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The Potential of Young Coconut Fiber as an Organic Dye and Its Applications on Silk Thread

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Abstract: Young coconut fibers, often found as waste, contain tannin and anthocyanin compounds that can produce various natural colors, so they can be used as organic dyes. The research method used was an experiment with a focus on testing silk thread dyeing using young coconut fiber extract dissolved in rice field water. This study aims to explore and develop the use of young coconut fibers as a source of environmentally friendly natural dyes. The results showed that young coconut fibers have the potential as organic dyes. Young coconut fiber extract with fermented rice field water solvents produced three color variations depending on the fixator used: brownish black (ferrous sulfate), gray (alum), and brown (lime). Structural tests using Scanning Electron Microscopy (SEM) proved that the dyeing process did not change the cross-sectional shape of the silk thread. In terms of tensile strength, yarn with alum fixation had the highest strength compared to native yarn, ferrous sulfate fixation, and lime fixation. Elongation tests showed the highest elasticity in yarn with alum fixation, followed by lime, ferrous sulfate, and native yarn. The color fastness test against washing at a temperature of 40°C showed a fairly good level of fastness for organic dyes from young coconut fiber.

Keywords: Fermented rice field water; Organic Dye; Silk Thread; Young Coconut Fiber

Introduction

The textile industry is one of the important economic sectors that has long used synthetic dyes to achieve the desired color variations in textile products (Islam et al., 2022). However, the use of these synthetic dyes often causes significant environmental problems, including water and soil pollution, as well as risks to human health due to their toxic and carcinogenic properties (Al-Tohamy et al., 2022; Islam et al., 2023). Awareness of these negative impacts has given rise to the need to develop more environmentally friendly dye alternatives, prompting researchers to explore the potential of natural materials as sources of organic dyes (Selvaraj et al., 2021; Pranta & Rahaman, 2024). Indonesia as a tropical country has abundant natural resources, one of which is the coconut plant (Cocos nucifera L.) (Subramanian et al., 2024). Coconuts grow abundantly along the coast and are a mainstay commodity in various regions (Syarifuddin et al., 2022). Indonesian people have long utilized almost all parts of the coconut plant, from water, fruit flesh, to the trunk and leaves. However, ironically, coconut fiber is often considered as waste that has little economic value and only becomes waste that pollutes the environment (Shah et al., 2022; Vieira et al., 2024).

Young coconut fiber, which is brownish green in color, has great potential as a source of natural dyes (Singh et al., 2024). Young coconut fiber contains various polyphenol, tannin, and anthocyanin compounds that can produce color pigments (Karouw et al., 2020). The content of these compounds allows young coconut fiber

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to be used as an environmentally friendly natural dye (Sahara et al., 2020). The color produced from young coconut fiber extract tends to have a brown to greenish color spectrum depending on the level of fruit ripeness and the extraction method used (Pandiselvam et al., 2024). The use of young coconut fiber as an organic dye is also in line with the principles of a circular economy which is now a global trend.(Elfahmi et al., 2024). The circular economy encourages the utilization of waste into value-added products, so that it can reduce waste and create a sustainable production cycle (Thapliyal et al., 2023). By utilizing young coconut fiber as an organic dye, we not only get environmentally friendly dyes but also reduce agricultural waste which has been a problem in coconut production centers (Stelte et al., 2023).

Silk, as one of the most valuable natural fibers, has unique characteristics in the form of natural shine, fiber strength, and good ability to absorb dyes (Sanda & Liliana, 2021). These characteristics make silk a very suitable material for application with natural dyes (Talib et al., 2023). The interaction between fibroin protein in silk fibers and polyphenol compounds in young coconut fiber extract allows for strong bonds, resulting in long-lasting and fade-resistant coloring (Shi et al., 2024). The development of organic dyes from young coconut fiber for application on silk thread also has its own unique value from a cultural perspective (Bureekhampun & Maneepun, 2021). Indonesia has a rich tradition of weaving and batik that has been recognized worldwide (Hidayani, 2024). The use of natural dyes in traditional textiles in Indonesia has been carried out for generations and is part of local wisdom (Siallagan et al., 2024). By integrating young coconut fiber as an organic dye in the traditional textile industry, we not only preserve the environment but also enrich the treasury of natural dyes in Indonesia (Dkhar & Tiwari, 2020).

