Alotrop (Jurnal Pendidikan dan Ilmu Kimia), Vol.7, No.2, (2023), (92-99)
Program Studi Pendidikan Kimia-Universitas Bengkulu
https://ejournal.unib.ac.id/alotropjurnal/
DOI: 10.33369/alo.v7i2.30804

Alotrop

Jurnal Pendidikan dan Ilmu Kimia

p-ISSN 2252-8075 e-ISSN 2615-2819

THE EFFECT OF CONTACT TIME AND BIOSORBENT TEMPERATURE ON THE ADSORPTION OF *INDIGO CARMINE* DYES IN KAPOK HUSK BIOSORBENT MODIFIED WITH SNAIL MEAT AND KINETIC STUDY

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ABSTRACT

The use of indigo carmine dye in the textile industry is a source of pollution for the environment. The presence of dye pollutants in the environment can threaten the health of living creatures and the sustainability of the ecosystem. This research uses kapok husk biosorbent modified with snail meat. Previously, research on adsorption was carried out on metals and cationic dyes from kapok husk, then in this research adsorption was carried out using the batch method to adsorb anionic dyes. The biosorbent modification process using snail meat aims to add active sites in the form of functional groups to the biosorbent to optimize the dye adsorption capacity. The contact objective of this research is to determine the heating time and temperature conditions for optimal adsorption of indigo carmine using the batch method. The research results showed that the adsorption capacity was at optimum conditions for the adsorption of indigo carmine at a contact time of 60 minutes and a temperature of 25°C.

Keywords: *indigo carmine; batch method; kinetic; kapok husk.*

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INTRODUCTION

With the rapid growth of industry, the consumption of dyes has also increased exponentially in textiles, leather, printed paper, pharmaceuticals, cosmetics and many other sectors. The wastewater released from these industrial experiments contains a variety of untreated dyes that are harmful to human life and aquatic organisms. Dye wastewater treatment is difficult because dyes usually have complex molecular structures, which makes them more stable and difficult to degrade [1].

Indigo carmine dye is complex and stable against the degradation process. A variety of different processes have been used to treat wastewater containing these dyes, such as adsorption [2], coagulation [3], flocculation [4], photochemistry treatments [5], and ultrafiltration [6]. Among these methods, adsorption is preferred because of efficient and simple. However, existing technology is sometimes inefficient and expensive. The biosorption method is an efficient and superior approach. Biosorption is an environmentally friendly method for dealing with environmental pollution, which involves the use of biological materials such as biomass from agricultural and fisheries waste [7].

The use of biomass waste is very popular in various applications, such as corrosion inhibitors [8], engineering addictives [9] and adsorption [10]. Utilization of biomass waste has potential as a biosorbent for cationic and anionic dyes thanks to its active functional groups. Apart from cleaning contaminants, the use of these biological materials helps manage solid organic waste in the environment. This not only saves the environment from dye contaminants, but also reduces the buildup of unused biomass waste, improving overall environmental cleanliness [11].

Kapok (*Ceiba pentandra L*) is a plant that is often found in Indonesia. The community uses kapok plant fibers to fill mattresses, pillows and dolls. The part of the fiber that is used produces waste in the form of kapok skin which is often left to pile up in the environment or sometimes burned for disposal. Kapok bark contains high amounts of cellulose, hemicellulose and lignin making it suitable for use as a biosorbent. The chemical components in kapok skin contain active groups such as hydroxyl, carbonyl and carboxyl which play a role in adsorbing dye pollutants [12].

In Indonesia, faunal diversity involves a variety of animals, with significant exploration potential. One animal that is often considered a crop pest is the snail (*Achatina Fulica*), which can be detrimental to farmers. Interestingly, snail meat, whose potential has not yet been fully explored, is a rich source of animal protein. The protein content in snail flour reaches 61.60% [13], making it attractive in efforts to increase the adsorption capacity of kapok skin. In this context, snail meat is used as a modifier because it contains many amino groups which play a role in increasing the ability to adsorb anionic dyes such as indigo carmine. Thus, this research opens up the potential for using snails as a source of high protein and strengthening the adsorption capacity of certain materials, which may have positive implications in agriculture and waste processing. Further research on snails and their potential applications in agricultural environments and waste management becomes relevant.

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METHOD

Tools and Materials

The material used in this research was kapok bark obtained from the Ombilin Singkarak kapok plantation in Kab. Solok, West Sumatra, indigo carmine dye (Merck), distilled water, p.a. HNO3 (65% Merck), KCl (Merck), 96% ethanol, filter paper (all chemicals used are analytical grade), and UV-Vis spectrophotometer (Genesys 1280 Serial No A120657).

