Indonesian Journal of Chemical Science and Technology (IJCST)
State University of Medan, https://jurnal.unimed.ac.id/2012/index.php/aromatika

IJCST-UNIMED 2026, Vol. 09, No. 2, Page; 303 – 311
Received : Jan 12nd, 2026 Accepted : Jul 16th, 2026 Web Published : Jul 31st, 2026

Effectiveness of Corn Cob (*Zea mays* L.) Activated Carbon Modified with Cetyl Trimethyl Ammonium Bromide (CTAB) in the Adsorption of Metanil Yellow

Ramanda Fatwa*, Ratna Sari Dewi

Chemistry Depertment, Faculty pf Mathematics and Natural Science, Universitas Negeri Medan, 2021, Indonesia

**Email : ramandafatwa.4211210003@mhs.unimed.ac.id*

ABSTRACT

This study examines the potential of corn cob waste (Zea mays L.) as a raw material for activated carbon to remove Metanil Yellow dye from textile waste. Activated carbon was prepared through a carbonization process at 400°C followed by chemical activation using KOH to expand the pore structure. To optimize the affinity for anionic dyes, the carbon surface was modified with a cationic surfactant, Cetyl Trimethyl Ammonium Bromide (CTAB). FTIR characterization results showed successful modification, characterized by the appearance of C−N group vibrations at wavenumbers 1371 cm−1 and 1217 cm−1. The adsorption test was carried out at a maximum wavelength of 494 nm. The results showed that the adsorption efficiency increased significantly with increasing adsorbent mass and contact time, with the highest efficiency reaching 98-100% in the 90-120 minute time range. This proves that CTAB modification effectively increases the electrostatic interaction between the positively charged adsorbent surface and the negatively charged Metanil Yellow molecules..

Keywords: corn cob, activated carbon, CTAB, adsorption, Metanil Yellow

1. INTRODUCTION

The increasing activity of the textile industry contributes to increasing water pollution due to the discharge of liquid waste containing synthetic dyes. Azo dyes, such as Metanil Yellow, are non-biodegradable, chemically stable, and potentially toxic and carcinogenic to living organisms. Their presence in aquatic environments can inhibit light penetration, disrupt photosynthesis, and degrade ecosystem quality, necessitating effective and environmentally friendly waste treatment methods.

Adsorption is a widely used method due to its simple and efficient process. Activated carbon is known as a highly effective adsorbent, but its production costs are relatively high. Therefore, utilizing agricultural

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

waste as a raw material for activated carbon is a promising alternative. Corn cobs (Zea mays L.) have high cellulose and lignin content, making them potentially suitable for development as a low-cost adsorbent. Chemical activation using KOH can increase the surface area and porosity of the carbon, but the resulting activated carbon is still less than optimal for adsorbing anionic dyes.

Surface modification using cationic surfactant Cetyl Trimethyl Ammonium Bromide (CTAB) can increase the positive charge of the surface of activated carbon, thereby strengthening the electrostatic interaction with Metanil Yellow. Therefore, this study aims to examine the characteristics and performance of KOH-activated corn cob activated carbon modified with CTAB in adsorbing Metanil Yellow, as an effort to develop an alternative adsorbent that is economical and environmentally friendly for the treatment of textile industrial wastewater.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

The equipment used for this study included a 100-mesh sieve, a furnace, a porcelain crucible, a thermometer, an oven, glassware (Pyrex), a desiccator, a spatula, aluminum foil, a grinder, a magnetic hot plate stirrer, and a UV-Vis (Ultraviolet-Visible), FTIR (Fourier Transform Infra-Red) spectrophotometer. The materials used in this study were KOH (e-Merck), distilled water, Whatman No. 1 filter paper, corn cobs, and Metanil Yellow dye.