From an economic perspective, the use of young coconut fiber as an organic dye can provide significant added value.(D'Almeida & de Albuquerque, 2024). Coconut farmers not only rely on coconut flesh as a source of income, but can also utilize young coconut fibers which have previously had little economic value. This has the potential to improve the welfare of coconut farmers spread across various regions in Indonesia. In addition, textile products with natural dyes usually have a higher selling value because they are seen as premium and environmentally friendly products (Utama et al., 2024). Research on the extraction and application of dyes from young coconut fibers is still developing. Various extraction methods have been tried to obtain optimal results, ranging from conventional methods such as soaking and boiling to modern methods such as ultrasonic extraction and microwave assisted extraction (Khan et al., 2022). Each method has advantages and disadvantages in terms of efficiency, quality of results, and environmental impact. Optimization of the extraction process is the key to obtaining high-quality organic dyes at affordable production costs. (Khadhraoui et al., 2021).

Challenges in utilizing young coconut fiber as an organic dye include the consistency of the color produced and the color resistance to washing and exposure to sunlight. The characteristics of young coconut fiber can vary depending on the coconut variety, soil conditions, and climate where it grows. This affects the composition and concentration of the coloring compounds contained in it. To overcome this problem, process standardization and the use of appropriate mordant materials are needed to improve color resistance (Azam et al., 2023). Mordant is a substance that functions as a chemical bridge between fiber and dye, thus increasing the affinity of the dye to the fiber and making the color more durable (Do et al., 2022). In dyeing silk yarn with young coconut fiber extract, various types of natural mordants can be used, such as alum, lime and ferrous sulfate. The selection of the type of mordant not only affects the color fastness but can also produce different color variations from the same dye (El-Zaher et al., 2021).

From a health perspective, organic dyes from young coconut fiber also offer advantages over synthetic dyes. Synthetic dyes often contain heavy metals and dangerous chemicals that can cause skin irritation and other health problems for textile product users (Khan et al., 2023). On the other hand, organic dyes from young coconut fiber are hypoallergenic and safe for sensitive skin. This advantage makes textiles dyed with organic dyes from young coconut fiber suitable for use by all groups, including those who have certain skin problems (Rana et al., 2022). Given its various potentials, the development of young coconut fiber as an organic dye for silk thread deserves serious attention from various parties, including the government, academics, and industry players. Synergistic collaboration is needed to overcome various technical, economic, and social challenges in its widespread implementation. With the right support, the use of young coconut fiber as an organic dye will not only provide economic benefits but also contribute significantly to environmental conservation and the development of a sustainable textile industry in Indonesia (Novais et al., 2022).

The purpose of this study is to explore and develop the use of young coconut fiber as a source of environmentally friendly natural dyes. This study also seeks to optimize the extraction process of young coconut fiber, as well as to test its effectiveness as a textile dye, especially on silk yarn. In addition, this study also aims to see the results of dyeing on silk yarn, silk yarn structure, tensile strength of silk yarn, elongation and fastness of silk yarn. Through this research, it is expected to encourage the use of young coconut agricultural waste more optimally, while supporting a more environmentally friendly textile industry.

Method

In this section, we present the types of research used, materials and equipment, the extraction process of young coconut fiber, and the working procedures in the dyeing process on silk threads. The stages of young coconut fiber extraction can be seen in Figure 1 and the stages in dyeing silk thread are shown in Figure 2.

Type of Researce

This type of research is an experiment that focuses on testing the coloring of silk threads by utilizing young coconut fiber extract dissolved in fermented rice field water. The next process is fixation using lime, alum and ferrous sulfate to generate color. The next stage is color locking using mineral water. The main objective of this study is to analyze young coconut fiber extract with fermented rice field water solvent used in the silk thread dyeing process, as well as to evaluate the aspects of strength, elongation and color fastness of silk threads that have gone through the dyeing process.

Tools and materials

The equipment used in this study were gas stoves, digital scales, wooden spoons, plastic buckets, cloth filters, measuring cups, aluminum steamers. The materials used were young coconut fiber, fermented rice field water, lime, ferrous sulfate, alum and mineral water.

Work procedures

To obtain optimal results in dyeing silk thread, several stages are carried out, including extraction from young coconut fiber, maceration process (dyeing), fixation (color generation), color locking, and then testing on silk thread.