Sample Preparation

Kapok skin was cleaned from attached kapok fibers, dried in air at room temperature, then finely chopped and ground into fine powder using a grinder, and sieved with a 400 mesh sieve until a uniform size is obtained. In this process, kapok bark powder was soaked in HNO_3 solution. Then several washing steps were carried out with distilled water to remove remaining acids and impurities until the pH becomes neutral. Once washing was complete, the mixture was filtered to separate the solids from the liquid. Then the filtered kapok bark powder was allowed to dry naturally with the help of air circulation [14].

Biosorbent Modification

The snail meat is separated from the shell, finely chopped, then dried to remove the water content in the snail meat. The snail meat is then ground into a fine powder and sieved. A total of 9 g of kapok skin powder was mixed with 9 g of snail meat powder, then 75 mL of 96% ethanol was added. The mixture was sonicated for 15 minutes, followed by filtration. The biosorbent is then dried for 24 hours [15].

Adsorption Studies

The adsorption studies were carried out using batch method. The adsorption process in this study was studied at parameters of contact time (5-120 minutes), and adsorbent heating temperature (25-200 °C). The adsorption studies applied at initial dye concentration of 1800 mg/L, 10 ml of indigo carmine solution was added in Erlenmeyer flask, adjusted to pH 2 by adding acid and base as well as buffer. 0.1 g of biosorbent was added, stirred at a speed of 150 rpm, then filtered. The mixture was filtered, then the filtrate was measured using UV-Vis spectrophotometer (Genesys 1280 Serial No A120657) at wavelength (λ_{max}) of 609 nm. The removal rate of the dye from the solution is calculated by the following equation.

$$(\%R) = \frac{(C_0\text{-}C_e)}{C_0} \times 100\% \qquad (1)$$

The amount of dye adsorbed q (mg/g) by the adsorbent at equilibrium is calculated by following Equation (2):

$$q = \frac{(C_0\text{-}C_e)}{m} \times V \qquad (2)$$

Where, C_0 and Ce (mg/L) are the initial and equilibrium concentration of dye in the solution. V is the total volume of solution (L). m is the amount of adsorbent dose (g) [16].

RESULTS AND DISCUSSION

Effect of Contact Time

Contact time was one of the factors that influence the adsorption process. Contact time was an important parameter for determining the minimum time required to achieve maximum

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adsorption capacity [17]. The adsorption studies was carried out using batch method.

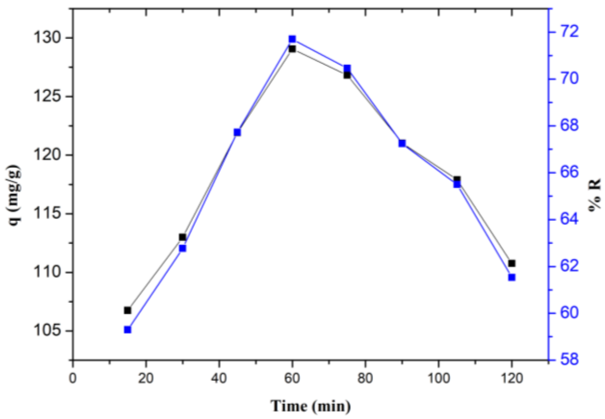

Figure 1. The effect of contact time on the adsorption capacity of indigo carmine dye.

In (Figure 1) showed an increase in the adsorption capacity with an increase in contact time. The adsorption process carried out under pH 2, biosorbent mass 0.1 g, initial concentration of 1800 mg.L^{-1}, volume solution 10 mL, and stirring speed 150 rpm. The maximum adsorption capacity was 129.3421 mg.g^{-1} and contact time of 60 minutes. The graph indicates as the contact time increases, the adsorption capacity tends to rise. This was because there were still available free active sites on the adsorbent surface to initially bind with the indigo carmine [18]. However, after reaching the optimal contact time, the adsorption capacity decreases due to saturation and limited active surface sites [19].

Based on the explanation above, the adsorption process occurs in the initial stages, and the desorption of the adsorbate into the solution happens as the contact time increases. The decrease in adsorption capacity was due to the saturation of active surface sites on the adsorbent. Once the active surface sites are saturated, no more adsorbate can be adsorbed by the adsorbent even with extended contact time. Furthermore, prolonged contact time can result in the release of the bound dye molecules back into the solution [20].

Effect of Biosorbent Temperature

The influence of heating temperature was studied to determine the relationship between the weight loss of the biosorbent and the adsorption capacity for indigo carmine. Heating the biosorbent at a specific temperature affects the adsorption capacity of the adsorption process. The purpose of heating the biosorbent was to assess it resistance to temperature [21].

