S is one of the dyes normally used in the textile industry. Synthetic dyes have two groups in a molecule, chromophores and auxochromes. The chromophore group is used to make dyes in materials where the chromophore group contains an azo group [21]. This dye can impart good color to textile fabrics, but waste can cause cytotoxic effects. In addition, concentrated sunlight can prevent the entry of water bodies, thereby interfering with photosynthesis in the air. Bioremediation using certain microorganisms has been used to reduce substances in dye waste [22].

In this study, we investigated the adsorption kinetics of banana peel and corncob bioadsorbents in reducing the toxic textile dye Naphthol Yellow S in wastewater. The novelty lies in the use of banana peel and corncobs as bioadsorbents for this dye, which provides a sustainable and cost-effective solution for wastewater treatment. The results of this study will contribute to the development of eco-friendly methods for removing harmful dyes from industrial effluents. This study highlights the importance of using natural waste materials for environmental remediation.

2. RESEARCH METHOD

2.1. Research types and designs

This type of research is purely an experimentation. The research process involved the addition of banana peel and corncob bioadsorbents with mass variations of 0.1, 0.2, and 0.3 grams. Each group was replicated thrice. The adsorption process was carried out by adding various adsorbent masses to 250 ml of Naphthol Yellow solution and stirring at 30 rpm with contact time. Filtration was performed using filter paper to separate the biadsorbent from the filtrate. The resulting filtrate was tested in the laboratory to determine the concentration of the dye after the treatment using a spectrophotometric method. Banana peel material is obtained from waste from the domestic industry, whereas corncobs are obtained from processed cooking products. Artificial water, banana peel, and corncob bioadsorbents, as well as the adsorption process, were carried out at the Chemistry Laboratory of the Department of Environmental Health, Poltekkes Kemenkes, Surabaya.

2.2. Research object

The object used in this study was an artificial Naphthol Yellow S solution made from Naphthol powder with an initial concentration of 80 ppm. This solution was then processed by adsorption using activated banana peels and corncobs to reduce the Naphthol Yellow S dye concentration. The activated banana peels and corncobs were then subjected to x-ray diffraction (XRD) to identify and analyze the phase of the material, and scanning electron microscopy (SEM) was performed to observe the surface morphology of the sample.

2.3. Research instrument

The instrument used in this research was to carry out a batch system adsorption process on Naphthol Yellow S solution using banana peel and corncob adsorbents to reduce the concentration of dye. The research was carried out by activating banana peels and corncobs, followed by an adsorption process on banana peels that had been activated with 0.5 M H2SO4. Enter various adsorbent masses, namely 0.1, 0.2, and 0.3 grams, into a sample of Naphthol Yellow S solution whose dye concentration is known. Stirring was then carried out at a speed of 30 rpm at various contact times, namely, 3, 6, 9, and 12 hours. Each measurement was repeated three times. Naphthol Yellow S dye concentration was measured before and after treatment.

2.4. Making banana peel and corncob bioadsorbent

Banana peel and corncob bioadsorbents were produced at different stages. The first step in making a banana peel bioadsorbent is cutting the banana peel into small pieces and then washing the banana peel with running water until it is clean of dirt. Next, the banana peel was dried in the sun. The dried banana peel was placed in an oven at 110 °C for 1 hours. Subsequently, it was placed in a furnace at a temperature of 400 °C for 2 hours until it became carbon. The banana peel bioadsorbent, which was converted to carbon, was then cooled in a desiccator for 15 min. It was then ground using a mortar and pestle and sifted using a 120-mesh sieve. Bioadsorbent activation was carried out by soaking banana peel carbon in a 0.5 M H2SO4 solution for

2 hours. This method has also been applied to the manufacture of corncob bioadsorbents. After all the procedures have been carried out, the water content, ash content, and absorption capacity of the I2 solution are then measured to meet the active carbon quality requirements of SNI 06-3730-1995.

2.5. Bioabsorbent activation

The process of activating banana peels and corncobs, making Naphthol Yellow S solution, the adsorption process, and checking the concentration of dyes were carried out at the Chemistry Laboratory of the Department of Environmental Health, Poltekkes Kemenkes, Surabaya, while the SEM and XRD tests for banana peel and corncob adsorbents were carried out at the Institut Teknologi Sepuluh Nopember (ITS) Surabaya Energy and Environment Laboratory. This study was conducted to analyze the ability of banana peel and corncob bioadsorbents to reduce the concentration of Naphthol Yellow S dye.

2.6. Data collection technique

In the context of the study on the activation of banana peels and corncobs for dye removal, various data collection techniques were employed. The activation process involved the preparation of adsorbents from agricultural waste, specifically banana peels and corncobs. The synthesis of Naphthol Yellow S solution and the preparation of a 0.5 M H2SO4 solution were critical for the experimental setup. Subsequently, SEM and XRD analyses were conducted to characterize the physical and structural properties of the activated materials. These techniques provided insights into the surface morphology and crystallinity, essential for understanding the adsorption mechanisms. Finally, the concentration of Naphthol Yellow S dye was quantitatively assessed before and after treatment using spectrophotometric methods, allowing for the evaluation of the efficacy of the activated adsorbents. This multi-faceted approach ensures a comprehensive understanding of the materials' performance in dye removal applications.