2.2. Research Procedure

2.2.1 Preparation and Carbonization of Corn Cobs with KOH Activation

Corn cobs were prepared by cutting them into small pieces, then washing them thoroughly with running tap water to remove any impurities adhering to them. They were then dried in the sun for three days until completely dry (Purnamawati et al., 2019). The dried corn cobs were then ground using a grinder and sieved using a 100-mesh sieve. Next, the corn cobs were carbonized in a furnace at 400°C for 15 minutes to produce charcoal. The resulting charcoal was then sieved through a 100-mesh sieve (Perdanie et al., 2024). To improve adsorption performance, the corn cob adsorbent needed to be activated. The process used in this study was chemical activation (Wakid et al., 2020). The resulting carbon was mixed with an activating agent, potassium hydroxide (KOH).This is done by soaking the corn cob adsorbent in a KOH solution for 24 hours. The next step is to filter the adsorbent, filtered carbon, to separate the sediment and filtrate. The filtrate is discarded, and the sediment can be washed with distilled water until its pH is neutral to remove any remaining KOH. The adsorbent is then dried in an oven at 110°C for 3 hours.

2.2.2 *Modification of Activated Carbon with CTAB (Cetyl Trimethyl Ammonium Bromide) Surfactant*

The adsorbent modification process using Cetyl Trimethyl Ammonium Bromide (CTAB) was carried out using the previous method. A total of 5 g of activated carbon was soaked in 100 mL of a 1% CTAB solution for 24 hours, then filtered. The resulting precipitate was then dried in an oven at 75 °C for 6 hours.

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

2.2.3 *Adsorbent Characterization*

Characterization was carried out using Fourier Transform Infrared (FTIR) to identify functional groups found in carbon, activated carbon, and activated carbon that had been modified with the surfactant Cetyl Trimethyl Ammonium Bromide (CTAB).

2.2.4 *Determination of Maximum Wavelengh of Metanil Yellow*

Wavelength determination was carried out to determine the absorption area expressed as an absorbance value. Analysis was carried out using a UV–Visible (UV-Vis) spectrophotometer at a wavelength range of 400–500 nm to obtain the maximum wavelength of Metanil Yellow, using a Metanil Yellow solution with a concentration of 30 ppm.

2.2.5 *Determination of Optimum Mass of the Adsorption Power of Metanil Yellow*

The optimum mass determination was carried out on CTAB-modified activated carbon (KA-CTAB). Each adsorbent was added to 100 mL of 25 ppm Metanil Yellow solution with mass variations of 0.5 g; 1 g; 1.5 g; and 2 g. The mixture was then stirred at 100 rpm at room temperature for 30 minutes. After the adsorption process, the mixture was separated and the filtrate was analyzed using a UV-Vis spectrophotometer at a predetermined maximum wavelength to calculate the adsorption capacity.

2.2.6 *Determination of Optimum Concentration of Metanil Yellow Dye Solution Absorption Capacity*

Determination of optimal concentration in KA-CTAB. 100 ml of 10, 15, 20, and 25 ppm of metanil yellow solution was put into a 250 mL beaker. The optimal mass of activated carbon and KA-CTAB modification was then put into the beaker at each concentration. Next, it was stirred at a speed of 100 rpm at room temperature for 30 minutes. After that, the mixture was separated and the filtrate was analyzed using Ultraviolet-Visible (U V-Vis) at the maximum wavelength that had been obtained to determine its adsorption capacity.

2.2.7 *Determination of Optimum Contact Time for the Absorption Power of Metanil Yellow Dye Solution*

The determination of the optimum contact time was carried out on KA-CTAB adsorbents. A total of 100 mL of Metanil Yellow solution with the optimum concentration was mixed with activated carbon and KA-CTAB at the optimum mass, then stirred at a speed of 100 rpm at room temperature with contact time variations of 30, 60, 90, and 120 minutes. After the adsorption process, the mixture was separated and the filtrate was analyzed using a UV–Vis spectrophotometer at a predetermined maximum wavelength to calculate the adsorption capacity.

