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Characteristics of Dyeing Cotton Thread Using *Fine Particle Powder from Tectona Grandis Leaf*

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Abstract: In Lombok, the traditional process of dyeing woven fabrics primarily involves the use of synthetic dyes, which can contribute to environmental pollution. This study aimed to identify the characteristics of woven yarn and assess the effect of dye solution pH on yarn properties when using teak leaves (Tectona grandis) to produce dye powder through a mechanical thermal method. The thread coloring process comprised mordanting, coloring, and fixation stages, with the assistance of Android applications for color analysis and a Universal Tensile Machine Type RTG-1310 to assess mechanical properties. The results revealed that dyeing yarn with anthocyanin powder from teak leaves yielded a range of colors, including shades of gray, brown, and red. The highest tensile strength observed was 2,664 cN/dtex, and the solution's pH significantly influenced the dominant color, with red being prominent. Notably, optimal tensile strength (1,649 cN/dtex) was achieved at pH six. These findings highlight the potential for producing high-quality cotton threads using different dyeing processes and techniques. The study's insights contribute to both environmental protection and thread quality enhancement in the textile industry.

Keywords: Anthocyanin; Natural Dye; Teak Leaves; Tensile Strength

Introduction

Tourism in Lombok has grown along with the emergence of the Mandalika Circuit in the Mandalika Special Economic Zone. Tourism expansion positively contributes to the textile and crafts industry. Weaving is a textile industry that attracts both domestic and foreign visitors. This weaving is a legacy from the ancestors of the indigenous people in Lombok. An exciting tradition in Lombok is that a girl cannot marry if she cannot weave. Other than that, traditional heritage emphasizes the use of natural colors. Meanwhile, developments of synthetic dyes transformed the weaving community's habits, which initially utilized colors from natural sources to artificial colorants. Nowadays, more than 60% of weavers use synthetic dyes. However, the dye production process produces hazardous waste and has a detrimental impact on the environment. Hence, comprehensive research should be conducted to keep natural pigments sustainable.

As can be seen, many types of plants around that can be used as a source of natural dyes. Various parts of plants that have a source of color pigments include pieces of the bark, stems, leaves, roots, flowers, seeds, and sap (Sutara 2009). One of the plants that can be used as a source of natural dyes is the teak tree (Tectona grandis), which is part of the leaves (Rosyida and Didik 2014). Teak leaf is a plant that belongs to the Verbenaceae family, which has a comprehensive and large size. These leaves can be used as natural dyes because they contain anthocyanin compounds. Anthocyanins can give red, purple, to dark red (Ariviani 2010). Anthocyanins are found in vacuoles in plant cells. This compound is very reactive, easily oxidized or reduced, and has glycosidic bonds that are easily hydrolyzed. Besides anthocyanins acting as natural dyes, anthocyanins are also free radical scavengers and inhibit the initiation of chemical reactions that cause carcinogenesis. There are several other pigments in teak leaves, namely chlorophyll, alkaloids, flavonoids, and tannins (Surianti, 2019).

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Chlorophyll is the primary pigment found in leaves, and chlorophyll has a bluish-green pigment that can absorb light. Furthermore, alkaloids are alkaline color pigments, allowing teak leaves to be isolated to obtain more stable colors with acidic solutions such as HCl and H_2SO_4. There are also flavonoid compounds which are the essential compounds in teak leaves because they contain anthocyanins which are included in them. Flavonoids produce red, purple, and some yellow dyes found in plants (Hermawati, et.al., 2015). The yellow color is produced by the tannin content in teak leaves which belongs to the flavonoid group. The tannins in the leaves function to bind and precipitate proteins (Novia, et.al., 2020). Anthocyanin dyes will produce color variations if there is a decrease or increase in the pH of the solution used (Fathinatullabibah, et.al, 2014). This uniqueness encourages researchers to examine interesting phenomena in it. This phenomenon can be studied from the coloring process.