2.7. Data analysis

The obtained data were analyzed descriptively and analytically. To determine the difference in the average decrease in concentration of Naphthol Yellow S dye in Naphthol Yellow S solution samples based on variations in adsorbent mass, namely (0.1, 0.2, and 0.3 grams) and various stirring times (3, 6, 9 and 12 hours) two-way analysis of variance (ANOVA) analysis was carried out. Before conducting the influence analysis, the data were tested for normality and homogeneity. After the research data were proven to be normal and homogeneous, an effect test was performed for each treatment using an ANOVA. Statistical testing (normality test, homogeneity test, and two-way ANOVA test) was performed to analyze differences in variations in adsorbent mass and stirring time on the adsorption kinetics of banana peel and corncob bioadsorbent in reducing Naphthol Yellow S dye.

3. RESULTS AND DISCUSSION

Banana peels and corncobs converted into active carbon were measured to determine the quality requirements of the activated carbon. This measurement was performed to determine whether the quality of activated carbon from banana peels and corncobs met the requirements in accordance with SNI 06-3730-1995 concerning technically active charcoal. The results of measuring the quality requirements for activated carbon for banana peels and corncobs are presented in Table 1. Based on Table 1 shows that the results of measurements of banana peel and corncob bioadsorbent at water content were respectively 4.67 and 6.12%, ash content was 3.14 and 5.25%, and iodine absorption capacity amounting to 850.29 and 799.53 mg/g. From the three active carbon quality requirements above, it is known that banana peel and corncob bioadsorbents have met the quality standards set by SNI 06-3730-1995.

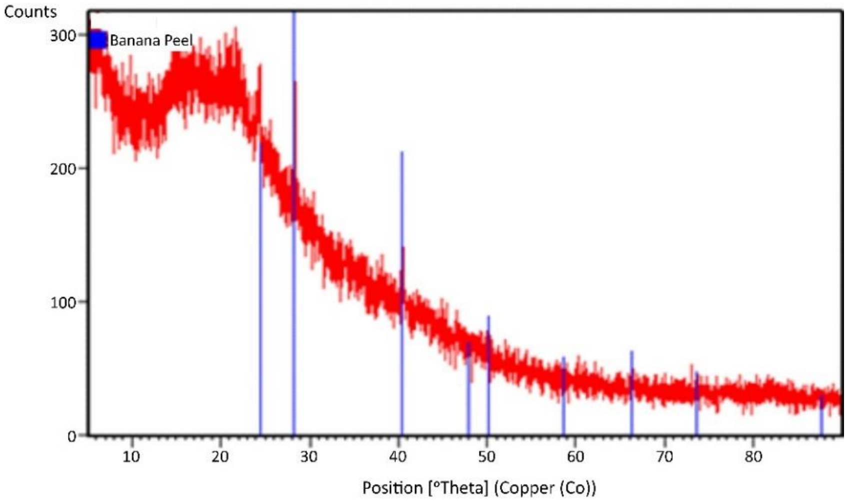
Table 1. Results of measuring the quality requirements for activated carbon for banana peels and corncobs according to SNI 06-3730-1995

No	Description	Powder requirements	Measurement results	
			Banana peel	Corncob
1	Water content	Max. 15%	4.67%	6.12%
2	Ash content	Max 10%	3.14%	5.25%
3	Absorption capacity of I2 solution	Min. 750 mg/g	850.29 mg/g	799.53 mg/g

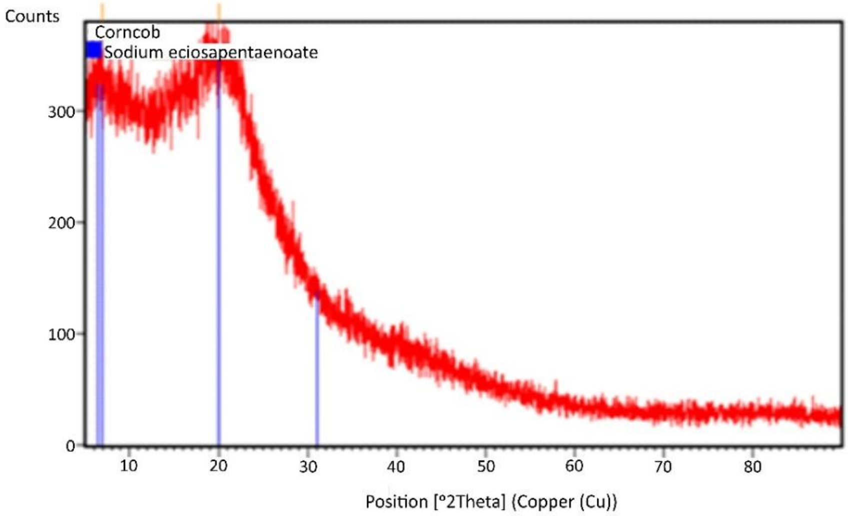
3.1. Characterization of banana peel and corncob bioadsorbent

Figure 1 shows the results of the XRD test for the banana peel bioadsorbent (Figure 1(a)) at an angle of 2θ. Several distinctive peaks can be observed in the diffractogram, and the dominant minerals are contained therein. The typical peaks formed at an angle of 2θ are 24.360, 28.280, 40.510, and 50.110. The graph shows that the highest peak of the diffraction pattern at an angle of 2θ was located at 28.280°. Potassium chloride was the dominant mineral in the banana-peel bioadsorbent.