Extraction proces

The extraction process of young coconut fiber begins with washing and cleaning the fresh fiber. Then the young coconut fiber is dried and separated from the shell. Next, the fiber is cut into small pieces and then ground until smooth. The process continues with boiling using fermented rice field water with a ratio of 1:15 (1 kg of young coconut fiber to 15 L of fermented rice field water). The boiling temperature ranges from 60°C-100°C and is carried out until the water volume shrinks to one third of the initial volume. After that, the extraction solution is filtered, collected, and cooled.

Coloring proces

After the extraction is complete, it is continued with the coloring stage (maceration) by soaking for 110 hours (5 days). During this process, the thread is turned over routinely every day so that the natural dye can be absorbed more quickly into the silk thread. After the soaking period of 110 hours (5 days) is over, the thread is then dried to remove the water content in the thread.

Color generation proces

The color generation process (fixation) is carried out using alum, chalk, and tunjung. At this stage, the silk thread that has gone through the coloring process (maceration) and has dried is dipped into a natural color solution, then lifted and put into a solution of alum, chalk, and ferrous sulfate, then dipped into clean water. This stage is repeated 6 times until silk thread with natural dyes is obtained. After the fixation process is complete, the thread is washed using clean running water.

Coor locking proces

The color locking process is done using mineral water that has a pH of 7.6, then the silk thread is dried. This step is done in the hope that the silk thread that has gone through all stages of coloring can achieve optimal results.

Research sampe testing

To assess the color quality of silk thread samples after going through the dyeing process, a series of tests were carried out including yarn structure, tensile strength, elongation, and fastness to washing at a temperature of 40°C. Yarn structure testing was carried out using a Scanning Electron Microscopy (SEM) tool, tensile strength and elongation tests using the SNI 7650:2010 method with a Statimat Tester tool that has a clamping distance of 250 mm, with the test results shown in tables 1 and 2. Meanwhile, fastness testing was carried out using the SNI ISO 105-C06:2010 A2S method with observation parameters including color changes, staining on cotton, and staining on silk, with the test results shown in table 3 (Neliyarti et al., 2025).

Results and Discussion

The results of this study will discuss the potential of young coconut fiber as an organic dye and its application to silk thread. At this stage, the first thing discussed is the extraction stage of young coconut fiber which will be used as an organic dye. Furthermore, it discusses the coloring process, silk thread coloring results, laboratory test results of silk thread structure, tensile strength, elongation, color fastness to washing at 40^{o}C

Young coconut fiber extraction stage

In this process, fresh young coconut fiber is cleaned and separated from the shell, then after cleaning it is dried in the sun until dry, after drying the coconut fiber is chopped to get the desired size, the next stage is to refine the young coconut fiber by pounding it, after the young coconut fiber is smooth then the boiling process is carried out with solvent water (fermented rice field water). The extraction solution ratio is 1:15 (1 kg of young coconut fiber and 15 L of fermented rice field water. The temperature during boiling ranges from 60°C-100°C, the boiling time until the water volume becomes one third of the original volume. Then the young coconut fiber extract solution is filtered, collected and cooled. The young coconut fiber extraction process can be seen in Figure 1.