Generally, the dyeing process in textiles consists of three crucial stages: mordant, coloring, and fixation. The mordant is a process to open the pores of the threads so that the color pigments can adhere to the threads optimally. Coloring is the process of sharpening an element so that the material elements are clearly visible. Meanwhile, the fixation process is used as a medium to lock the color so that the attached color does not fade quickly. Various materials commonly used as a mordant and fixation materials are quicklime, alum, and tujung. Each type of material will produce different color characteristics when applied to the yarn (Pujilestari, 2014). The difference in coloring techniques will make different colors even though the source of the dye is the same.

Based on the description above, many studies have examined using Tectona grandis leaves as a source of natural dyes. However, not many studies still review the characteristics produced on yarn colored with Tectona Grandis leaves, particularly from a physics point of view, such as the mechanical properties of the resulting string. This is very important because it is one of the determining factors for the quality of the strength of the weaving to be obtained. Therefore, this study analyzed the color and mechanical properties of the yarn from each dyeing stage and the pH of the colorant solution.

Method

Tools and materials

Applying dyeing cotton thread with anthocyanin requires several main ingredients, such as Tectona grandis leaves, water, cotton thread, and alum. A solution of HCL 1M and NaOH 1M is needed to modify the color. The characterization tool used to identify the mechanical properties of threads is the Universal Tensile Machine (UTM) Type RTG-1310. Besides that, Android software with valuable tools, including the color tool, color analyzer, and color grab, was utilized to analyze the color attributes.

Procedure

Experiments on cotton thread dyeing techniques were divided into two main phases: making anthocyanin compound powders and dyeing cotton threads with anthocyanins. The outline of the research stages can be seen in Figure 1.

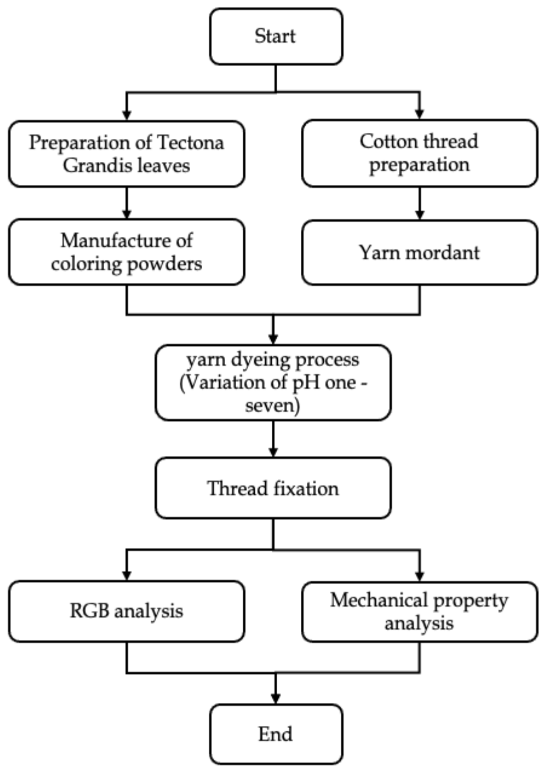

Figure 1. The research stages

Manufacturing of Dye Powder

Dye powder from Tectona grandis leaves was prepared using the mechanical thermal method consisting of several procedures. Firstly, the leaves are cleaned and cut with a width of 0.5 cm to quickly reduce the water content in the leaves. The drying process was then applied by utilizing an oven. After that, the leaves were baked for two hours at 70°C. In the following step, leaves are mashed to produce a coloring powder. Then the powder was homogenized, making use of a 100-mesh sieve.

Dyeing Process

The yarn dyeing technique is implemented in three main stages: mordant, coloring, and fixation (Figure 2). The naming of the sample is done by giving the code for each treatment. Where are the untreated threads (sample A), mordant threads (sample B), dyed threads (sample C), and fixed threads (sample D).