The corncob bioadsorbent (Figure 1(b)) characterization was performed using XRD at an angle of 2θ. The diffractogram results show several typical peaks formed at angles of 2θ, namely 6.970 and 19.990. The graph shows the highest peak in the diffraction pattern at 2θ=6.970°. The dominant mineral in the corncob bioadsorbent was sodium eicosapentaenoic acid.



(a)



(b)

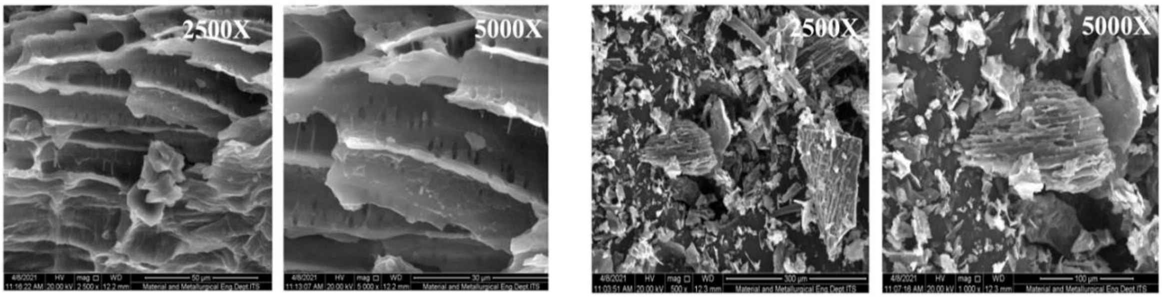
Figure 1. Diffractogram results of (a) banana peel bioadsorbent and (b) corncob bioadsorbent

3.2. Scanning electron microscope test

The activated banana peel and corncob bioadsorbents were subjected to SEM. The SEM test aims to determine the surface topography of a material or the pore surface structure as a result of changes in carbonization and activation temperatures. The SEM examination results were obtained at magnifications of 2500X and 5000X. Figure 2 shows the SEM analysis results on banana peel bioadsorbent (Figure 2(a)) and corncob bioadsorbent (Figure 2(b)).

The SEM analysis results showed that after carbonization into charcoal, pores began to form. The activation of banana peel charcoal into activated carbon causes an increase in the number and diameter of pores. In addition, the use of H2SO4 increased the number of pores to become larger and opened small pores.

This shows that H2SO4 opens the pores in banana peel-activated carbon by oxidizing it, thereby increasing its absorption capacity. Based on the results of SEM analysis on corncob bioadsorbent, it showed that pores were formed. The pores in the activated carbon were formed by the carbonization process at a temperature of 400 °C. Carbonization degrades material components to produce charcoal. In addition to the carbonization process, the activation process was performed using H2SO4 to produce activated carbon.



(a) (b)

Figure 2. SEM analysis results on (a) banana peel bioadsorbent and (b) corncob bioadsorbent

3.3. Examination of Naphthol Yellow S dye concentration before and after bioadsorbent application

The application of banana peel and corncob bioadsorbents to reduce the concentration of dyes was carried out at the Chemistry Laboratory of the Department of Environmental Health, Poltekkes Kemenkes, Surabaya. The results of examining the concentration of Naphthol Yellow S dye before and after the application of banana peel and corncob bioadsorbent are shown in Table 2. The difference in the average concentration of Naphthol Yellow S dye before and after treatment; the concentration of Naphthol Yellow S dye was lower than that before treatment. The dye concentration used was 80 mg/L. From the two treatments above, the highest percentage of dye reduction was found in the banana peel bioadsorbent with an adsorbent mass of 0.3 grams and a stirring time of 3 hours, namely 34.88%, while the lowest percentage of dye reduction was observed in the corncob bioadsorbent group with an adsorbent mass of 0.1 grams and a stirring time of 3 hours (9.95 %).

Table 2. Results of examination of Naphthol Yellow S dye concentration before and after application of banana peel and corncob bioadsorbent

Type adsorbent	Mass (grams)	Contact time (hours)	Before	After	Decreased value (mg/L)	Percentage decline (%)
Banana peel	0.1	3	80	59.94	20.06	25.07
		6	80	58.44	21.56	26.95
		9	80	57.77	22.23	27.78
		12	80	59.44	20.56	25.70
	0.2	3	80	55.47	24.53	30.66
		6	80	56.17	23.83	29.78
		9	80	57.92	22.08	27.60
		12	80	59.69	20.13	25.38
	0.3	3	80	52.09	27.91	34.88
		6	80	53.64	26.36	32.95
		9	80	64.15	25.85	31.97
		12	80	55.70	24.30	30.30
Corncob	0.1	3	80	72.04	7.96	9.95
		6	80	70.87	9.13	11.41
		9	80	71.59	8.41	10.51
		12	80	71	9	11.25
	0.2	3	80	60	20	25
		6	80	59.71	20.29	25.36
		9	80	59.57	20.43	25.53
		12	80	58.87	21.13	26.41
	0.3	3	80	65.92	14.08	17.6
		6	80	66.58	13.42	16.77
		9	80	66.59	13.41	16.76
		12	80	66.53	13.47	16.83