3. RESULTS AND DISCUSSION

3.1. Preparation and Carbonization of Corn Cobs with Potassium Hydroxide (KOH) Activation

In this study, corn cobs were used as the raw material for the adsorbent. The process began with the collection of corn cob waste, which was then washed with running water to remove dirt. Then, it was dried in

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

the sun for 7 days (7 x 12 hours) until the water content was reduced to approximately 10%. The dried corn cobs were then cut into 2–3 cm pieces to facilitate the grinding process, then sieved using a 100-mesh sieve to obtain fine, uniform particles. The smaller particle size allows for a more even and optimal carbonization process. The activated carbon was then neutralized by repeatedly washing with water until the pH was near neutral. The neutralization stage aims to remove any remaining substances or contaminants adsorbed on the surface of the activated carbon after the activation process. The neutralized activated carbon was then dried in an oven at 105 °C for 2 hours before use (Verma et al., 2023).

3.2. Modification of Activated Carbon with CTAB (Cetyl Trimethyl Ammonium Bromide) surfactant

After the activation process, the activated carbon was further modified using Cetyl Trimethyl Ammonium Bromide (CTAB) surfactant to increase its adsorption capacity towards Metanil Yellow dye waste. A total of 5 g of bagasse activated carbon was contacted with 100 mL of 1% CTAB solution for 24 hours at low pressure, then filtered using filter paper. Modification with CTAB is effective for adsorbing anionic dyes due to the presence of quaternary ammonium groups containing partially positively charged nitrogen atoms, thus providing cationic properties on the surface of the activated carbon and strengthening the electrostatic interaction with the anionic dye molecules.

3.3. Adsorbent Characterization

Characterization using Fourier Transform Infrared (FTIR) spectroscopy was carried out to identify functional groups present on the surface of activated carbon before and after modification with Cetyl Trimethyl Ammonium Bromide (CTAB). Figure 1 displays the FTIR spectrum used to observe the presence of functional groups on KOH-activated activated carbon from sugarcane bagasse and activated carbon that has been modified with CTAB surfactant.

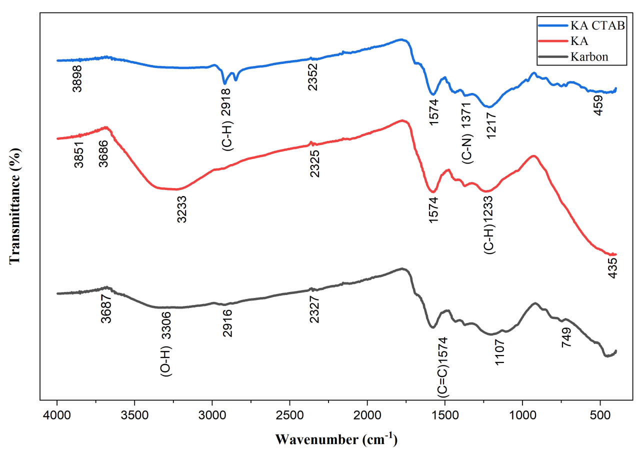

Figure 1. FTIR results of carbon, KA, KA

Based on the FTIR spectrum results of corn cob carbon, KOH activated carbon (KA), and CTAB surfactant modified activated carbon (KA-CTAB) showed changes in functional groups indicating the success of the activation process and modification of the adsorbent surface. In the initial carbon, the broad absorption band at wave numbers around 3306–3687 cm^{-1} is related to the –OH stretching vibration of the

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

hydroxyl groups of cellulose, hemicellulose, and lignin. The presence of a band at 2916 cm^{-1} indicates aliphatic C–H stretching, while the band at 1574 cm^{-1} is related to aromatic C=C vibration, indicating the formation of aromatic carbon structures resulting from biomass carbonization. The absorption band at 1107 cm^{-1} is attributed to the C–O vibration of the alcohol and ether groups, and the band at 749 cm^{-1} indicates aromatic C–H bending.