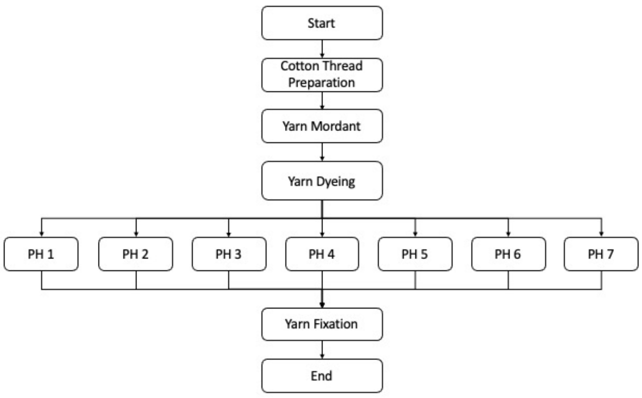

Figure 2. Yarn dyeing process

Yarn with a size of 50 cm is prepared for this coloring process. Where mordant thread using alum solution for 12 hours. After finishing soaking, the thread is dried and then ready to be colored with dyes from Tectona grandis leaves. The coloring technique is done at the coloring stage using the heating method. The dye powder from teak leaves was dissolved using distilled water which was added with 1M HCl and 1M NaOH to the dye solution to obtain a pH of one to seven. Heating was carried out until the volume of the solution became half of the initial volume. Then the yarn is dried again to dry. The final stage is fixation. The dyed threads were fixed using an alum solution for 30 minutes. Yarn that has gone through the dyeing process is ready to be analyzed for its color and mechanical properties.

Data Analysis

Data were analyzed into two characteristics. The first characteristic is the color produced on the cotton thread. The dyed cotton thread is identified by color, color-coded, and RGB using color tool, color analyzer, and color grab. Color trends were compared with each treatment. Meanwhile, the mechanical examination used Tensilon. Mechanical properties consist of the modulus of elasticity, strain, and stress. In testing the mechanical properties, the value of Young's modulus or elastic modulus (E) can be determined statically by pulling yarn. This is done by applying a load on both ends. The tensile force given is F (Newton). Then the material will increase in length (Δl). The initial measurement is called the strain and is expressed by the equation below:

$$\varepsilon = \frac{\Delta l}{l_o} \quad (1)$$

where ε is the strain, Δl is the increase in length (m), l is the initial length (m), and l_o is the final length (m).

The force ratio to the cross-sectional area when the pressure is applied is known as stress. The maximum tensile stress is the tensile strength of a material which is prompted by dividing the leading tensile force with the initial cross-sectional area, expressed in the following equation:

$$\sigma = \frac{F_m}{A_o} \quad (2)$$

Where σ is the maximum tensile stress (N/m²), A_o is the initial cross-sectional area (m²), and F_m is the full tensile force (N). Meanwhile, the equation of young's modulus is as follows:

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

where E is the modulus of elasticity (N/m²) (Rahmayanti, et.al., 2019).

Result and Discussion

Characteristics in the Dyeing Process

Cotton thread coloring using anthocyanin from Tectona grandis leaves has been implemented successfully. The primary step in the coloring, such as the mordant, paint, and fixation processes, give different characteristics of the color results (Table 1).

Table 1 Analysis of yarn colors with the Android application

Sample	Photo	RGB	Type & Color Code
A		206; 209; 218	*Zumthor* #Ced1da
B		163; 166; 157	*Grey* #A3a690
C		142; 112; 109	*Ferra* #8e706d
D		137; 100; 101	*Light wood* #896465

Color changes occurred in untreated yarn (sample A) during the thread mordant process until the fixation process (sample D). Changes in the mordant process (sample B) occurred due to the white powder of alum sticking to the pores of the thread. So that in the mordant process, the line changes color from zumthor to gray. The zumthor color combines light gray with white, while the gray color is a combination of gray with dominant white. The results of other studies also showed a change in thread color during the mordant process from white to slightly grayish white (Putri, et.al, 2020). The thread-mordant process is vital in dyeing techniques. Usually, this process serves to increase the strength of the color, open the orifice of the thread, expand the line pores so that it easily absorbs color, and obtain sharpness and evenness of the shade during the dyeing process (Maharani, R., dan Irma 2016)(Lestari, et.al, 2018) (Putri, et.al, 2020).