3.4. Difference in an average reduction in the concentration of Naphthol Yellow S dyes using banana peel and corncob bioadsorbents

Based on the results of the normality test for reducing the concentration of Naphthol Yellow S dye using banana peel and corncob bioadsorbent, the P-value varied in the adsorbent mass (0.1, 0.2, and 0.3 grams) and stirring times (3, 6, 9, and 12 hours) were 0.701 and 0.064, respectively. This indicates that the data falls into the normal distribution category. Next, the data were tested for homogeneity, and the results obtained were P-values of 0.162 and 0.296, respectively. After all data were normally distributed and homogeneous, the two-way ANOVA test was continued to determine the average differences in each variable. The results of the two-way ANOVA test for reducing the concentration of Naphthol Yellow S dye using banana peel and corncob bioadsorbent are shown in Table 3.

Based on Table 3, the results show that there are differences in the adsorbent mass, stirring time, and interaction between adsorbent mass and stirring time on the adsorption kinetics of the banana peel bioadsorbent in reducing Naphthol Yellow S dye (P=0.000<0.005). Meanwhile, for the corncob adsorbent type, there was only a difference in the adsorbent mass on the adsorption kinetics of the bioadsorbent in reducing Naphthol Yellow S dye (P=0.000<0.05). For variables that are specifically related can be seen in the post hoc test in Tables 4-6.

Table 3. Two-way ANOVA test results for reducing the concentration of Naphthol Yellow S dyes using banana peel and corncob bioadsorbents

No	Adsorbent type	Sources of variation	P
1	Banana peel	Adsorbent mass	0.000
		Mixing time	0.000
		Mass*stirring time	0.000
2	Corncob	Adsorbent mass	0.000
		Mixing time	0.381
		Mass*stirring time	0.268

Table 4 shows the post hoc test results of decreased concentration of Naphthol Yellow dyes between adsorbent mass variations. There was a difference in adsorbent mass on the adsorption kinetics of banana peel and corncob bioadsorbent in reducing Naphthol Yellow S dye (P=0.000<0.005). Table 5 shows the post hoc test results decreased concentration of Naphthol Yellow dyes between varying stirring times. Variations in the mixing time of banana peel bioadsorbent in reducing Naphthol Yellow S dye have different P-values. Banana peel bioadsorbent with varying mixing times of 12 hours had a P-value of 0.000<0.05, which means there was a significant difference in the reduction of Naphthol Yellow dye. Table 6 shows post hoc test results decrease in concentration of Naphthol Yellow dyes between adsorbent mass variations and stirring time. There was an interaction between mass variations of 0.1, 0.2, and 0.3 grams with a stirring time of 3 hours on the adsorption kinetics of banana peel bioadsorbent in reducing Naphthol Yellow S dye (P=0.000<0.005).

Table 4. Post hoc test results decreased the concentration of Naphthol Yellow dyes between adsorbent mass variations

Adsorbent Mass	P	
	Banana peel	Corncob
0.1 grams with 0.2 grams	0.000	0.000
0.1 grams with 0.3 grams	0.000	0.000
0.2 grams with 0.3 grams	0.000	0.000

Table 5. Post hoc test results decreased the concentration of Naphthol Yellow dyes between varying stirring times

Mixing Time	P
	Banana peel
3 hours with 6 hours	0.881
3 hours with 9 hours	0.122
3 hours with 12 hours	0.000
6 hours with 9 hours	0.409
6 hours with 12 hours	0.000
9 hours with 12 hours	0.000

Table 6. Post hoc test results decrease in the concentration of Naphthol Yellow dyes between adsorbent mass variations and stirring time

Mixing Time	P Banana peel
0.1 grams+3 hours with 0.1 grams+6 hours	0.351
0.1 grams+3 hours with 0.1 grams+9 hours	0.040
0.1 grams+3 hours with 0.1 grams+12 hours	0.999
0.1 grams+6 hours with 0.1 grams+9 hours	0.989
0.1 grams+6 hours with 0.1 grams+12 hours	0.850
0.1 grams+9 hours with 0.1 grams+12 hours	0.221
0.2 grams+3 hours with 0.2 grams+6 hours	0.984
0.2 grams+3 hours with 0.2 grams+9 hours	0.013
0.2 grams+3 hours with 0.2 grams+12 hours	0.000
0.2 grams+6 hours with 0.2 grams+9 hours	0.168
0.2 grams+6 hours with 0.2 grams+12 hours	0.000
0.2 grams+9 hours with 0.2 grams+12 hours	0.163
0.3 grams+3 hours with 0.3 grams+6 hours	0.311
0.3 grams+3 hours with 0.3 grams+9 hours	0.060
0.3 grams+3 hours with 0.3 grams+12 hours	0.000
0.3 grams+6 hours with 0.3 grams+9 hours	0.999
0.3 grams+6 hours with 0.3 grams+12 hours	0.060
0.3 grams+9 hours with 0.3 grams+12 hours	0.311

3.5. Kinetics of adsorption of banana peel and corncob bioadsorbent in reducing the concentration of Naphthol Yellow S dyes

Adsorption kinetics can be determined using various kinetic models. Before determining the adsorption kinetics, the adsorption isotherms were determined. Changes in the adsorbate concentration due to the adsorption process, according to the adsorption mechanism, can be studied by determining the adsorption isotherm. The commonly used adsorption isotherms are the Freundlich and Langmuir isotherms. Figure 3 shows the results of adsorption capacity measurements using banana peel and corncob bioadsorbents to reduce Naphthol Yellow S dye.

