Eksergi
Jurnal Ilmiah Teknik Kimia
Vol 20, No. 3. 2023

ISSN: 1410-394X
e-ISSN: 2460-8203

Pengaruh Penambahan ZnO terhadap Karakteristik Kain Katun pada Proses Pewarnaan Kain Batik

Effect of ZnO Addition on The Characteristics of Cotton Fabric in The Batik Fabric Dyeing Process

Siti Fatimah[a], Syaifunnisa Puspa Kencana[a*], Shofwatul ‘Aarifah[a] and Istihanah Nurul Eskani[b]

[a]*Department of Chemical Engineering, Faculty of Engineering, Muhammadiyah University of Surakarta, Sukoharjo 57169, Indonesia*

[b]*Centre for Craft and Batik, Ministry of Industry, Yogyakarta 55166, Indonesia*

Artikel histori :

Diterima 14 Juni 2023
Diterima dalam revisi 21 September 2023
Diterima 22 September 2023
Online 1 November 2023

ABSTRAK: Kain batik merupakan kebutuhan sehari-hari dan telah menjadi bagian dari masyarakat Indonesia, misalnya dalam upacara kelahiran hingga kematian. Selain beberapa kelebihan kain batik berbahan katun, kain batik juga memiliki kekurangan karena bakteri cepat berkembang biak. Oleh karena itu, penting untuk mengembangkan sifat antibakteri pada kain batik. Penelitian ini bertujuan untuk menganalisis sifat mekanik dan ketahanan warna kain katun pada proses pewarnaan kain batik dengan penambahan ZnO sebagai antibakteri. Kain batik dilapisi ZnO dengan menambahkan Zn asetat dihidrat sebelum direaksikan dengan NaOH. Pemanasan dilakukan sambil terus diaduk selama 20 menit (sampel A) dan dilanjutkan 20 menit (sampel B) kemudian dikeringkan. Karakteristik kain batik dianalisis menggunakan uji kuat tarik, uji ketahanan luntur warna terhadap gosokan, dan uji ketahanan luntur warna terhadap sinar. Hasil penelitian menunjukkan bahwa pemberian ZnO berpengaruh terhadap sifat mekanik kain batik berupa peningkatan kuat tarik dan perpanjangan putus. Hasil penelitian juga menunjukkan bahwa ZnO tidak mempengaruhi ketahanan luntur warna terhadap gosokan dan sinar dengan nilai yang sama dengan kain batik tanpa perlakuan, yaitu 4-5 (baik).
Kata Kunci: Batik; Kain Katun; ZnO; Uji Tarik; Ketahanan Luntur Warna

ABSTRACT: Batik fabric is essential for daily use and has become a part of Indonesian people, e.g., birth to death ceremonies. Besides some advantages of batik fabric made from cotton, it also has disadvantages because it quickly grows bacterial. Hence, it is essential to develop antibacterial properties on batik fabrics. This research aims to analyze the mechanical properties and colorfastness of cotton fabric in the batik fabric dyeing process by adding ZnO as an antibacterial. Batik fabric is coated with ZnO by adding Zn acetate dihydrate before reacting with NaOH. Heating was carried out while continuously stirring for 20 minutes (sample A) and continued for 20 minutes (sample B) and dried. The characteristics of batik fabric were analyzed using a tensile strength test, colorfastness test to rubbing, and colorfastness test to light. The results showed that applying ZnO affected the mechanical properties of batik fabric by increasing the tensile strength and elongation at break. The result also showed that the ZnO did not affect the colorfastness of rubber and light by the similar value of untreated batik fabric, which is 4-5 (good).
Keywords: Batik; Cotton Fabric; ZnO; Tensile Strength; Colorfastness

1. Introduction

For centuries, batik fabric has been a part of Indonesian culture and is recognized by United Nations Educational, Scientific and Cultural Organization (UNESCO) as an Intangible Cultural Heritage of Humanity for ten years. In Indonesia, it is an integral part of various ceremonies from birth to death and become an everyday use such as manufacturing and bedding (I. Eskani et al., 2021). Therefore, the development of functional batik becomes very important. Functional batik is a type of batik that functions more like a clothing material. This material can also be antibacterial, anti-ultraviolet, hydrophobic (water

* Corresponding Author:
Email: syaifunnisap@mail.com

repellent), not easily wrinkled, and not easily dirty (self-cleaning) (I. N. Eskani et al., 2020).