Colored cotton thread (sample C) with anthocyanin powder produces Ferra color. Ferra's color is synonymous with gray, brown, and red. The appearance of the dominant red and brown stains on the thread is due to the anthocyanin content of the Tectona grandis leaf powder. The following coloring process is fixation. The dyed yarn needs to be fixed to lock the color on the thread. Alum is used as a fixator to keep the color from fading. Usually, using alum does not change the direction of the resulting color. It just fades the color slightly (Afan, et.al., 2020). The color fades because the color pigment attached to the thread is not locked perfectly. This phenomenon occurs due to the fixation process when the color pigment is lifted by the fixation solution used. This is indicated by the results of the threads that have been fixed to produce a light wood color (a mixture of gray, brown, and red). The combination of colors in the staining and fixation processes did not differ, but the difference was only seen in the brightness of the resulting colors. In addition to the color change at each stage of yarn dyeing, the application of yarn dyeing also affects the mechanical properties of cotton yarn (Table 2).

Table 2 Analysis of the mechanical properties of cotton yarn at each dyeing stage

Sample	*Stress* (cN/dtex)	*Strain* (%)	Modulus Elastis (cN/dtex)	*Elongation* (mm)
A	2.603	15.93	1.194	39.76
B	2.580	15.15	1.197	37.84
C	2.664	14.43	1.139	36.04
D	1.649	12.17	0.895	30.35

Changes in the mechanical properties of cotton threads can be seen at each stage of thread dyeing (Table 2). The optimal thread stress value occurs in the thread coloring process (sample C) (Figure 3). However, during the fixation process, the cotton thread stress decreased. In addition to stress, the maximum stretching ability, characterized by strain, also changes. The cotton thread strain has reduced from the initial stage to the final coloring. Likewise, the same things happened to the maximum shift value, namely elongation.

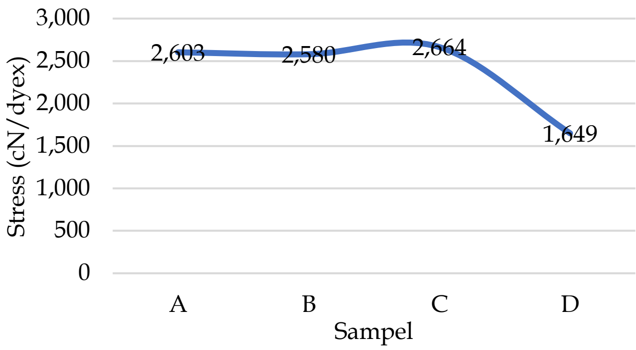

Figure 3 Identification of cotton thread stress in each thread dyeing process

Interesting alterations in mechanical aspects are the stress of cotton threads. The coloring of cotton threads with anthocyanin affects the stress characteristics of cotton threads. In Figure 3, strain declines in the mordant process (sample B) because the mordant substance plays a role in opening the pores of the thread. As a consequence, the line is more brittle than the initial conditions. However, the cotton thread tension increased during the dyeing process (sample C). The enhancement was caused by the thread pores that were opened due to the mordant process being filled again by anthocyanin pigments so that the thread pores were more closed. Thread coloring is also a technique to improve yarn quality (Rahayu et.al., 2021). In the fixation process, the thread stress went down significantly from 2,664 cN/dtex to 1,649 cN/dtex. This is mainly because the characteristics of the alum fixator, applied to the anthocyanin, had a fading effect on the thread color. Fading of the color illustrates that the dye attached to the pores of the thread has decreased. thereby thread stress deteriorated.