Figure 3(a) explains in detail about the banana peel Freundlich isotherm curve, Figure 3(b) explains in detail about the banana peel Langmuir isotherm curve, Figure 3(c) shows the Freundlich isotherm curve corncob, and Figure 3(d) shows the Langmuir isotherm curve corncob. The regression value (R2) in the Langmuir isotherm equation is greater than the R2 value in the Freundlich isotherm equation. The Freundlich and Langmuir isotherm equations were converted to straight-line equilibrium curves by calculating the adsorption capacity of the Freundlich and Langmuir equations. The isotherm model depends on the value of the determinant coefficient (R) with the highest value. This showed that the adsorption of banana peel bioadsorbent follows the Langmuir isotherm equation. Based on the linear curve of the relationship between 1/Ce and 1/qe, the adsorption capacities of banana peel and corncobs were 4.6516 and 5.2825 mg/g, respectively. The calculation of the adsorption capacity of Banana Peel and corncob bioadsorbent is as follows:

i) Banana peel bioadsorbent

In (1) is the calculation of banana peel bioadsorbent where qe is the amount of Naphthol Yellow S adsorbed (mg/g), Co is the initial Naphthol Yellow concentration=80 mg/l, Ce is the final Naphthol Yellow concentration=52.09 mg/l, V is the volume of solution=0.05 L, and M is adsorbent mass=0.3 grams.

$$qe = \frac{(Co-Ce)sV}{M} = \frac{(80-52.09)s0.05}{0.3} = 4.651\ mg/g \quad (1)$$

ii) Corncob bioadsorbent

In (2) is the calculation of banana peel bioadsorbent where qe is the amount of Naphthol Yellow S adsorbed (mg/g), Co is the initial Naphthol Yellow concentration=80 mg/l, Ce is the final Naphthol Yellow concentration=58.87 mg/l, V is the volume of solution=0.05 L, and M is adsorbent mass=0.2 grams.

$$qe = \frac{(Co-Ce)sV}{M} = \frac{(80-58.87)s0.05}{0.2} = 5.2825\ mg/g \quad (2)$$

Zero-order, first-order, and second-order kinetic models were used in this study. The optimum mass used to determine the kinetic model was banana peel bioadsorbent with a mass of 0.3 grams and corncobs (mass, of 0.2 grams with stirring times of 3, 6, 9, and 12 hours. The following are the results of measuring the adsorption kinetics using banana peel and corncob bioadsorbents to reduce Naphthol Yellow S dye.

Banana peels and corncobs can be used as bioadsorbents in the adsorption process because they are porous materials (molecular sieves) [23], [24]. In addition, banana peels and corncobs contain ingredients that can absorb dyes, one of which is the dye Naphthol Yellow S. Banana peels contain biochemical components, including cellulose, hemicellulose, chlorophyll pigments, and pectin substances, which contain galacturonic acid, arabinose, galactose, and rhamnose [25]. Corncobs contain carbon compounds such as cellulose, hemicellulose, and lignin. The content of these compounds is quite high, indicating that corncobs have potential as ingredients for producing active carbon [26]. To absorb the dye Naphthol Yellow S, it is necessary to process banana peels and corncobs into bioadsorbents to produce a maximum reduction in dye concentration.