After activation using KOH, the spectrum of activated carbon (AC) shows changes in intensity and shifts in several absorption bands. The broad band at ~3233 cm^{-1} remains present and indicates the presence of surface –OH groups, but with a sharper intensity due to the formation of pores and the opening of active groups during activation. KOH activation is known to develop porosity through a reduction-oxidation reaction between KOH and carbon that produces CO and CO_2 gases, thereby increasing the surface area and the number of active adsorption sites. The appearance of a band at ~2325 cm^{-1} indicates the vibration of O=C=O or adsorbed CO_2, while the band at 1574 cm^{-1} still indicates the presence of the aromatic structure of carbon. The band at ~1233 cm^{-1} is related to the C–H or C–O vibration, indicating chemical modification of the carbon surface due to base activation.

The spectrum of CTAB-modified activated carbon (KA-CTAB) exhibits new characteristics confirming the success of the surfactant modification process. The band at 2918 cm^{-1} indicates the aliphatic C–H stretching of the long alkyl chain of CTAB, while the bands at 1371 cm^{-1} and 1217 cm^{-1} are attributed to the C–N vibration of the quaternary ammonium group of CTAB. The presence of the band at ~1574 cm^{-1} still indicates the aromatic framework of carbon, while the emergence of new bands and the increase in the intensity of the C–N band indicate the binding of CTAB molecules to the surface of activated carbon. Theoretically, the positively charged ammonium groups in CTAB increase the positive charge of the adsorbent surface, thereby strengthening the electrostatic interaction with anionic dyes such as Metanil Yellow. Therefore, CTAB modification not only changes the chemical characteristics of the carbon surface but also plays a significant role in improving the adsorption capacity and efficiency.

3.4. Determination of Maximum Wavelength of Metanil Yellow

Based on Figure 3, the results of the analysis using a UV–Vis spectrophotometer, the Metanil Yellow solution shows a maximum absorption value at a wavelength of 494 nm.

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

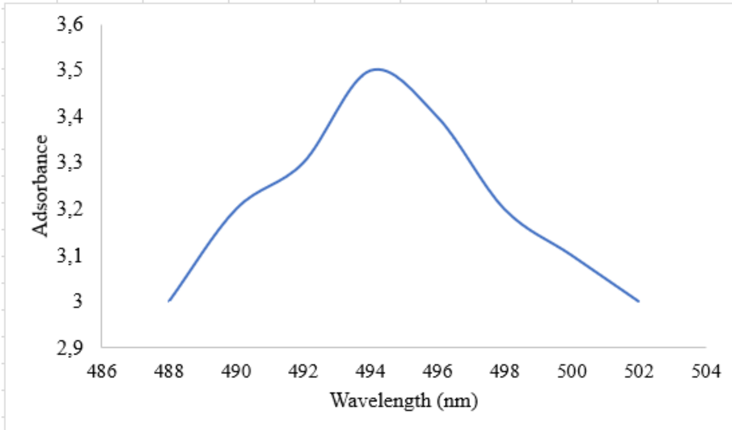

Figure 2. Maximum Wavelength of Metanil

This wavelength was chosen because it is in the region of maximum absorption of dye molecules, so it is used as a reference in determining concentration. The use of the maximum wavelength aims to obtain accurate data in accordance with the Lambert–Beer law, which states that the absorbance value is directly proportional to the concentration of the solution. The λmax value of 494 nm obtained in this study is relatively in line with previously reported results, which stated that Metanil Yellow has a maximum wavelength of 484 nm. This small difference is still within the tolerance limit and can be influenced by the solution conditions, concentration, and type of solvent used in each study. Therefore, the wavelength of 494 nm is considered appropriate to be used as λmax in this study.