Colors can be created using natural or synthetic dyes during batik manufacturing. A variety of synthetic dyes has been chosen for this work. Synthetic dyes commonly used in the batik manufacturing processes are indigosol, remazole, rapid, and indanthrene dyes (I. Eskani et al., 2021). Batik production requires natural fibers, such as cotton and silk that absorbs color quickly. Cotton fabric has been chosen for experimentation for several advantages: smooth absorption capacity, comfort, high breathability, and easy dyeing with various dyes. However, cotton fabrics are made of natural fibers and are an ideal medium for bacterial growth, making them problematic for daily use. Staphylococcus aureus bacteria on cotton fabric fibers causes odor, damage to the fabric fibers, discoloration, and reduced mechanical properties of textiles (Setiyani & Dina, 2015). Given the widespread use of batik fabric made from cotton, the development of batik fabrics that prevent the growth of bacteria may help improve hygiene (I. N. Eskani et al., 2022).

The invention of metal oxides, such as ZnO, TiO_2, SiO_2, and MgO, which can improve textile performance, offers solutions to several problems in the antibacterial growth of batik production (I. N. Eskani et al., 2020). Zinc oxide applied to the batik fabric can provide antibacterial properties and improve color quality. Cotton fabric that forms alkali cellulose through the carboxymethylation process has antimicrobial properties and good colorfastness (Mohamed et al., 2016). Zinc oxide was chosen for its specific antibacterial activity (I. N. Eskani et al., 2022).

With the above background information about the improvement of batik fabric made from cotton, the present study was carried out with the main objective of applying ZnO to evaluate the finishing on the characteristics of the batik fabric made from cotton in the dyeing process.

2. Research Method

2.1. Materials and Methods

The materials required in this study are Zn acetate dihydrate $[Zn(C_3HCOO)_2.2H_2O]$, Sodium hydroxide (NaOH), Potassium sodium tartrate ($KNaC_4H_4O_6.4H_2O$), aquades, non-ionic detergents/TRO, and batik fabric made from cotton.

2.2. Materials and Methods

The antibacterial finishing process on batik fabric is as follows (Souza et al., 2018). Prepare batik fabric as a sample. First, the batik A sample is immersed in water and non-ionic detergent/TRO solution to remove the dirt attached to the surface. As much as 0.3 M Zn acetate and 0.035 mol Potassium sodium tartrate were dissolved in 350 ml of distilled water. The batik fabric sample is put into the solution and heated until it boils. 1 M sodium hydroxide was added gradually into the solution until pH 11. Heating was continued while stirring was continued for about 20 minutes. After that, batik fabric is taken and dried at about 40°C. Then, the batik B sample is put into solution, heated with a constant temperature of about 90-95°C, and stirred for 20 minutes. After reaching a time of 20 minutes, the batik B sample is taken and dried.

2.3. Tensile Strength Testing

Tensile strength testing is done by the Universal Testing Machine (UTM) tool. Take the fabric test sample and the blank sample fabric and cut it according to the tensile test pattern with 20 cm length and 4 cm width, as many as 12 pieces on each fabric sample consisting of 6 pieces of warp and 6 pieces of weft fabric. Strain the threads on the long side of the fabric with a ruler so that the fabric sample's width becomes 25 mm. Ensure the top and bottom clamp on the Tensile Strength are aligned with the clamping distance (75 ± 1) mm. Give the initial stress at the lower end of the test sample, not more than 0.5%, and the maximum tensile strength of the test sample. Clamp the test sample symmetrically on the bottom clamp pair. Run Tensile Strength and the test sample is stretched until the fabric breaks. Stop the Tensile Strength and record the magnitude of the tensile and elongation strength that is read on a scale, graph, or monitor display.