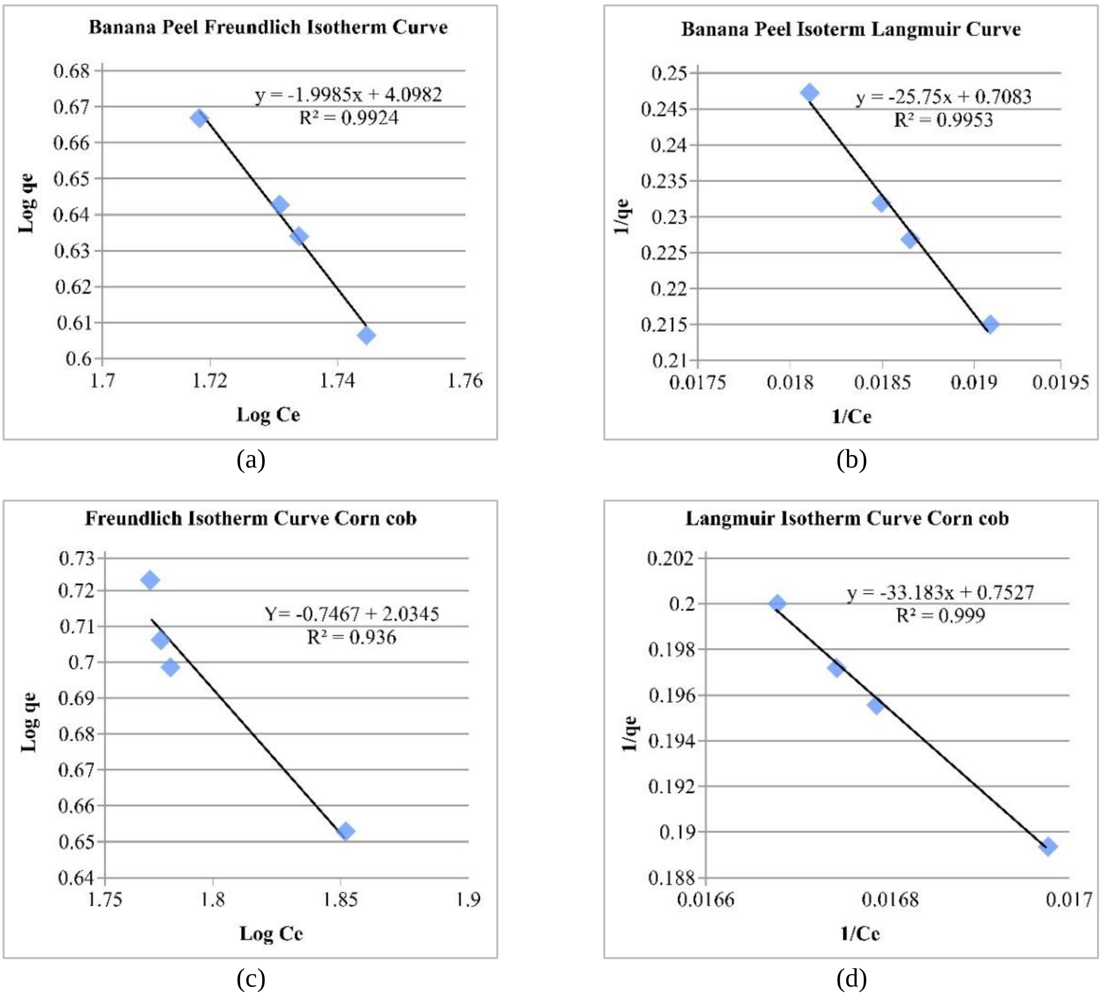


Figure 3. Adsorption isotherm curves of (a) banana peel Freundlich isotherm curve, (b) banana peel Langmuir isotherm curve, (c) Freundlich isotherm curve corncob, and (d) Langmuir isotherm curve corncob

The water content, ash content, and absorption capacity of the I2 solution are parameters that meet the quality requirements of activated carbon. The quality requirements for the water content, ash content, and absorption capacity of I2 solutions were a maximum of 15, 10%, and a minimum of 750 mg/g, respectively. This parameter is very important for determining the effectiveness of activated carbon in various applications such as water purification. Activated carbon that meets these quality standards provides optimal results for water treatment [27].

The results of measuring the water contents of the banana peel and corncob bioadsorbents were 4.67 and 6.12%, respectively. The activated carbon produced had low water content and did not exceed the maximum quality standard for activated carbon water content, which was set at a maximum of 15%. The determination of the water content of activated carbon aims to determine the hygroscopic properties of the activated carbon. This shows that the higher the oven temperature, the higher the water content, which remains constant if all the water evaporates. Measuring the water content of activated carbon is important to ensure the quality and effectiveness of the adsorption process. In addition, understanding the hygroscopic properties of activated carbon helps optimize the bioadsorbent production process [28].

Determination of the ash content aims to determine the oxide content of the activated carbon. The ash content can affect the absorption capacity of the activated carbon. The results of measuring the ash content of the banana-peel bioadsorbent were 3.14%, whereas that of the corncob bioadsorbent was 5.25%. The results of these measurements show that the banana peel and corncob bioadsorbents meet the requirements for ash content in activated carbon. This shows that the two bioadsorbents have a good potential for absorbing dangerous substances. As the ash content affects the effectiveness of activated carbon as an adsorbent, it is important to consider the results of these measurements when using bioadsorbents [29].

Determining the absorption capacity of an I2 solution is a general requirement for assessing the quality of activated carbon. The results of measuring the adsorption capacity of the I2 solution on the banana peel bioadsorbent was 850.29 mg/g, while the adsorption capacity of the I2 solution on the corncob bioadsorbent was 799.53 mg/g. Based on these results, the banana peel and corncob bioadsorbents met the requirements for the solution absorption capacity of the I2 solution. The higher the level of absorption of the I2 solution, the better the adsorption [30].

XRD analysis of banana peel and corncob bioadsorbents revealed the presence of potassium chloride and sodium eicosapentaenoic as the dominant minerals. The highest peak was observed at 2θ=28.280, while the other peaks were at 6.970 and 19.990, respectively. These results indicate the crystalline structure of the bioadsorbents and suggest their potential application in wastewater treatment owing to their mineral composition. The mineral composition of the bioadsorbent can be beneficial for an effective and efficient wastewater treatment process [31]. The discovery of the highest peak at 2θ=28.280° was also successful in identifying the dominant minerals in the bioadsorbent samples.