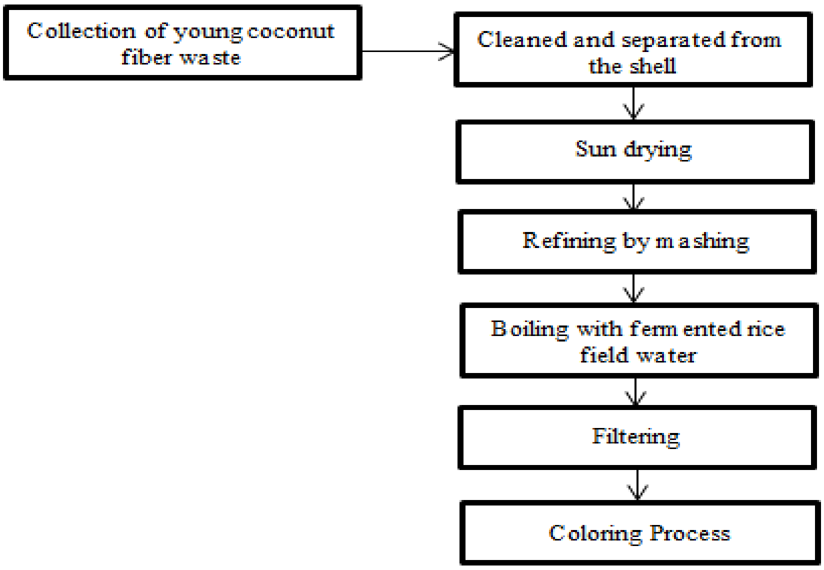


Figure 1. Young Coconut Fiber Extraction Stage

Coloring stage

After going through the extraction stage, the next process carried out is coloring the yarn. In the coloring process, the first thing to do is prepare the tools and materials, this aims to facilitate the coloring process. So that it will be smoother, easier and shorten the coloring process time. The coloring stages are shown in Figure 2.

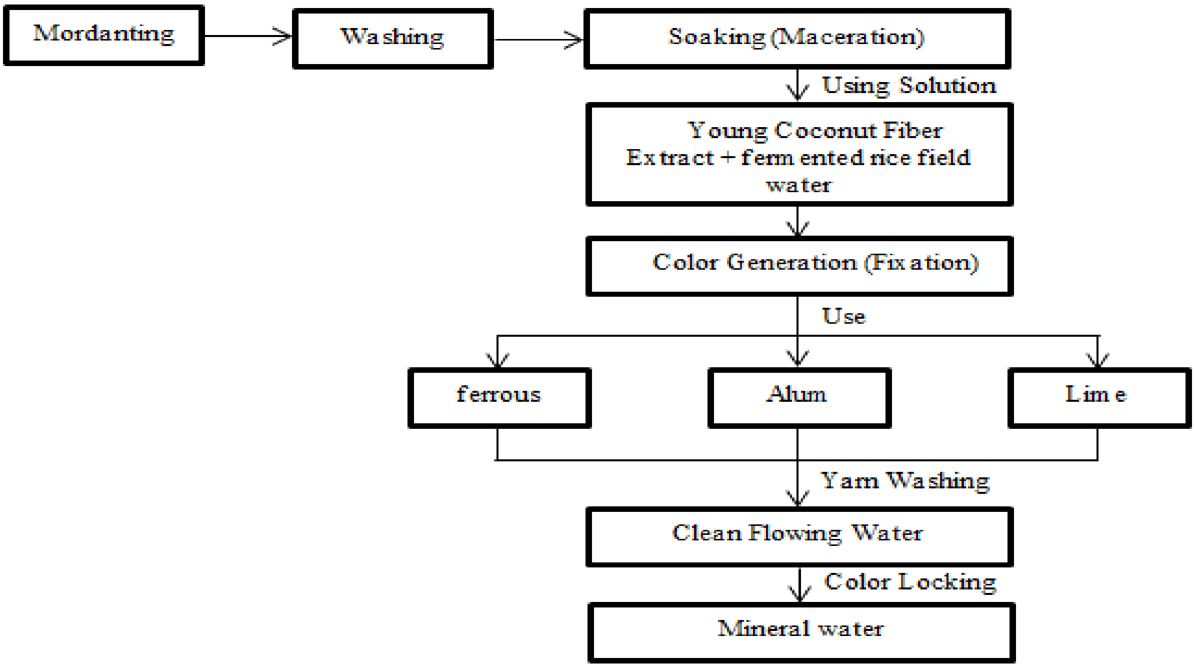


Figure 2. Coloring Stage

After preparing the tools and materials for the dyeing process, the first step is to wash the yarn with clean water. Then continue with the dyeing process through the maceration method, which is soaking the yarn in young coconut fiber extract mixed with fermented rice field water for 110 hours or 5 days. This soaking is intended so that the natural dye can be absorbed into the silk thread. After the soaking period is complete, the silk thread is dried in the sun until dry. The next step is the fixation process or color generation on the yarn using ferrous sulfate, alum, and lime. This stage is carried out to obtain dyes with good fastness. In this process, the silk thread is dipped into a solution of ferrous sulfate, alum, and lime 6 times, then washed with clean water and dried in the sun until dry. The final stage is locking the color on the yarn that has been dyed by washing it using mineral water with a pH of 7.6, then dried in the sun until dry. This locking stage is important to ensure that the color produced from the dyeing process can last a long time.

Silk thread dyeaing results

After going through the extraction and coloring stages, the results of the coloring on the silk thread are obtained. The coloring produces 3 different color variations, which appear due to the use of ferrous sulfate, alum, and lime at the fixation or color generation stage. The results of the coloring can be seen in Figure 3.