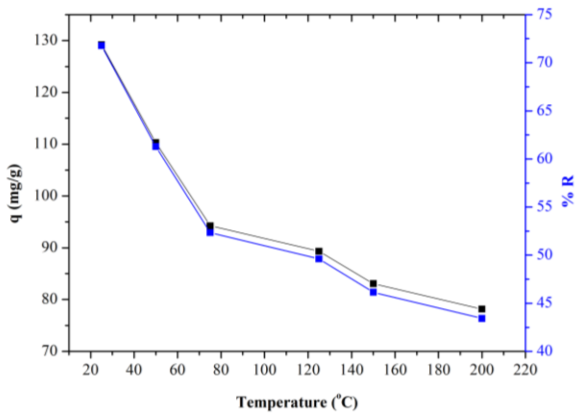

Figure 2. The effect of biosorbent heating temperature on the adsorption capacity of indigo carmine dye.

The adsorption process carried out under pH 2, biosorbent mass 0.1 g, initial concentration of 1800 mg.L^{-1}, volume solution 10 mL, 60 minutes of contact time, and stirring speed 150 rpm. Based on Figure 2, the optimal adsorption temperature for indigo carmine was observed at 25°C, with an adsorption capacity 129.3421 mg.g^{-1}. According to the information from

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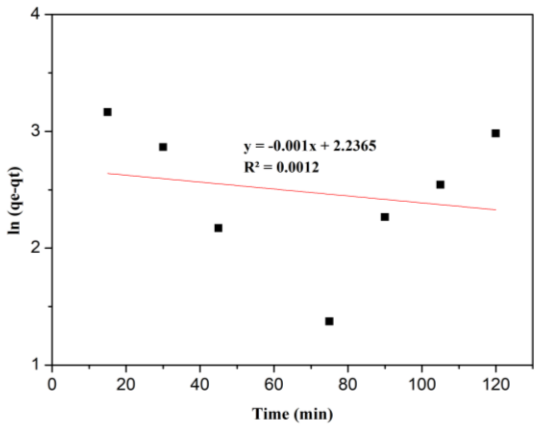
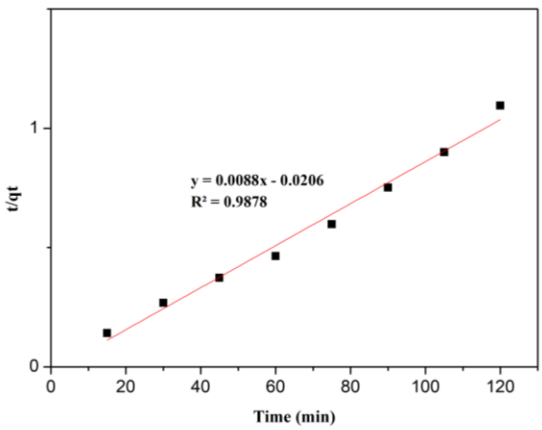
Figure 2, there was a decrease in the adsorption capacity of indigo carmine dye as the heating temperature of the biosorbent increases. This phenomenon was due to the continuous rise in the heating temperature leading to the denaturation of the biosorbent caused by the breakdown of organic compounds present in the biosorbent, resulting in a reduction in the active sites of the biosorbent. As a result, the adsorption capacity decreases [22].

Kinetic Study

The data on the influence of contact time on the adsorption capacity were used to determine the adsorption kinetic models. Adsorption kinetic studies were conducted to predict the rate and mechanism of the adsorbate reaction in the solution towards the adsorbent. The kinetic models used in this study are the pseudo-first-order and pseudo-second-order kinetic models. The kinetic model representing the adsorption process is chosen based on the R^2 value that approaches one [23].



(a)



(b)

Figure 3. Kinetics model of indigo carmine sorption (a) first order pseudo kinetics model (b) second order pseudo kinetics model

In (Figure 3) depict the pseudo-first-order and pseudo-second-order kinetic models. The R^2 value for the pseudo-second-order kinetic model was higher than the pseudo-first-order kinetic model. Based on this, it can be concluded that the adsorption process of indigo carmine dye follows the pseudo-second-order kinetics. This indicated the adsorption of indigo carmine dye involves chemisorption, where the concentration of the adsorbate determines the reaction rate [24]. A similar behavior was also reported in the adsorption of IC using oil palm fibers [25].