3.5. Determination of Optimum Mass, Concentration, and Time on Adsorption of Metanil Yellow

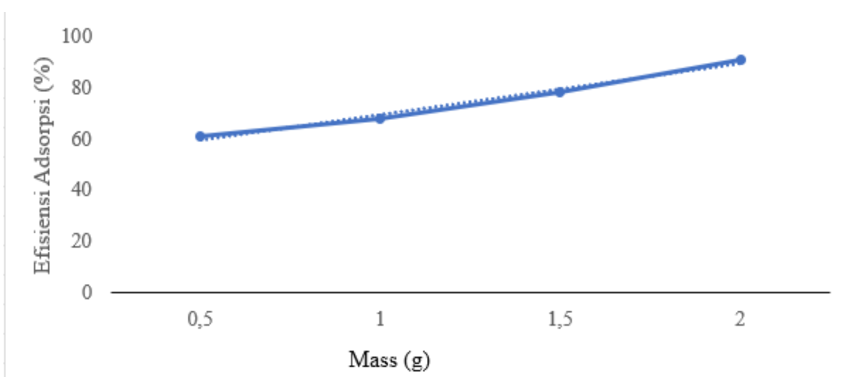

Figure 3. Optimum Mass of metanil Yellow Adsorption

Based on the information presented in the graph, the adsorption efficiency increases with increasing mass of activated carbon from CTAB-modified corn cobs. When the adsorbent mass is increased from 0.5 grams to 2.0 grams, the adsorption efficiency measured by a UV-Vis spectrophotometer increases from approximately 65% to nearly 90%. This trend indicates that the greater the mass of adsorbent used, the more active sites on the surface of the activated carbon are available to interact and bind pollutant molecules in

© 2026 State University of Medan

solution, resulting in a greater amount of adsorbed substances. In general, increasing the mass of the adsorbent tends to increase the adsorption capacity because the available specific surface area is also larger.

In this context, modification with CTAB (cetyltrimethylammonium bromide) surfactant plays a role in increasing the affinity of the activated carbon surface to solutes. CTAB is a cationic surfactant that can change the surface character of activated carbon to be more electropositive and increase electrostatic interactions with charged or polar adsorbates, thus supporting a more efficient adsorption process. This result is consistent with the basic principle of adsorption that increasing the mass of the adsorbent will increase the number of adsorption points and adsorption capacity to a certain extent, as explained in the scientific literature on adsorption behavior on activated carbon.

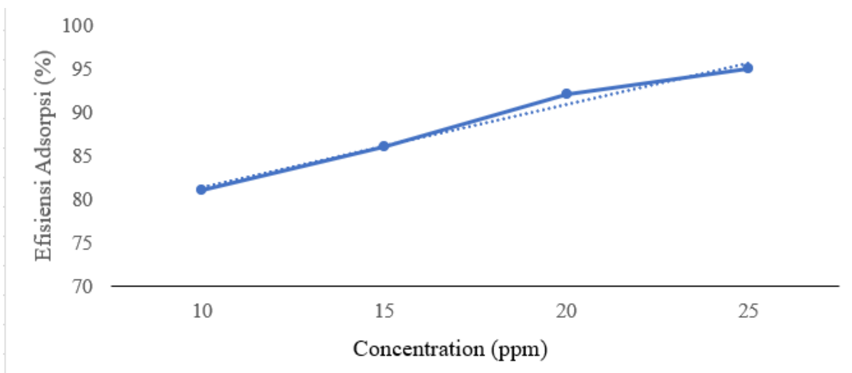

Figure 4. Optimum Concentration of Metanil Yellow Adsorption

Based on the graph shown, the adsorption efficiency increases gradually with increasing concentration of CTAB-modified activated carbon in the test solution. When the adsorbent concentration is increased from 10 ppm to 25 ppm, the adsorption efficiency increases from approximately 82% to nearly 95%. This pattern indicates that the greater the amount of adsorbent available in the solution, the more pollutant molecules can be adsorbed from the liquid phase to the surface of the activated carbon. This is in accordance with the basic theory of adsorption which states that increasing the adsorbent concentration generally provides more surface active sites so that the interaction between the adsorbent and adsorbate becomes more effective and the overall adsorption efficiency increases.