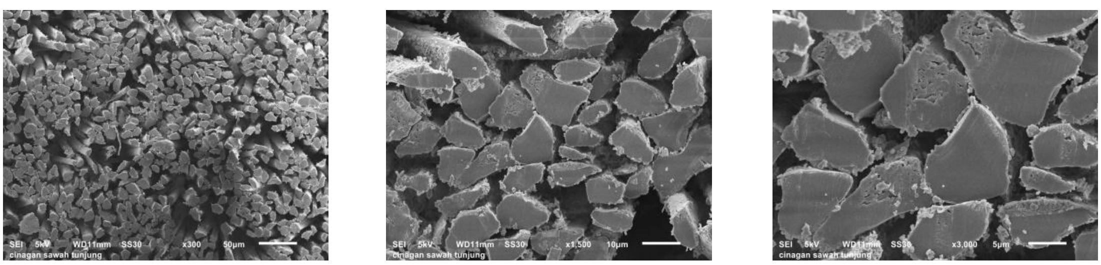
(a) (b) (c) (d)

Figure 3. Dyeing Results on Silk Thread Information**:** (a). Original Silk, (b). Extraction of Young Coconut Fiber, Fermented Rice Field Water and Ferrous Sulphate, (c). Extraction of Young Coconut Fiber, Fermented Rice Field Water and Alum, (d). Extraction of Young Coconut Fiber, Fermented Rice Field Water and Lime

Dyeing using young coconut fiber extract with Fermented Rice Field Water solvent, combined with a color generation process using ferrous sulfate, alum, and lime, produces different color variations. Silk thread processed using the extract and then raised with ferrous sulfate produces a brownish black color. Meanwhile, silk thread that is raised using alum after going through the same extract process produces a gray color. Meanwhile, silk thread that goes through the dyeing stage with the same extract but raised with lime produces a brown color.

Silk thread structure test results

The yarn structure test was conducted using a Scanning Electron Microscopy (SEM) tool. The SEM tool was chosen because this microscopy technique uses electron beams to produce images of the sample surface with very high resolution. In yarn structure testing, SEM is used to observe very small yarn surface details. The results of the yarn structure test can be seen in Figure 4 .



(a) (b) (c)

Figure 4. Silk Thread Structure Test Results
Description: (a). SEM photo at 300 X magnification, (b). SEM photo at 1,500 X magnification, (c). SEM photo at 3,000 X magnification.

From Figure 4 above, it can be seen that the yarn structure test was carried out using a Scanning Electron Microscopy (SEM) tool with a magnification of 300 X, 1,500 X and 3,000 X. The results of the yarn structure test show the cross-sectional shape of the fermented rice field water yarn. The cross-sectional shape of the silk is triangular or angular which causes the appearance of the silk yarn sample with shiny results. It is also known that silk yarn that has gone through the dyeing process does not change the cross-sectional shape of the silk yarn. These results can be concluded that silk yarn that has gone through the dyeing process does not change the cross-sectional shape and still has shiny results.

Silk thread tensile strength test results

Tensile strength test is a common method used to measure the mechanical properties of yarn. This test aims to determine the resistance of the yarn to pulling. In this test, the sample used is silk yarn that has been dyed using young coconut fiber extract with fermented rice field water solvent and has gone through a fixation process using ferrous sulfate, alum, and lime. In addition, original silk yarn without dyeing is also used in the test. This is done to compare the tensile strength between original silk yarn and dyed silk yarn. The results of the tensile strength test can be seen in Figure 5.

Table 1. Data on the Tensile Strength of Fermented Rice Field Water Silk Thread

Thread Types	Tensile Strength /hl, cN (g)	CV	How to Test
Genuine Silk	160 (157)	8.7 %	SNI 7650 : 2010 Clamping distance 250 mm Statimat Tester
Fermented Rice Field Water Ferro Sulfate	190 (194)	11.8 %	
Fermented Rice Field Water Alum	233 (238)	10.9 %	
Fermented Rice Field Water Lime	220 (224)	8.4 %	