CONCLUSIONS

The adsorption process of indigo carmine dye using kapok skin modified with snail meat showed optimum results under conditions of 60 minutes of contact time and 25°C temperature, with a relatively high adsorption capacity of 129.3421 mg/g. This shows that the modification process can provide optimal results in removing dye

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pollutants in solution. The study of the adsorption kinetics model shows that the adsorption process of indigo carmine dye takes place chemically by following the 2nd order kinetic model. The results of the research show that kapok skin biosorbent modified with snail meat can be used as a good adsorber of indigo carmine dye by obtaining a relatively high adsorption capacity.

REFERENCES

[1] P. Vairavel, N. Rampal, and G. Jeppu, "Adsorption of toxic Congo red dye from aqueous solution using untreated coffee husks: kinetics, equilibrium, thermodynamics and desorption study," *International Journal of Environmental Analytical Chemistry*, vol. 00, no. 00, pp. 1–20, 2021, doi: 10.1080/03067319.2021.1897982.

[2] T. N. Ramesh and V. Pavagada Sreenivasa, "Removal of Indigo Carmine Dye from Aqueous Solution Using Magnesium Hydroxide as an Adsorbent," *Journal of Materials*, vol. 2015, no. i, pp. 1–10, 2015, doi: 10.1155/2015/753057.

[3] B. Shi, G. Li, D. Wang, C. Feng, and H. Tang, "Removal of direct dyes by coagulation: The performance of preformed polymeric aluminum species," *Journal of Hazardous Materials*, vol. 143, no. 1–2, pp. 567–574, 2007, doi: 10.1016/j.jhazmat.2006.09.076.

[4] F. Harrelkas, A. Azizi, A. Yaacoubi, A. Benhammou, and M. N. Pons, "Treatment of textile dye effluents using coagulation-flocculation coupled with membrane processes or adsorption on powdered activated carbon," *Desalination*, vol. 235, no. 1–3, pp. 330–339, 2009, doi: 10.1016/j.desal.2008.02.012.

[5] J. Kashyap, S. M. Ashraf, and U. Riaz, "Highly Efficient Photocatalytic Degradation of Amido Black 10B Dye Using Polycarbazole-Decorated TiO2 Nanohybrids," *ACS Omega*, vol. 2, no. 11, pp. 8354–8365, 2017, doi: 10.1021/acsomega.7b01154.

[6] A. Kesraoui, M. Seffen, and F. Brouers, "Non linear modelisation of dyes removal from aqueous solution sorption onto Luffa cylindrica fibers," *Moroccan Journal of Chemistry*, vol. 4, pp. 659–676, 2017.

[7] M. Güler, S. Çetintaş, and D. Bingöl, "Cinnamon bark as low-cost and eco-friendly adsorbent for the removal of indigo carmine and malachite green dyestuffs," *International Journal of Environmental Analytical Chemistry*, vol. 101, no. 6, pp. 735–757, 2021, doi: 10.1080/03067319.2019.1670171.

[8] Emriadi, P. Untari, and M. Efdi, "LEAVE EXTRACT OF Syzygium malaccense AS GREEN INHIBITOR OF MILD STEEL IN ACIDIC MEDIUM," *Rasayan Journal Chemistry*, vol. 14, no. 1, pp. 569–577, 2021.

[9] H. Yao *et al.*, "Review on Applications of Lignin in Pavement Engineering : A Recent Survey," *Frontiers in Materials*, vol. 8, no. January, pp. 1–15, 2022, doi: 10.3389/fmats.2021.803524.

[10] A. O. Dada *et al.*, "Sustainable

and low-cost Ocimum gratissimum for biosorption of indigo carmine dye: kinetics, isotherm, and thermodynamic studies," *International Journal of Phytoremediation*, vol. 0, no. 0, pp. 1524–1537, 2020, doi: 10.1080/15226514.2020.1785389.

[11] G. F. K. Nindjio *et al.*, "Lignocellulosic-Based Materials from Bean and Pistachio Pod Wastes for Dye-Contaminated Water Treatment: Optimization and Modeling of Indigo Carmine Sorption," *Polymers*, vol. 14, no. 18, 2022, doi: 10.3390/polym14183776.

[12] I. W. Sudiarta, A. A. S. D. Prameswari, and I. M. S. Negara, "BIOSORPSI Cr(III) OLEH BIOSORBEN KULIT KAPUK (Ceiba pentandra (L.) Gaertn) TERAKTIVASI ASAM NITRAT," *Jurnal Kimia*, vol. 16, no. 1, p. 93, 2022, doi: 10.24843/jchem.2022.v16.i01.p12.