The SEM examination results were obtained at magnifications of 2500X and 5000X. SEM analysis of the banana peel bioadsorbent showed that after carbonization into charcoal, pores began to form. The activation of banana peel charcoal into activated carbon causes an increase in the number and diameter of pores. In addition, the use of H2SO4 increased the number of pores to become larger and opened small pores. This indicates that H2SO4 opens the pores in banana peel-activated carbon by oxidizing it, thereby increasing its absorption capacity [32].

Based on the results of SEM analysis on corncob bioadsorbent, it shows that pores are formed. The pores formed were not too tight, and the adsorption results were compared with those of the banana peel bioadsorbent, which was not significant in reducing Naphthol Yellow dye. The pores in the activated carbon were formed by the carbonization process at a temperature of 400 °C. Carbonization degrades material components to produce charcoal. In addition to carbonization, activation was performed using H2SO4 to produce activated carbon [33].

The results in Table 2 show that there was a difference in the concentration of Naphthol Yellow S dye before and after treatment, where the dye concentration after treatment was lower than that before treatment. Disposal of colored wastewater, such as that in the textile industry, damages the aesthetics of the water bodies receiving the waste. However, they can also threaten the sustainability of the environment and the life of organisms [34]. Colored waste can poison aquatic biota in the water [35]. In addition, concentrated dyes can block sunlight from penetrating water bodies, thereby affecting photosynthesis [36]. As a result, little oxygen is produced during photosynthesis, which disrupts aquatic biota.

The decrease in the concentration of Naphthol Yellow S dye after application of banana peel and corncob bioadsorbent using variations in adsorbent mass (0.1, 0.2, and 0.3 grams and stirring times (3, 6, 9, and 12 hours) produced value reductions and percentages, as shown in Table 2. Based on Table 2, the 24 treatments produced different reduction values. The best adsorbent mass and stirring time for banana peel bioadsorbent in reducing the concentration of Naphthol Yellow S dye is at an adsorbent mass of 0.3 grams with a stirring time of 3 hours, while the best adsorbent mass and stirring time for corncob bioadsorbent are at an adsorbent mass of 0.2 grams with a mixing time of 12 hours. This can occur because the adsorbent mass and optimal stirring time can maximize the interaction between the bioadsorbent and the dye to be adsorbed, resulting in a high reduction value [37]. Thus, choosing appropriate operational conditions is very important for achieving maximum efficiency in the bioadsorption process. An optimal does not always mean the longest or the most abundant, but rather the right combination of adsorbent mass and stirring time, so that the bioadsorption process can run efficiently [38].

The highest reduction value and percentage for the banana peel bioadsorbent were 27.91 mg/l and 34.88%, respectively, while those of the corncob bioadsorbent was 21.13 mg/l and 26.41%, respectively. The lowest reduction value for the banana peel bioadsorbent occurred at an adsorbent mass of 0.1 gram with a stirring time of 3 hours, whereas for the corncob bioadsorbent, it occurred at an adsorbent mass of 0.1 gram with a stirring time of 3 hours. This is because it is possible that, with time and the existing mass, it has reached the optimal point in the adsorption process, so there is no further increase in efficiency. This shows that increasing the adsorbent mass or stirring time did not provide better results in reducing the heavy metal levels in the solution.

The difference in the average decrease in the concentration of Naphthol Yellow S dye was influenced by various variations in the adsorbent mass 0.1, 0.2, and 0.3 grams and stirring times of 3, 6, 9, and 12 hours. To determine whether there was a difference in the average decrease in the concentration of Naphthol Yellow S dye for each variation in the adsorbent mass and stirring time, a two-way ANOVA test was performed.

Based on Table 3, the research results show that the type of banana peel adsorbent produces a P-value of 0.000<0.05, which means that there are differences in adsorbent mass, stirring time, adsorbent mass interaction, and stirring time on the adsorption kinetics of banana peel bioadsorbent in reducing Naphthol Yellow dye. S. Meanwhile, for the corncob adsorbent type with variations in adsorbent mass, the results obtained were P=0.000<0.05, which means that there were differences in the adsorbent mass variations. However, there was no significant difference in the stirring time and adsorbent mass interaction on the adsorption kinetics of the corncob bioadsorbent in reducing the Naphthol Yellow S dye. The results of this study showed that the banana peel adsorbent was more effective than the corncob adsorbent in the adsorption process. Banana peel has a more complex structure and higher porosity, so it is able to absorb Naphthol Yellow S dye more efficiently [39]. Bioabsorbents from banana peel are known to have a high active compound content [40]. Therefore, they provide better adsorption results than corncob bioadsorbents.

Changes in the adsorbate concentration due to the adsorption process, according to the adsorption mechanism, can be studied by determining the adsorption isotherm. The commonly used adsorption isotherms are the Freundlich and Langmuir isotherms. The Freundlich and Langmuir isotherm equations were transformed into straight-line equilibrium curves. The isotherm model depends on the value of the determinant coefficient (R) with the highest value.