2.4. Colorfastness to Rubbing Testing

a. Dry Rubbing

The test sample is placed flat on the tool tester with a long, unidirectional side with the direction of rubbing. Finger crock meter wrapped with dry fabric white rubbed 10 times forward-backward (20× rub) with the one revolution per second speed. The white fabric is then taken to evaluate color staining using a staining scale. Evaluation is done by comparing color staining on a white fabric against the staining scale.

b. Wet Rubbing

The test sample is placed flat on the tool tester with a long, unidirectional side with the direction of rubbing. Finger crock meter wrapped in dry white fabric moistened with aquades and rubbed 10 times back and forth (20× rub) at one revolution per second. The white fabric is air-dried. Evaluation is done by comparing color staining on a white fabric against the staining scale.

2.5. Colorfastness to Light Testing

Cut the fabric test sample according to the test pattern with a length of 13 cm and a width of 7 cm. Prepare 5 patterned opaque cardboard to cover the sample cloth so it is not exposed to light. Put the 4 samples into the patterned opaque cardboard, then clamp the 4 patterned opaque cardboard with the aluminum test specimen to be tightly closed. Prepare the blue wool 1-5, attach it sequentially to the opaque cardboard according to the test, and then clamp it with the aluminum test specimen. Put 5 opaque cartons clamped with aluminum specimens into the vacuum pump. Close the vacuum pump. Connect the power outlet and press the ON button on the appliance. Press the menu button, set the temperature to 67°C, and the duration is 40 hours. When finished, the tool will turn off automatically. If the time has reached 40 hours, the sample will be evaluated with a final

ISSN: 1410-394X
e-ISSN: 2460-8203

assessment of the light expressed in numbers. The test sample's color fastness value is the blue wool value, which has the same contrast between the illuminated and unilluminated areas as the contrast of the test sample. If the difference of the test sample lies approximately between the two blue wool standards, it is assigned a median value, for example, a value of 3-4 or L2-L3.

3. Result and Discussion

3.1. ZnO Application

According to Kasuma et al. (2021), the reactions that occur during the synthesis of ZnO in fabric fibers are as follows:

$$Zn(CH_3COO)_2.2H_2O_{(aq)} + 2NaOH_{(aq)} \rightarrow Zn(OH)_2.2H_2O_{(aq)} + 2CH_3COONa_{(aq)} \quad (1)$$

$$Zn(OH)_2.2H_2O_{(aq)} \rightarrow Zn(OH)_2 + 2H_2O_{(aq)} \quad (2)$$

$$Zn(OH)_2 \rightarrow ZnO + H_2O \quad (3)$$

According to I. Eskani et al. (2021), the batik A sample is finished by adding a zinc acetate dihydrate precursor solution before reacting with NaOH. When the solution boils, slowly add the 1 M NaOH solution to the precursor solution with stirring until reactions (1) to (3) are formed. First, 1 M NaOH solution was added to the zinc acetate dihydrate precursor solution, and the color changed to milky white. The color of the solution indicates the formation of a $Zn(OH)_2$ group in the reaction medium. In addition, these groups will dissolve into Zn^{2+} and OH^- ions. In cotton fabric, there will be a change in non-active cellulose (Cell-OH) to active cellulose (Cell-O-), which will form a complex with Zn^{2+} ions (zinc-cellulose complex). This complex will function as the basic growth unit of the ZnO nucleus with the dehydration of OH^- ion. The concentration of growth units in the solution increases until it reaches critical saturation. The complex will be formed into the ZnO nucleus. The addition of an alkaline atmosphere and increased temperature swell the cotton fabric, breaking intermolecular hydrogen bonds and promoting the penetration of ZnO particles into the fiber structure of the fabric.