[13] J. B. Dewi, D. Ramadayani, M. D. Wahyunandha, M. K. B. P. Gustari, and T. W. P. Jr, "Tepung Bekicot (Achatina Fulica) Sebagai Pakan Tambahan untuk Meningkatkan Kualitas Semen Domba (Ovis Aries) Snail Flour (Achatina Fulica) as Supplementary Feed to Improve Semen Quality of Rams (Ovis Aries)," *Jurnal Sain Veteriner*, vol. 40, no. 3, 2022.

[14] R. Zein, C. Akmal, S. Safni, S. Fauzia, and P. Ramadhani, "Banana Stem (Musa balbisiana Colla) as Potential Biosorbent to Remove," *Applied Environmental Research*, vol. 45, no. 3, 2023.

[15] R. Zein, J. S. Purnomo, P. Ramadhani, M. F. Alif, and S. Safni, "Lemongrass (Cymbopogon nardus) leaves biowaste as an effective and low-cost adsorbent for methylene blue dyes removal: isotherms, kinetics, and thermodynamics studies," *Separation Science and Technology (Philadelphia)*, vol. 57, no. 15, pp. 2341–2357, 2022, doi: 10.1080/01496395.2022.2058549.

[16] R. Zein, P. Ramadhani, H. Aziz, and R. Suhaili, "Pensi shell (Corbicula moltkiana)as a biosorbent for metanil yellow dyes removal: pH and equilibrium model evaluation," *Jurnal Litbang Industri*, pp. 15–22, 2019.

[17] D. Arifiyana and V. Devianti, "Optimization of pH and contact time adsorption of banana peels as adsorbent of Co (II) and Ni (II) from liquid solutions," vol. 070007, no. March, 2021.

[18] G. Agbor Tabi *et al.*, "Non-linear modelling of the adsorption of Indigo Carmine dye from wastewater onto characterized activated carbon/volcanic ash composite," *Arabian Journal of Chemistry*, vol. 15, no. 1, p. 103515, 2022, doi: 10.1016/j.arabjc.2021.103515.

[19] M. Iqhrammullah, Marlina, and S. Nur, "Adsorption Behaviour of Hazardous Dye (Methyl Orange) on Cellulose- Acetate Polyurethane Sheets Adsorption Behaviour of Hazardous Dye (Methyl Orange) on Cellulose-Acetate Polyurethane Sheets," 2020, doi: 10.1088/1757-899X/845/1/012035.

[20] D. Kurniawati, L. R. Fasa, and H. Smith, "Effect of Contact Time Adsorption of Rhodamine B , Methyl Orange and Methylene Blue Colours on Langsat Shell with Batch Methods Effect of Contact Time Adsorption of Rhodamine B , Methyl Orange and Methylene Blue Colours on Langsat Shell with Batch Methods," in *1st International Conference on Chemistry and Science Education (ICChSE) 2020*, 2021, pp. 1–6, doi: 10.1088/1742-6596/1788/1/012008.

[21] P. Ramadhani, Z. Chaidir, Zilfa, Z. B. Tomi, D. Rahmiarti, and R. Zein, "Shrimp shell (Metapenaeus monoceros) waste as a low-cost adsorbent for metanil yellow dye removal in aqueous solution," *Desalination and Water Treatment*, vol. 197, pp. 413–423, 2020, doi: 10.5004/dwt.2020.25963.

[22] A. G. Adeniyi and J. O. Ighalo, "Biosorption of pollutants by plant leaves: An empirical review," *Journal of Environmental Chemical Engineering*, vol. 7, no. 3, p. 103100, 2019, doi: 10.1016/j.jece.2019.103100.

[23] M. Musah, Y. Azeh, J. Mathew, M. Umar, Z. Abdulhamid, and A. Muhammad, "Adsorption Kinetics and Isotherm Models: A Review," *Caliphate Journal of Science and Technology*, vol. 4, no. 1, pp. 20–26, 2022, doi: 10.4314/cajost.v4i1.3.

[24] M. A. Hubbe, S. Azizian, and S. Douven, "Implications of apparent pseudo-second-order adsorption kinetics onto cellulosic materials: A review," *BioResources*, vol. 14, no. 3, pp. 7582–7626, 2019, doi: 10.15376/biores.14.3.hubbe.

[25] M. C. D. Ngaha, E. Njanja, G. Doungmo, A. Tamo Kamdem, and I. K. Tonle, "Indigo Carmine and 2,6-Dichlorophenolindophenol Removal Using Cetyltrimethylammonium Bromide-Modified Palm Oil Fiber: Adsorption Isotherms and Mass Transfer Kinetics," *International Journal of Biomaterials*, vol. 2019, 2019, doi: 10.1155/2019/6862825.