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Effectiveness of Metanil Yellow Adsorption Using CTAB-Modified Activated Carbon from Areca Nut Husk *(Areca catechu L.)*

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ABSTRACT

This study investigates the adsorption efficiency of Metanil Yellow using activated carbon derived from areca nut husk (*Areca catechu L.*), which was chemically activated with KOH and modified with CTAB surfactant. The adsorbent was characterized using FTIR and UV-Vis spectroscopy to identify functional groups and determine optimum adsorption parameters. FTIR analysis confirmed the presence of functional groups such as $–CH_2$, –C–N, and $–N^+(CH_3)_3$, indicating successful surface modification. UV-Vis analysis showed that the maximum adsorption occurred at a wavelength of 494 nm. The optimum conditions were achieved at an adsorbent mass of 1.5 g, dye concentration of 15 ppm, and contact time of 60 minutes, with adsorption efficiency reaching over 97%. These findings suggest that CTAB-modified areca nut husk activated carbon has strong potential as an effective and low-cost adsorbent for removing dyes from wastewater.

Keywords: Activated carbon, areca nut husk, CTAB, adsorption, KOH.

1. INTRODUCTION

Water pollution caused by textile industry wastewater containing synthetic dyes such as metanil yellow ($C_{18}H_{14}N_3NaO_3S$) has become a serious environmental issue. This dye is toxic, carcinogenic, and resistant to natural degradation, posing significant threats to aquatic ecosystems and human health [1]. Although primarily used as a textile dye, metanil yellow is often illegally used as a food colorant, despite being banned for such purposes under the Regulation of the Minister of Health No. 1168/Menkes/PER/X/1996 [2]. Therefore, there is an urgent need for effective and environmentally friendly wastewater treatment methods to mitigate its harmful impact.

Adsorption using activated carbon is one of the most promising methods for dye removal. Activated carbon possesses a high surface area and excellent porosity, allowing it to efficiently adsorb pollutants [3]. However, conventional activated carbon often shows limited adsorption capacity for anionic dyes like metanil yellow due to unfavorable surface charge characteristics. To address this limitation, surface modification of activated carbon using cationic surfactants such as Cetyl Trimethyl Ammonium Bromide (CTAB) has been shown to enhance adsorption performance through electrostatic interactions [4].

Areca nut husk (*Areca catechu L.*) is an abundant agricultural waste in Indonesia and has great potential as a raw material for activated carbon due to its high cellulose content (63.20%) [5]. Utilizing areca husk as an adsorbent not only addresses environmental pollution but also adds economic value to agricultural waste. Previous studies have shown that KOH-activated areca husk-based carbon has a surface area of 41.101 m²/g and is effective in adsorbing dyes [6]. However, studies on the modification of areca husk-based activated carbon with CTAB for the adsorption of metanil yellow remain limited.

Based on this background, this study aims to characterize areca husk-derived activated carbon, activated with KOH and modified with CTAB, using UV-VIS and FTIR analysis. The findings are expected to contribute to the development of effective, economical, and environmentally friendly adsorbents derived from agricultural waste for textile dye wastewater treatment.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

The main material used in this research was areca nut fiber (*Area catechu. L*) The chemicals used included potassium hydroxide (KOH), metanil yellow, distilled water, and filter paper. The equipment used in this study included laboratory glassware, furnace, analytical balance, 100 mesh sieve, oven, hot plate, aluminum foil, as well as FTIR (*Fourier Transform Infrared*) instruments and UV-VIS

2.2. Research Procedure.

2.2.1. Preparation of Area Nut Fiber

Areca nut husks were separated from the seeds and outer shells, washed with tap water followed by distilled water, cut into small pieces, and sun-dried for approximately 3 days. The dried samples were then ground and sieved through a 120-mesh screen.

2.2.2. Carboonization and Activation of Areca Nut Husk Activated Carbon

Activated carbon was prepared by carbonizing areca nut husks using a furnace at 300°C for approximately 45 minutes. The resulting carbon was then activated with 5 M KOH solution at a 1:4 (b/v) ratio, stirred using a magnetic stirrer at 200 rpm on a hotplate at 80°C for 4 hours, and soaked for 24 hours. After soaking, the mixture was filtered and repeatedly washed with distilled water until a neutral pH was achieved. The activated carbon was then dried in an oven at 150°C for 30 minutes [6].

2.2.3. Modification of Areca Nut Husk Activated Carbon with CTAB Surfactant

Modification of areca nut husk activated carbon with 1% CTAB surfactant was carried out by adding 5 grams of activated carbon into a beaker, followed by the addition of 100 mL of 1% CTAB solution. The mixture was left at room temperature for 24 hours. Afterward, it was filtered and the residue was separated, then dried in an oven at 75°C for 6 hours.