Characteristics of Yarn with pH Variations

In the coloring process, the dye powder will typically be dissolved with a water solvent. In this study, the pH of the solvent was varied to see the characteristics of the cotton threads resulting from the dyeing process. Differences in the solvents' pH during the coloring process produce different color characteristics (Table 3).

Table 3 Analysis of the colors produced on cotton threads with differences in solvent pH

Sample	Photo	RGB	Type & Color Code
pH 1		145; 111; 91	*Beaver* #916f5b

Sample	Photo	RGB	Type & Color Code
pH 2		149; 109; 90	*Beaver* #916f5b
pH 3		149; 126; 116	*Hemp* #957e74
pH 4		154; 133; 128	*Opium* #9a8580
pH 5		145; 120; 114	*Bazaar* #917872
pH 6		137; 100; 101	*Light wood* #896465
pH 7		154; 122; 121	*Opium* #9a8580

The results of color analysis on cotton threads stained with anthocyanin solutions starting from pH one to pH seven depict that the dominant mixture was red. In addition, the variation in the pH of the solution affects the type of color obtained, such as beaver, hemp, opium, bazaar, and light wood. The distinction in the color results was not significant; still in the same color mixture, namely gray, brown, orange, and red. The color difference is only seen in the brightness level of the owned color. The color disparity occurs because the stability of the anthocyanin, which can stick to the cotton thread, is disturbed by the solution's acidity.

In addition to differences in color, variations in the solvent's pH also affect the yarn's mechanical properties. Some of the mechanical properties analyzed are stress, strain, and elongation. In general, the values of tension and elongation are directly proportional. The elongation value enhances when the strain value rises, and vice versa. Meanwhile, the stress value of cotton thread escalated from pH one to pH six except at pH seven (Figure 4).

Table 4 Analysis of the mechanical properties of cotton threads with dyeing techniques using variable pH solutions

Sample	*Stress* (cN/dtex)	*Strain* (%)	Elastic Modulus (cN/dtex)	*Elongation* (mm)
pH 1	1.017	10.17	0,862	25.35
pH 2	1.258	11.46	0,929	28.62
pH 3	1.339	12.41	0,866	30.91
pH 4	1.368	12.96	0,837	32.34
pH 5	1.543	12.52	0,890	31.26
pH 6	1.649	12.17	0,895	30.35
pH 7	1.389	10.38	0,882	23.39

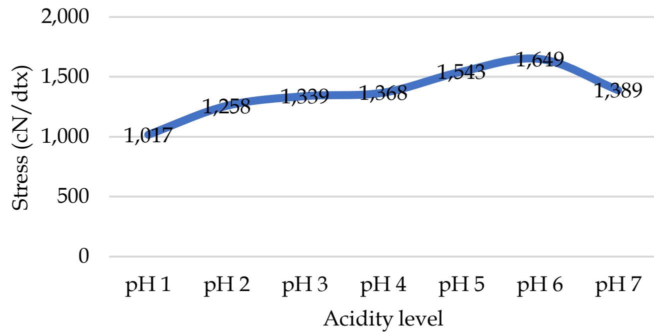

Figure 4 Identify the stress value of cotton thread based on the acidity level of the dye solution

Based on Figure 4, the most optimal stress value is in a solution of pH six. This occurs because, at pH six, more anthocyanin is absorbed and stick to the cotton thread than at another pH (Table 4). The large number of anthocyanins affiliated to the pores of the thread in more pores being closed therefore the density increases. Additionally, a pH six solution is prepared using purified water to ensure the stability of anthocyanin is not affected. Whereas at pH seven, there was a decrease in the stress value on the cotton thread. Several factors cause a reduction in this stress value, like the amount of anthocyanin attached to the line decreases. The solidity of the thread pores is lower than pH seven. Furthermore, the second factor is adding an alkaline solution of NaOH, which causes the thread to shrink and damages the lignocellulose in the thread.