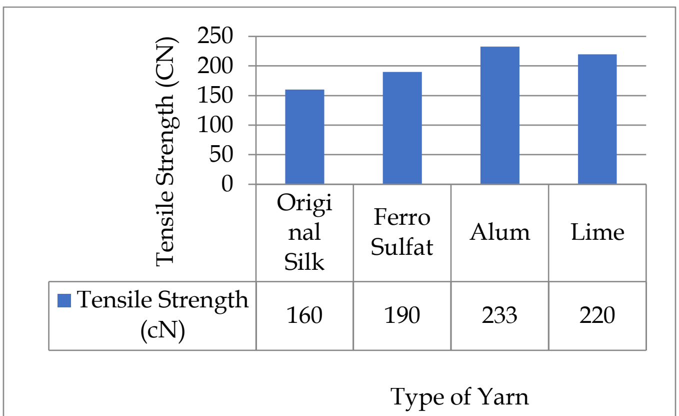


Figure 5. Tensile Strength Test Results

The results of the tensile strength test on silk threads that went through the dyeing process using young coconut fiber extract with fermented rice field water solvent and fixation using alum had the highest tensile strength compared to threads fixed using tunjung and chalk. The picture shows that the original silk thread has a tensile strength value of 160/g, while the thread with alum fixation reaches 233/g, showing a significant increase. The thread fixed with ferrous sulfate and chalk each has a value of 190/g and 220/g.

Silk thread elongation test results

The elongation test of silk thread is a test method to evaluate the strength and tenacity of the thread. Silk thread, which is known for its strength, needs to be tested to ensure its quality. The elongation test method is an effective way to assess the quality of silk thread. By knowing the mechanical characteristics of silk thread, its use can be optimized. In this study, the elongation test was carried out according to the SNI 7650:2010 standard, namely using a clamping distance of 250 mm and using a static tester. The results of the elongation test can be seen in Figure 6.

Table 2. Data on the Results of the Silk Thread Elongation Test of Fermented Rice Field Water

Thread Types	Stretch	CV	How to Test
Genuine Silk	5.7 %	10.8 %	SNI 7650 : 2010 Clamping distance 250 mm Statimat Tester
Fermented Rice Field Water Ferro Sulfate	6.9 %	12.3 %	
Fermented Rice Field Water Alum	7.5 %	7.3 %	
Fermented Rice Field Water Lime	7.4 %	9.2 %	

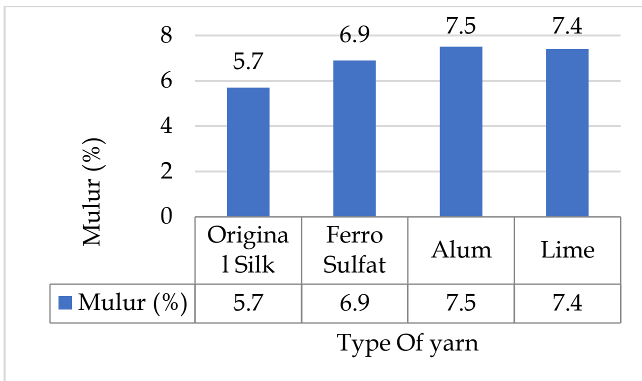


Figure 6. Creep Test Results

The results of the elongation test on silk thread that went through a dyeing process using young coconut fiber extract with fermented rice field water as a solvent and fixation using alum had the highest elasticity compared to thread that was fixed using ferrous sulfate and lime. The results of the creep test shown in Figure 6 were obtained at 7.5% alum fermented rice field water, 6.9% ferrous sulfate fermented rice field water and 7.4% lime fermented rice field water. The results obtained for the original silk thread type obtained a creep test value of 5.7%, this result was obtained because the original silk thread did not go through a dyeing process. The type of fermented rice field water ferrous sulfate, alum and lime yarn that can be seen in the picture is said to be successful in the creep test and has very good elasticity.

Results of silk thread color fastness test to washing at 40°C

The color fastness test on silk thread was carried out through a washing method at a temperature of 40°C. This test aims to measure the strength of the dye bond on the silk thread when exposed to various influences such as washing. The evaluation was carried out by observing color changes, the level of staining on cotton, and the level of staining on silk, in accordance with the SNI ISO 105-C06:2010 A2S standard. The results of the color fastness test can be seen in Figure 7.