This phenomenon also indicates that surface modification with CTAB (cetyltrimethylammonium bromide) contributes to the increase in adsorption capacity. CTAB as a cationic surfactant can increase the surface charge of activated carbon, thereby strengthening the electrostatic interaction with target molecules in solution. With a modified surface, the adsorbent is able to attract and retain more pollutant molecules at higher concentration intensities, consistent with the principle that surface modification can increase the affinity of the adsorbent for certain adsorbates. This observation is supported by the results of UV-Vis measurements, where the absorbance of the solution decreases with increasing adsorbent concentration, indicating a decrease in the concentration of adsorbate in the solution as a result of the adsorption process.

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

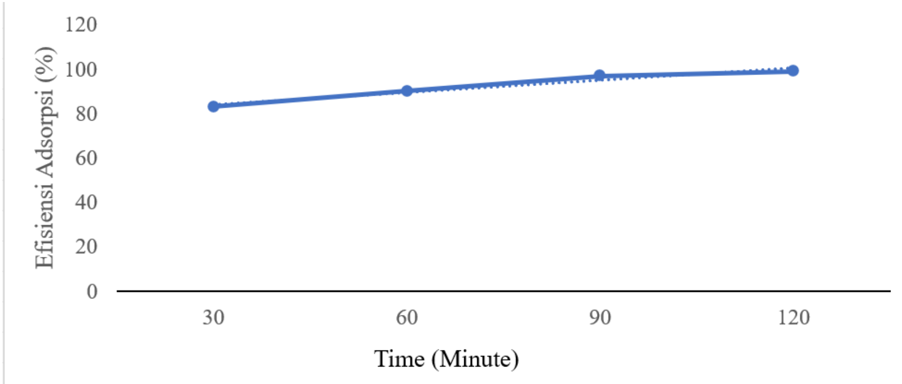

Figure 5. Optimum Time of Metnail Yellow Adsorption

Based on the graph, it can be seen that the adsorption efficiency increases with increasing contact time between the adsorbate solution and CTAB-modified activated carbon. At 30 minutes, the adsorption efficiency is in the range of ±82%, then increases to around 90% at 60 minutes and continues to rise to reach ±98–100% at 90–120 minutes. This increase indicates that the longer the contact time, the more adsorbate molecules move from the solution phase to the surface of the activated carbon, so that the amount of adsorbed substance increases significantly.

At 90–120 minutes, the increase in efficiency began to plateau and approached a maximum, indicating that the system had approached adsorption equilibrium. At this stage, most of the active sites on the activated carbon had been occupied by adsorbate, resulting in a slowdown in the adsorption rate. CTAB modification plays a crucial role because this cationic surfactant increases the affinity of the activated carbon surface for adsorbate molecules, accelerating the formation of electrostatic bonds and accelerating the attainment of equilibrium. Thus, the optimum adsorption time in this system is around 90–120 minutes, when the efficiency has reached nearly its maximum value.

4. CONCLUSION

This study concludes that activated carbon from corncobs modified with CTAB surfactant is a highly effective adsorbent to overcome Metanil Yellow dye contamination. The KOH activation process successfully opened the pore structure, while the addition of CTAB provided an electropositive charge on the carbon surface so that it was able to bind dye molecules optimally through electrostatic interactions. Experimental data showed that the adsorption performance was strongly influenced by the mass and contact duration variables, where the system reached a maximum efficiency of up to 100% at a contact time of 120 minutes. Overall, the utilization of this agricultural waste offers an economical and environmentally friendly textile waste treatment solution with a very high absorption capacity.