Based on research, the phases of the dyeing procedure delivered distinct mechanical features of thread. The coloring technique provided the best investigation of the mechanical attributes of the three approaches. In addition, the pH of the solution affected the hue and mechanical properties. Divergences in PH orchestrated beaver-to-opium shades with a red anthocyanin color base. Meanwhile, the best-computerized effects of PH variations were obtained at

PH six. Thus, the anthocyanin staining technique with teak leaves was excellent, employing a tint solution with a pH of seven.

Conclusion

Anthocyanins can be extracted from Tectona grandis leaves using mechanical thermal techniques. The dye was in fine particle powder. Dye powder could be operated to dye yarn and textiles as an alternative to synthetic powder. The coloring procedure utilized three main phases: mordant, staining, and fixation. The staining stage was the most noteworthy by examining the solution.

Color characteristics were observed based on the staining scheme and pH of the solution. The dyeing technique affected the color of the thread. Starting from the zumthor color in an untreated line, it transformed to gray during the mordant, Ferra throughout the dyeing process, and light wood in fixation. Transformations ensue because of dye particles, mordant particles, and fixation. Some of these compounds filled the pores of the thread, and some were eroded during dyeing. Besides that, color metamorphoses occurred when staining with pH variations. For example, pH one and two delivered a beaver color. Then, pH four and seven made a poppy color. Lastly, pH three, five, and six fabricated hemp, bazaar, and light wood colors. This was caused by anthocyanin, which was unstable in acidic conditions.

Furthermore, there was an alteration in the mechanical possessions of yarn. The wool treated with dyeing had the most optimum stress compared to the mordant and fixation system in 2,664 cN/dtex. Meanwhile, pH variations in the dye solution also affected the mechanical properties of the fleece. The higher the pH was, the stronger the thread stretched. However, the ideal prerequisites were obtained in a pH six solution with a tensile strength of 1,649 cN/dtex. While at pH seven, the thread's tensile strength decreased to 1,389 cN/dtex. This happened because anthocyanin was unstable in acidic conditions. The density of the thread pores was also disturbed, and the lignocellulose became damaged.

Based on the research analysis results, anthocyanins from Tectona grandis leaves had great potential as a substitute for synthetic dyes. Anthocyanin powder can be used while applying conventional staining techniques from mordant to fixation. The uniqueness of anthocyanin was that it generated different types of colors by adjusting the acidity of the dye solution. However, it is necessary to research how the industry uses the coloring method to acquire the tiniest fading. Therefore, further research has to be arranged so that the product is ready for use quickly and precisely.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Afan, M., Agrippina, W., Sry, A., & Ruslan. (2020). Pemanfaatan Ekstrak Daun Sirih Hijau (Piper Betle L.) Sebagai Zat Pewarna Alami (ZPA) Tekstil Dan Aplikasinya Pada Benang Tenun. *Jurnal Pendidikan Kimia Dan Ilmu Kimia* 3(2): 20–27. Retrieved from https://jurnal.stkipbima.ac.id/index.php/RE/article/view/423

Ariviani, S. (2010). Total Antosianin Ekstrak Buah Salam Dan Korelasinya Dengan Kapasitas Anti Peroksidasi Pada Sistem Linoleat. *Jurnal Agrointek.* 4(2): 121–27. https://doi.org/10.21107/agrointek.v4i2.1364

Fathinatullabibah, Kawiji, & Lia, U.K. (2014). Stabilitas Antosianin Ekstrak Daun Jati (Tectona Grandis) Terhadap Perlakuan PH Dan Suhu. Jurnal Aplikasi Teknologi Pangan. *Jurnal Aplikasi Teknologi Pangan.* 3(2): 60–63. Retrieved from https://jatp.ift.or.id/index.php/jatp/article/view/79

Hermawati, Y., Ainur, R., & Poncojari, W. (2015). Pengaruh Konsentrasi Asam Sitrat Terhadap Ekstrak Antosianin Daun Jati Serta Uji Stabilitasnya Dalam Es Krim. *Jurnal Seminar Nasional Pendidikan Biologi 2015*: 301–8. Retrieved from https://onesearch.id/Record/IOS4109.20845