2.2.4. Adsorbent Characterization

Characterization using FTIR was conducted to identify the functional groups present in the carbon, activated carbon, and surfactant-modified activated carbon.

2.2.5. Preparation of Calibration Curve for Metanil Yellow Solution

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Standard solutions of Metanil Yellow with concentrations of 10, 15, 20, 25, and 30 ppm were prepared. The absorbance of each solution was measured using a UV-Vis spectrophotometer at a wavelength of 494 nm. The resulting data were then used to construct a calibration curve by plotting absorbance versus concentration.

2.2.6. Determination of the Optimum Mass of Areca Nut Husk Adsorbent

A total of 100 mL of Metanil Yellow solution at a concentration of 25 ppm was placed into a 250 mL Erlenmeyer flask. Then, CTAB-modified activated carbon (KA-CTAB) was added at varying masses of 1 g, 1.5 g, and 2 g at room temperature. The mixture was stirred using a magnetic stirrer at 100 rpm for 30 minutes. After stirring, the solution was filtered using Whatman filter paper, and the absorbance was measured using a UV-Vis spectrophotometer.

2.2.7. Determination of the Optimum Contact of Areca Nut Husk Adsorbent

Contact time is a crucial parameter in adsorption processes. Increasing contact time between the dye and adsorbent generally enhances adsorption. To determine the optimum contact time for Metanil Yellow removal, 100 mL of 25 ppm solution was added to a 250 mL Erlenmeyer flask containing the optimum mass of KA-CTAB. The mixture was agitated using a rotary shaker at 100 rpm for 30, 60, and 90 minutes. Samples were then filtered with Whatman filter paper, and the absorbance was measured using a UV-Vis spectrophotometer [1].

3. RESULTS AND DISCUSSION

3.1. FTIR Characterization Analysis

FTIR characterization of Areca husk activated carbon and surfactant-modified activated carbon (CTAB) using FTIR instrumentation produced spectra that show the relationship between transmittance (%) and wavenumber (cm^{-1}). Fourier Transform Infrared (FTIR) spectroscopy is a highly useful method for detecting and analyzing the molecular structure of a compound. In this process, the obtained infrared spectrum provides information about chemical bonds and molecular structures. Each functional group within a molecule has a characteristic absorption frequency, which can be used for both qualitative and quantitative identification of compounds [7].

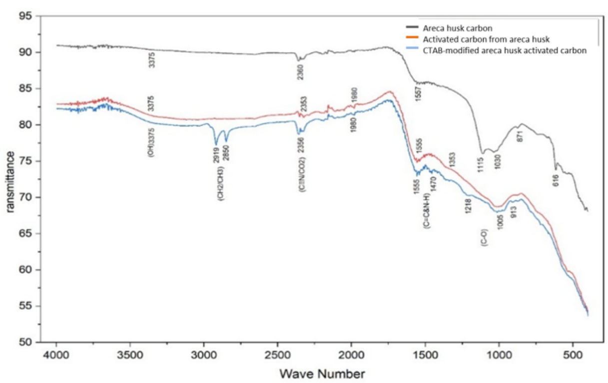

Figure 1. Comparison of FTIR Spectra

A broad absorption band observed around 3375 cm^{-1} corresponds to the stretching vibrations of hydroxyl groups (–OH), typically attributed to adsorbed water or phenolic compounds. The intensity of this band decreases after the activation and modification processes, indicating partial decomposition or reduction of hydroxyl functionalities due to thermal and chemical treatments. Similar findings were reported by (Sari et al., 2017), who noted that activation tends to eliminate certain hydrophilic surface groups on carbon. The absorption bands at 2919 cm^{-1} and 2850 cm^{-1}, more prominent in the CTAB-modified activated carbon, are associated with the asymmetric and symmetric stretching

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vibrations of aliphatic $–CH_2$ and $–CH_3$ groups. These peaks suggest the presence of methyl and methylene groups introduced by immobilized CTAB on the carbon surface. According to [9], the appearance of these bands confirms successful modification of carbon with a cationic surfactant.

A distinct peak near 2353 cm^{-1} corresponds to the stretching vibrations of nitrile (C≡N) or nitro (NO_2) groups, or possibly other carbonyl-containing compounds. The enhanced intensity of this peak following modification may indicate the formation of additional polar functionalities that improve the hydrophilic character of the carbon surface [10]. A sharp band at 1555 cm^{-1} is attributed to aromatic C=C or C=N stretching vibrations, while a band near 1470 cm^{-1} may indicate the presence of substituted amine groups such as N–H. The increased intensity of these bands after activation and modification suggests the formation of conjugated aromatic structures, which may facilitate electrostatic interactions with anionic dye molecules.