ACKNOWLEDGEMENT

The author expresses sincere gratitude to Dr. Ratna Sari Dewi, M.Si., for her guidance as supervisor. Appreciation is also extended to the laboratory staff at Medan State University, the University of North Sumatra, and the Health Laboratory for their technical support throughout this research.

e-ISSN : 2622-4968, p-ISSN : 2622-1349
© 2026 State University of Medan

REFERENCES

1. Ahmad, A., & Danish, M. (2022). Prospect of corn cob as a sustainable precursor for activated carbon production: A review on preparation and adsorption performance. *Journal of Cleaner Production*, 330, 129754.
2. Al-Musawi, T. J., & Balarak, D. (2024). Application of agricultural waste-derived activated carbon modified with CTAB for the removal of acid and azo dyes: Isotherm and kinetic studies. *International Journal of Environmental Analytical Chemistry*, 104(3), 412-428.
3. Fadhil, A. B., & Ahmed, K. M. (2023). Enhancement of anionic dye adsorption using surfactant-modified activated carbon derived from agricultural residues. *Environmental Science and Pollution Research*, 30(5), 12344-12358.
4. Kusrini, E., & Wijaya, C. J. (2022). Surface modification of agricultural waste-based activated carbon with CTAB for enhanced removal of acid dyes from aqueous solutions. *Journal of Water Process Engineering*, 46, 102589.
5. Li, H., & Zhang, Y. (2023). *Effects of surfactant modification on activated carbon adsorption performance***.** Journal of Colloid and Interface Science, 612, 74–89
6. Luo, X., & Liu, Y. (2023). Comparative study on the adsorption of Metanil Yellow by different chemically activated biomass: Kinetics and equilibrium. *Water, Air, & Soil Pollution*, 234(2), 87.
7. Nasir, A. M., & Yusof, N. (2024). Utilization of KOH-activated carbon from maize cobs for textile wastewater treatment: Performance and mechanism. *Journal of Environmental Chemical Engineering*, 12(1), 111520.
8. Niazi, A., & Yazdanipour, A. (2023). Surface modification of activated carbon prepared from Zea mays L. with cationic surfactants for enhanced removal of Metanil Yellow from aqueous solutions. *Journal of Dispersion Science and Technology*, 44(6), 1015-1027.
9. Pratiwi, R., & Rahayu, S. S. (2025). Analisis gugus fungsi FTIR dan mekanisme interaksi elektrostatik pada adsorben karbon aktif tongkol jagung termodifikasi CTAB. *Jurnal Kimia Sains dan Aplikasi*, 28(1), 55-64.
10. Putra, R. K., & Sari, D. P. (2023). Optimasi massa dan waktu kontak pada adsorpsi zat warna azo menggunakan karbon aktif termodifikasi surfaktan kationik. *Jurnal Teknologi Kimia dan Industri*, 12(2), 145-155.
11. Ramdhan, P., Pambudi, T., & Hakim, M. F. (2025). *Adsorpsi ion NO_2^- menggunakan activated carbon dan activated carbon termodifikasi cetyltrimethylammonium bromide (CTAB)*. Teknika**,** 12(1), 45–53.
12. Saleh, T. A., & Al-Hammadi, S. A. (2024). Functionalized activated carbon for the removal of toxic dyes: A review of surface chemistry and adsorption mechanisms. *Trends in Environmental Analytical Chemistry*, 41, e00223.
13. Tran, H. N., et al. (2023). *Adsorption kinetics and mechanisms of contaminants on biochar and activated carbon*. Journal of Environmental Chemical Engineering, 11, 109050.
14. Verma, M., Singh, A. K., & Kumar, S. (2023). Preparation and characterization of corn cob activated carbon: Effect of carbonization temperature and activation agent. *Biomass Conversion and Biorefinery*, 13(8), 6789-6802.
15. Zhang, Y., & Wang, L. (2022). Efficiency of CTAB-modified biochar in the removal of anionic dyes: Electrostatic interaction and surface properties. *Chemosphere*, 291, 132981.

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

© 2026 State University of Medan