Lestari, A.A., Evy, W., & Yeni, M. (2018). Pemanfaatan Tumbuhan Penghasil Warna Alami Untuk Tenun Ikat Oleh Suku Dayak Iban Di Dusun Tekalong Dan Dusun Kelawik Kapuas Hulu Kalimantan Barat. *Jurnal Hutan Lestari* 6(4): 837–47. https://dx.doi.org/10.26418/jhl.v6i4.29542

Maharani, R., & Irma, R. (2016). Pengaruh Teknik Mordanting Terhadap Hasil Jadi Pewarnaan Alami Pada Jilbab Berbahan Sutera Dengan Ekstrak

Gambir Menggunakan Teknik Tye Dye. J*urnal Tata Busana*. 5(2): 33–43.

Novia, D., Agung, G.S., & Novri, S. (2020). Skrining Fitokimia Ekstrak Etanol Daun Jati Dan Infusa Daun Jati (Tectona Grandis L.S) Dengan Metode Kromatografi Lapis Tipis (KLT). *Jurnal Ilmiah Farmacy* 7(2): 159–74. https://doi.org/10.52161/jiphar.v7i2.188

Pujilestari, T. (2014). Pengaruh Ekstraksi Zat Warna Alam Dan Fiksasi Terhadap Ketahanan Luntur Warna Pada Kain Katun. *Majalah Ilmiah: Dinamika Kerjajinan dan Batik.* 31(1): 1–9. http://dx.doi.org/10.22322/dkb.v31i1.1058

Putri, T.M., Eko, M., & Rosyid, R. (2020). Ekstraksi Senyawa Tanin Dari Mangrove (Brugueria Gymnorrhiza) Menggunakan Pelarut Aquades Dan Etanol Sebagai Pewarna Alami Dan Penguat Serat Kain. *Jurnal Crystal : Publikasi Penelitian Kimia dan Terapannya* 2(1): 13–24. https://doi.org/10.36526/jc.v2i1.922

Rahayu, S., D. W. Kurniawidi, L. S. Hudha, & Siti Alaa. (2021). New Techniques For Improving The Quality of Cotton Yarn Using Natural Dyes From Teak Leaves (Tectona Grandis), Ketapang Leaves (Terminalia Catappa), and Tender Skin (Lannea Coromandelica). *IOP Conference Series: Earth and Environmental Science* 637(1). https://doi.org/10.1088/1755-1315/637/1/012084

Rahmayanti, H.D., Rahmawati, M., Euis, S., & Mikrajuddin, A. (2019). Karakterisasi Sifat Mekanik Benang Wol Dan Benang Kasur. *Jurnal Fisika* 9(1): 28–36. https://doi.org/10.15294/jf.v9i1.19421

Rosyida, A., & Didik, A.W. (2014). Pemanfaatan Daun Jati Muda Untuk Pewarnaan Kain Kapas Pada Suhu Kamar. Jurnal Arena Tekstil. *Jurnal Arena Tekstil* 29(2): 115–24. https://dx.doi.org/10.31266/at.v29i2.882

Surianti, Halimah, H., & Sulfikar. (2019). Uji Stabilitas Pigmen Merah Antosianin Dari Daun Jati Muda (Tectona Grandis Linn f) Terhadap PH Sebagai Pewarna Alami. *Jurnal Chemica* 20(1): 94–101. https://doi.org/10.35580/chemica.v20i1.13623

Sutara, P.K. (2009). Jenis Tumbuhan Sebagai Pewarna Alam Pada Beberapa Perusahan Tenun Di Gianyar. Jurnal Bumi Lestari. *Jurnal Bumi Lestari* 9(2): 217–23. Retrieved from https://ojs.unud.ac.id/index.php/blje/article/view/1518