The absorption region between 1005–1218 cm^{-1} corresponds to C–O stretching vibrations, likely from ether or secondary alcohol groups. The more intense signal in the modified carbon suggests an increased presence of polar groups capable of forming hydrogen bonds with adsorbate molecules. As noted such groups play a significant role in the adsorption mechanism through hydrogen bonding interactions. Overall, chemical activation using KOH and surface modification with CTAB resulted in noticeable changes in the FTIR spectra of the areca husk-based activated carbon. The introduction of both aliphatic and polar functional groups contributes to enhanced adsorption capacity, especially for anionic dyes like Metanil Yellow. The incorporation of cationic groups through CTAB modification reinforces electrostatic interactions between the positively charged adsorbent and negatively charged adsorbate species (Sari et al., 2017).

CTAB-modified activated carbon shows promising potential as an adsorbent, particularly in the adsorption of nitrate ions. The modified activated carbon exhibits superior adsorption capacity compared to unmodified activated carbon. These findings indicate that both the activated carbon derived from areca husk and its surfactant-modified form using CTAB possess significant potential as adsorbents in the removal of metal ions and dyes from wastewater [2].

3.2. UV-Vis Characterization Analysis

UV-Vis analysis is used to determine the concentration of dye in solution before and after adsorption. This technique allows for the calculation of adsorption efficiency and capacity of the adsorbent toward the dye. In addition, UV-Vis is also used to determine the maximum wavelength (λmax) and to support the analysis of adsorption kinetics and isotherms [11].

Figure 2. Wavelength of *Metanil Yellow*

The determination of wavelength in this study was carried out within the range of 400–600 nm. The selection of this range was based on a which stated that the standard solution of Metanil Yellow is yellow in color and exhibits absorption in the visible light region. Based on the analysis conducted, the highest absorbance peak of the *metanil yellow* solution appeared at a wavelength of 494 nm**.** This indicates that 494 nm is the maximum wavelength (λmax) for *metanil yellow* under the conditions of this study (Anggriani et al., 2021).

3.2.1 Determination of the Optimum Mass of Areca Nut Fiber Adsorbent for the Adsorptivity of Metanil Yellow

Figure 3. Determination of the Optimum Mass of Areca Nut Fiber Adsorbent for the Adsorptivity of Metanil Yellow

It can be observed that increasing the adsorbent mass from 0.5 g to 1.5 g significantly increases the adsorption efficiency, from approximately 15% to over 97%. This is due to the greater number of active sites and the increased surface area available to bind dye molecules. According to [8], the greater the amount of adsorbent used, the more active groups are available, thereby enhancing the adsorption capacity. These results indicate that there is an optimum adsorbent mass, which is 1.5 g, that provides the highest adsorption efficiency for *metanil yellow*. Determining the optimum mass is important for process efficiency and cost-effectiveness in large-scale applications [13].

3.2.2 Determination of the Optimum Concentration of Areca Nut Fiber Adsorbent for the Adsorptivity of Metanil Yellow

Figure 4. Determination of the Optimum Concentration of Areca Nut Fiber Adsorbent for the Adsorptivity of Metanil Yellow

The variation of initial *metanil yellow* dye concentration on the adsorption efficiency by CTAB-modified areca nut fiber activated carbon is shown in the graph. It indicates that adsorption efficiency increases as the concentration rises from 5 ppm to 15 ppm, reaching a maximum efficiency close to 100%. However, at a concentration of 20 ppm, the efficiency slightly decreases. The increase in adsorption efficiency at initial concentrations between 5 and 15 ppm is due to the greater concentration gradient between the solution phase and the adsorbent surface. The higher the initial concentration, the more adsorbate molecules are available to interact with the active sites on the surface of the activated carbon. This condition promotes more intense contact between the dye molecules and the adsorbent surface, making the adsorption process more effective [14].

3.2.3 Determination of the Optimum Contact Time of Areca Nut Fiber Adsorbent for the Adsorptivity of Metanil Yellow

Figure 5. Determination of the Optimum Contact Time of Areca Nut Fiber Adsorbent for the Adsorptivity of Metanil Yellow

In this study, variations in contact time were carried out at 30, 60, and 90 minutes. Based on the graph, it can be seen that the adsorption efficiency increased from 89% at 30 minutes to 93% at 60 minutes. This increase is attributed to the improved diffusion of dye molecules over time, allowing more adsorbate molecules to interact with the active sites on the surface of the adsorbent. This finding is consistent with the study [15], which stated that longer contact time allows for the formation of more stable interactions between the adsorbate and the adsorbent, thereby enhancing the adsorption efficiency.

4. CONCLUSION

Activated carbon from areca husk (*Areca catechu L.*), activated with KOH and modified using CTAB surfactant, showed enhanced functional groups such as $–CH_2$, –C–N, and $–N^+(CH_3)_3$ based on FTIR analysis, confirming successful surface modification. The UV-Vis results determined the optimum conditions: 1.5 g adsorbent mass, 15 ppm concentration, and 60 minutes contact time. These modifications improve adsorption performance, indicating the potential of CTAB-modified activated carbon as an effective adsorbent. Further studies are recommended to explore its use in removing various pollutants, including heavy metals and dyes, from wastewater treatment systems.