3.2. Mechanical Properties

In this study, to know the effect of ZnO application on the mechanical properties of the batik fabric made from cotton, an analysis of the tensile strength and elongation at the break of untreated batik fabric and the ZnO coated batik fabric (Sample A and Sample B) was carried out. The tests performed using a Universal Testing Machine (UTM) are presented in Table 1.

Table 1 shows that the application of ZnO affected the mechanical properties of the batik fabric made from cotton. Sample A is the batik fabric coated with ZnO for 20 minutes, while sample B is the fabric coated with ZnO for 40 minutes. The tensile strength of batik fabric containing ZnO in sample B is more significant than untreated batik fabric and sample A. This reveals that the tensile strength of the batik fabric will increase with the ZnO coating. This is in whole settlement with previous studies (I. Eskani et al., 2021; Noorian et al., 2020; Rastgoo et al., 2017). The increase in tensile strength of batik fabric is due to the cross-linking effect of ZnO deposited between cotton fibers. The decreasing tensile strength of untreated batik fabric to sample A is caused by the reaction that makes cross-linking effect not in an optimum condition. In addition, when the batik fabric is coated for a longer time, the tensile strength is enhanced by applying ZnO. The result implies that applying ZnO enhances the fabric's tensile strength.

Table 1. The result of tensile strength and the elongation at break of the batik samples

Samples	Tensile Strength (F)	Elongation (mm)
Untreated batik fabric	179.52	15.54
Sample A	162.36	15.03
Sample B	195.42	16.28

Furthermore, the elongation at the break of sample A is lower than the untreated batik. This may be due to the hardening of the sample due to the deposition of ZnO. In contrast, the elongation at the break of sample B is more significant than untreated batik fabric. This is probably because more ZnO is incorporated into the fabric, significantly affecting the mechanical properties.

3.3. Colorfastness to Rubbing

The effect of ZnO application on the dyeing performance of the colorfastness to rubbing has been evaluated using a crock meter. The results of the colorfastness to rubbing tests are shown in Table 2.

Table 2. The result of colorfastness to dry and wet rubbing for the batik fabric samples

Samples	Value of Colorfastness to Rubbing		Evaluation
	Dry Cotton	Wet Cotton	
Untreated batik fabric	4 – 5	4 – 5	Strong (good)
ZnO post-treated batik fabric	4 – 5	4 – 5	Strong (good)

The result of testing the colorfastness to rubbing of untreated batik fabric and ZnO post-treated batik fabric is done in two ways: dry rubbing test and wet rubbing test with a staining scale. The colorfastness value to rubbing of untreated batik fabric has an optimal colorfastness with grades 4 and 5 (good). It is relatively similar to that of ZnO post-treated batik fabric. This indicates that applying ZnO adsorbed onto the batik fabric does not affect the colorfastness of rubbing the batik fabric made from cotton.

3.4. Colorfastness to Light

The evaluation of colorfastness to light is carried out in Table 3. The evaluation uses the grayscale standard to assess the color change of the batik fabric and blue wool to assess the weary of color to light. The analysis shows results in Table 3 below.

Table 3. The result of colorfastness to light for the batik fabric samples

Samples	Value of Colorfastness to Light	Value of Weary to The Color of Fabric	Evaluation
Untreated batik fabric	4 – 5	4 – 5	Strong (good)
ZnO post-treated batik fabric	4 – 5	4 – 5	Strong (good)

Comparing colorfastness to light between untreated batik fabric and ZnO post-treated batik fabric has the same results. It can be interpreted that ZnO application on batik fabric does not affect the colorfastness to light.