Table 3. Data of Fastness Test of Silk Thread Fermented Rice Field Water

Thread Types	Fastness Test Results			
	Change Color	Desecration On Cotton	Desecration of Silk	How to Test
Genuine Silk	4 - 5	4 - 5	4 - 5	SNI ISO 105-C06 : 2010 A2S
Fermented Rice Field Water Ferro Sulfate	3	2	2 - 3	
Fermented Rice Field Water Alum	2 - 3	3	3	
Fermented Rice Field Water Lime	2 - 3	2 - 3	2 - 3	

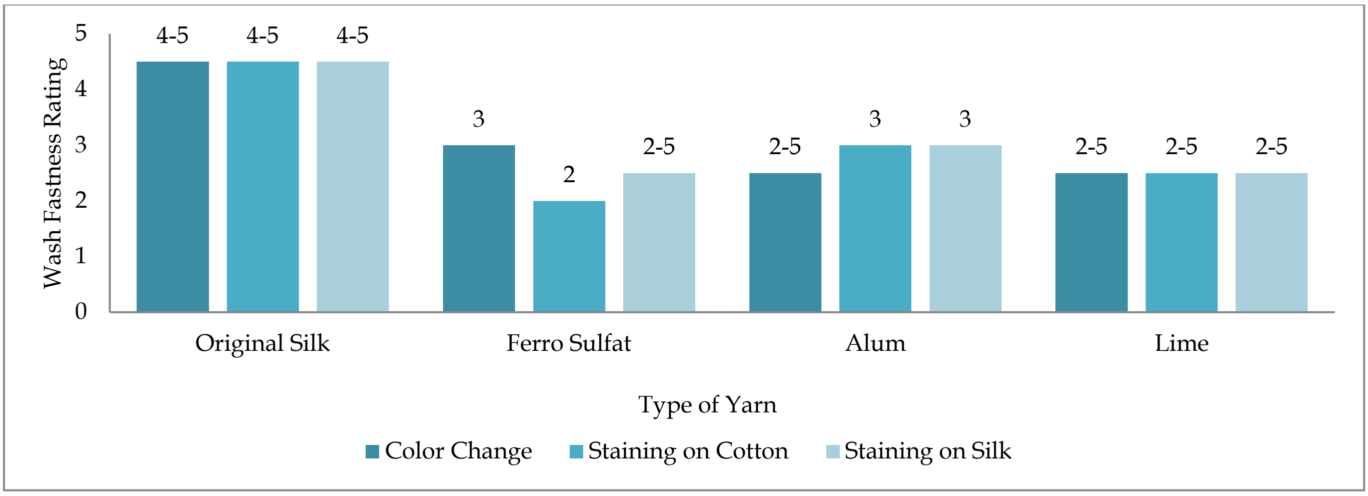


Figure 7. Fastness Test Results

The results of the color fastness test to 40°C washing on fermented rice field water silk yarn can be seen in Figure 7. The color fastness of the original silk yarn is no change with an average value of 4-5, this is because the original yarn does not go through a coloring process using young coconut fiber extract with fermented rice field water solvent. On the fermented rice field water ferro sulfate yarn with a color change test gets a value of 3, on the staining test on cotton gets a value of 2 and the staining on silk gets a value of 2-3. On the fermented rice field water alum yarn with a color change test gets a value of 2-3, on the staining test on cotton gets a value of 3 and the staining on silk gets a value of 3. On the fermented rice field water lime yarn with a color change test, staining on cotton and staining on silk gets a value of 2-3.

Discussion

The use of young coconut fiber as a natural dye shows great potential in the local textile industry. The results of the study showed that young coconut fiber extract combined with Fermented rice field water can produce effective organic dyes for silk yarn. This study is in line with the findings of Adeel, (2022) who stated that natural dyes from agricultural waste materials such as coconut fiber have the potential as an alternative to environmentally friendly synthetic dyes. Extraction of young coconut fiber with Fermented rice field water solvent produces color pigments that can adhere to silk fibers, providing different color variations depending on the fixative used(Pandit & Teli, 2022).

The maceration process for 110 hours (5 days) has proven effective in maximizing the absorption of dyes in silk threads. In this study, the use of a fairly long soaking time allows the color pigments from young coconut fibers to optimally penetrate into the silk fibers. These results support the research of Khatun & Mostafa, (2022) which states that the duration of soaking has a significant effect on the color intensity produced on fabrics with natural dyes. The maceration method carried out by routine turning every day also ensures even color absorption in the yarn, resulting in consistent dyeing quality (Uddin et al., 2022).