In this study, the straight-line equation produced from banana peel bioadsorbent in the Langmuir equation was y=-25.75x-0.7083 with a value of R2=0.9953, and the Freundlich equation was y=-1.9985x+4.0982 with a value of R2=0.9924. The corncob bioadsorbent produced the Langmuir equation, which was y=-33.183x+0.7527 with a value of R2=0.999, and the Freundlich equation was y=-0.7467x+2.0345 with a value of R2=0.936. The correlation coefficient (R) in the Langmuir equation is higher than that in the Freundlich equation, which indicates that the Naphthol Yellow S adsorption process follows the Langmuir isothermal adsorption model. This isothermal adsorption model assumes that the adsorption that occurs is influenced more by chemical interactions, such that the adsorption of Naphthol Yellow S by activated carbon is formed because of the chemical bond between Naphthol Yellow S and the carboxylic group found on the surface of the active carbon. The Langmuir isotherm model assumes that adsorption occurs at specific sites on the adsorbent surface, leading to a monolayer coverage. This suggests a more localized and specific interaction between Naphthol Yellow S and activated carbon compared with the Freundlich model. Overall, the Langmuir isotherm model provides a more detailed understanding of the adsorption process by emphasizing the formation of a single layer of adsorbate molecules on the surface. This model is particularly useful for studying systems in which adsorption occurs at specific sites with limited interactions between the adsorbate and the adsorbent.

The adsorption capacity of bioadsorbents, specifically banana peel and corncob, for Naphthol Yellow dye, was evaluated through the linear relationship between 1/Ce and 1/qe, as outlined in the calculation of the adsorption capacity of banana peel and corncob bioadsorbent. The findings indicate that both materials adhered to the Langmuir isotherm model, which is indicative of monolayer adsorption on a surface with a finite number of identical sites. The calculated maximum adsorption capacities were 4.6516 mg/g for banana peel and 5.2825 mg/g for corncob. These results highlight the potential of agricultural waste materials as effective adsorbents for dye removal, contributing to sustainable waste management practices. Further studies could explore the regeneration of these bioadsorbents and their efficacy in real wastewater treatment scenarios.

Adsorption kinetics can be determined using various kinetic models. The adsorption kinetics of Naphthol Yellow S dye were obtained by plotting a linear curve of the adsorption kinetics model equation. Zero-order, first-order, and second-order kinetic models were used in this study. The optimum mass used to determine the kinetic model was g banana peel bioadsorbent with a mass of 0.3 grams and corncobs with a mass of 0.2 grams with stirring times of 3, 6, 9, and 12 hours. The research results showed that the second-order kinetic model provided results that best matched the experimental data. This shows that the adsorption process of the Naphthol Yellow S dye followed second-order kinetics. This study provides important information for the development of methods to remove dyes from industrial waste using natural bioadsorbents.

The faster the time required to reach equilibrium, the higher the adsorption reaction rate [41]. Adsorption equilibrium was obtained when increasing the contact time did not result in a significant increase in the number of adsorbed ions [42]. The results of the observations of the effect of stirring time on reducing dye concentration using banana peel and corncob bioadsorbent showed that the amount of Naphthol Yellow S dye adsorbed on the adsorbent increased with increasing stirring time until equilibrium was reached. This indicates that the adsorption process reached equilibrium at a certain point, and a further increase in stirring time did not lead to a significant increase in dye adsorption. The data suggest that the adsorption rate of Naphthol Yellow S dye onto the bioadsorbents was efficient and reached equilibrium relatively quickly.

A contact time that is too fast will cause the absorption of the adsorbent to not reach its maximum, whereas a contact time that exceeds the optimum contact time can cause the adsorbent attached to the adsorbate to be released again [43]. Therefore, it is important to control the contact time carefully to achieve the most efficient adsorption process. Finding a balance between contact times that are too fast and too slow is crucial for maximizing adsorption efficiency [44]. The contact time also influences the adsorption process because it takes time for the adsorbent to reach equilibrium to absorb pollutants [45]. Monitoring and adjusting the contact time is essential to ensure that the adsorption process is effective and efficient. By optimizing the contact time, the adsorbent can effectively remove pollutants from the solution, leading to cleaner water and air [46].

4. CONCLUSION

Banana peel and corncob bioadsorbents tested by XRD produced the highest peaks at 2θ angles of 28.280 and 6.970°, respectively, while the dominant minerals in the banana peel bioadsorbent were potassium chloride and the corncob bioadsorbent sodium eicosapentaenoic. The concentration of dye in the sample water before treatment was 80 mg/l and the application of banana peel and corncob bioadsorbent resulted in the lowest reduction occurring in the corncob bioadsorbent with a mass of 0.1 grams and a stirring time of 3 hours, resulting in a reduction value of 7.91 mg/l. There is a difference in the average decrease in the concentration of Naphthol Yellow S dye in the sample water before and after the application of the banana peel and corncob bioadsorbent with the highest percentage decrease in the concentration of the Naphthol Yellow S dye being in the banana peel bioadsorbent with a mass of 0.3 grams and a stirring time of 3 hours by 34.88%. The adsorption kinetics of banana peel and corncob bioadsorbents in reducing Naphthol Yellow S dye followed the Langmuir isotherm equation and second-order kinetic model with R2 values of 0.9737 and 0.9152, respectively.

ACKNOWLEDGEMENTS

We thank the Ministry of Health for funding this research (number LB). 10/03/2024.334. The researcher would also like to thank Poltekkes Kemenkes Surabaya for providing laboratory access for the smooth running of this research.

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