4. Conclusion

The reaction of zinc acetate dihydrate precursor and NaOH forms ZnO. Applying ZnO on cotton fabric in the dyeing process affects the mechanical properties of batik fabric, namely the tensile strength and elongation at break. The results showed that the tensile strength and elongation at the break of the fabric increased with ZnO coating. The value of colorfastness to rubbing dry and wet batik fabric with and without ZnO is 4-5 (good). The value of colorfastness to light is good with grades 4-5 for both with and without ZnO. It is shown that the addition of ZnO did not affect the colorfastness to rubbing and the colorfastness to light of the batik fabric.

Acknowledgements
The author would like to express gratitude to the Kampus Merdeka, especially to the Mata Kuliah Konsentrasi Unggulan Program Studi (MKKUP) of Chemical Engineering Departement, Faculty of Engineering, Muhammadiyah University of Surakarta for the financial support given. We also would like to thank to the Centre for Craft and Batik, Ministry of Industry, Yogyakarta which has provided facilities to complete this research well.

References

Eskani, I., Laela, E., Haerudin, A., Setiawan, J., & Lestari, D. W. (2021). Finishing Antibakteri Pada Kain Batik Menggunakan Metode Chemical Bath Deposition (Cbd) Sederhana. *Seminar Nasional Himpenindo DIY, May 2022*, 183–190.

Eskani, I. N., Astuti, W., Farida, Haerudin, A., Setiawan, J., Lestari, D. W., Isnaini, & Widayatno, T. (2022). Antibacterial activities of synthesised Zno nanoparticles applied on reactive dyed batik fabrics. *Journal of the Textile Institute*, *113*(3), 430–439. https://doi.org/10.1080/00405000.2021.1883907

Eskani, I. N., Haerudin, A., Setiawan, J., Lestari, D. W., Isnaini, & Astuti, W. (2020). Modification of cotton fabric by ZnO nanoparticles for producing an antibacterial natural dyed batik. *IOP Conference Series: Earth and Environmental Science*, *462*(1). https://doi.org/10.1088/1755-1315/462/1/012031

Kasuma, W. N. S., Khair, M., & Kimia, S. V. J. (2021). Indonesian Journal of Chemical Science Synthesis and Characterization of ZnO Nanoparticles Using Sol-Gel Method. *J. Chem. Sci*, *10*(1), 59–67. http://journal.unnes.ac.id/sju/index.php/ijcs

Mohamed, F. A., Ibrahim, H. M., El-Kharadly, E. A., & El-Alfy, E. A. (2016). Improving dye ability and antimicrobial properties of cotton fabric. *Journal of Applied Pharmaceutical Science*, *6*(2), 119–123. https://doi.org/10.7324/JAPS.2016.60218

Noorian, S. A., Hemmatinejad, N., & Navarro, J. A. R. (2020). Ligand modified cellulose fabrics as support of zinc oxide nanoparticles for UV protection and antimicrobial activities. In *International Journal of Biological Macromolecules* (Vol. 154). Elsevier LTD. https://doi.org/10.1016/j.ijbiomac.2019.10.276

Rastgoo, M., Montazer, M., Harifi, T., & Mahmoudi Rad, M. (2017). In-situ sonosynthesis of cobblestone-like ZnO nanoparticles on cotton/polyester fabric improving photo, bio and sonocatalytic activities along with low toxicity and enhanced mechanical properties. *Materials Science in Semiconductor Processing*, *66*(December 2016), 92–98. https://doi.org/10.1016/j.mssp.2017.04.004

Setiyani, R., & Dina, K. M. (2015). Pemanfaatan Komposit Kitosan ZnO-SiO2 Sebagai Agen Antibakteri Terhadap Bakteri Staphylococcus aureus Pada Kain Katun. *UNESA Journal of Chemistry*, *4*(2), 88–93.

Souza, D. A. R., Gusatti, M., Ternus, R. Z., Fiori, M. A., & Riella, H. G. (2018). In situ growth of ZnO nanostructures on cotton fabric by solochemical process for antibacterial purposes. *Journal of Nanomaterials*, *2018*. https://doi.org/10.1155/2018/9082191