The color variations produced through the fixation process with ferrous sulfate, alum, and lime show the flexibility of natural dyes from young coconut fiber. Based on the results of the study, fixation with ferrous sulfate produces a brownish black color, alum produces a gray color, and lime produces a brown color. This color variation is in line with the research of Repon et al., (2024) which shows that the use of different mordants in natural dyes can produce a diverse color spectrum from one dye source. The ability to produce various colors from one natural dye source increases the economic and applicative value of young coconut fiber as a textile dye.

The yarn structure test using Scanning Electron Microscopy (SEM) proved that the dyeing process with young coconut fiber extract did not change the physical structure of the silk thread. The cross-section of the silk thread maintained a triangular or angular shape which gave a shiny effect to the thread. These results are consistent with the research of Pizzicato, (2023) which stated that natural dyes tend to be more friendly to the fiber structure compared to synthetic dyes which can cause damage to the fiber structure. Preservation of the original structure of the silk thread after the dyeing process is an important advantage of natural dyes from young coconut fiber, because it maintains the quality of the textiles produced.

The tensile strength test showed encouraging results where silk yarn dyed with young coconut fiber extract had higher tensile strength compared to original silk yarn. Yarn with alum fixation showed the highest increase in tensile strength (233g) compared to original yarn (160g), ferrous sulfate fixation (190g), and lime fixation (220g). This increase in tensile strength is in line with the research of Luo & Zhang, (2021) which found that several types of natural dyes can increase the tensile strength of fibers through chemical interactions between the dye and the fiber structure. This phenomenon of increasing tensile strength shows the added value of dyeing using young coconut fiber extract which not only provides color but also improves the mechanical quality of the yarn (Mishra & Basu, 2020).

The elongation test on silk yarn also showed an increase in elasticity after the dyeing process. Silk yarn with alum fixation had the highest elongation value (7.5%) compared to the original yarn (5.7%), ferrous sulfate fixation (6.9%), and lime fixation (7.4%). These results support the research of Ragab & Hassabo, (2021) which found that the mordanting and natural dyeing processes can modify the mechanical properties of fibers, including their elasticity. Increased elasticity in dyed yarn is an advantage in textile applications, especially for products that require flexibility and resistance to stretching, such as woven fabrics (Hassan et al., 2024).

The results of the color fastness test to washing at a temperature of 40°C showed that silk yarn with natural dyes from young coconut fiber had quite good color fastness. Yarn with ferrous sulfate fixation showed color change resistance with a value of 3 (quite good), while yarn with alum and lime fixation had a value of 2-3. Although this value is lower than that of the original yarn (4-5), this result is still acceptable for natural dyes. This finding is in line with the research of Islam et al., (2024) which observed that the color fastness of natural dyes is generally lower than that of synthetic dyes, but can be improved through proper fixation techniques. The color locking process using mineral water with a pH of 7.6 in this study is an effort to improve color fastness.

Overall, this study proves that young coconut fiber has great potential as a source of organic dyes for textile applications, especially in silk yarn. The combination with paddy water and proper fixation techniques not only produces attractive color variations but also improves the mechanical properties of silk yarn. These results support the research of Agustarini et al., (2022) which emphasizes the importance of developing local natural dyes as an effort to preserve culture and develop a creative economy based on local resources. The use of young coconut fiber as a natural dye is also in line with the global trend towards more sustainable and environmentally friendly textile products, opening up opportunities for the development of high-value textile products by utilizing agricultural waste that has so far been underutilized (Sigaard & Laitala, 2023).

Conclusion

Young coconut fiber has the potential to be used as an organic dye for silk thread. Extraction of young coconut fiber with fermented rice field water solvent produces three color variations depending on the fixator used: brownish black (ferrous sulfate), gray (alum), and brown (lime). The dyeing process does not change the transverse structure of the silk thread so it maintains its shiny appearance. Threads fixed with alum showed the best performance with tensile strength and elasticity, much higher than the original thread. The results of the color fastness test to washing at a temperature of 40°C showed quite good resistance. Overall, young coconut fiber has proven effective for use as an alternative organic dye for silk thread.

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Author Contribution

N: preparation of original draft, results, discussion, methodology, conclusion; E. B, A. R, N. S, H and M. S: analysis, review, proofreading and editing.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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