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REFERENCES

e-ISSN : 2622-4968, p-ISSN : 2622-1349

1. Asnawati, D., Handayani, S. S., Kamali, S. R., Hamdiani, S., Sumarlan, I., Darmayanti, M. G., & Aulia, L. G. **(2020).** Adsorpsi Metanil Yellow menggunakan karbon aktif limbah cangkang buah kawista (*Limonia acidissima* L.). *Jurnal Pijar Mipa*, *15*(3), 247–251.
2. Batu, M. S., Naes, E., & Kolo, M. M**. (2022).** Pembuatan karbon aktif dari limbah sabut pinang asal Pulau Timor sebagai biosorben logam Ca dan Mg dalam air tanah. *Jurnal Integrasi Proses*, *11*(1), 21–25.
3. Fitriansyah, A., Amir, H., & Elvinawati, E. **(2021)**. Karakterisasi adsorben karbon aktif dari sabut pinang (*Areca catechu*) terhadap kapasitas adsorpsi zat warna Indigosol Blue 04-B. *Alotrop*, *5*(1), 42–54.
4. Permatasari, F., Pradana, Y. S., & Handayani, D. **(2020)**. Modifikasi karbon aktif ampas tebu dengan surfaktan CTAB untuk adsorpsi logam berat Pb(II). *Jurnal Kimia dan Pendidikan Kimia*, *5*(1), 45–52.
5. Putri, E. Z., & Yudhastuti, R. **(2023)**. Analysis of food contamination with Metanil Yellow in Banyuwangi. *Media Gizi Kesmas*, *12*(2), 988.
6. Sari, M. F. P., Loekitowati, P., & Mohadi, R. **(2017)**. Penggunaan karbon aktif dari ampas tebu sebagai adsorben zat warna Procion Merah limbah cair industri songket. *Journal of Natural Resources and Environmental Management*, *7*(1), 37–40.
7. Wibowo, A., Herlina, D., & Prasetya, D. **(2021)**. Adsorpsi logam berat menggunakan karbon aktif dari limbah pertanian: Tinjauan literatur. *Jurnal Teknik Lingkungan*, *27*(2), 123–132.
8. Darussalam, R., Etika, S. B., Kurniawati, D., & Suryani, O. **(2024)**. Pengaruh waktu kontak adsorpsi Metanil Yellow terhadap ekstrak flavonoid dari kulit kelengkeng (*Dimocarpus longan*). *Jurnal Pendidikan Tambusai*, *8*(2), 19609–19616.
9. Laksmita, S. **(2022)**. Identifikasi kandungan Metanil Yellow pada nasi kuning yang beredar di Kota Denpasar. *Afiasi: Jurnal Kesehatan Masyarakat*, *7*(3), 308–313.
10. Pargiman, G. N., Arneli, & Astuti, Y. **(2018)**. Adsorption of HDTMA-Br surfactant with concentration variation by rice husk-based activated carbon produced by variation. *Jurnal Kimia Sains dan Aplikasi*, *21*(4), 171–174.
11. Rosanti, A. D., Kusumawati, Y., Hidayat, F., Fadlan, A., Wardani, A. R., & Anggraeni, H. A. **(2022)**. Adsorption of methylene blue and methyl orange from aqueous solution using orange peel and CTAB-modified orange peel. *Journal of the Turkish Chemical Society Section A: Chemistry*, *9*(1), 237–246.
12. Nurfazilah, N., Hidayati, W., & Putri, A. Y. **(2019)**. Penentuan kadar Metanil Yellow secara spektrofotometri UV-Vis pada berbagai jenis makanan jajanan. *Jurnal Riset Kimia*, *9*(2), 102–108.
13. Peday, H. T. N., Sialana, J., Mini, M., & Nanlohy, H. Y. **(2025)**. Karakterisasi arang karbon hasil pirolisis limbah kulit pinang dengan dan tanpa etanol sebagai aktivator. *Jurnal Rekayasa Material, Manufaktur, dan Energi*, *8*(1), 1-7
14. Ramadhani, D., Utami, M. R., & Hilmi, I. L. **(2022)**. Identifikasi zat pewarna Metanil Yellow dalam mi basah yang beredar di Kabupaten Karawang. *Pharmacon: Jurnal Ilmiah Farmasi*, *11*(4), 1730–1737.
15. Rustiah, W., Muharram, A. F., Arisanti, D., & Alfian, A. **(2021)**. Identifikasi senyawa tanin pada ekstrak sabut buah pinang (*Areca catechu* L.). *Lontara Journal of Health Science and Technology*, *2*(1), 35–41.

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