Chapter

The Commercial Value of Mangrove-Based Pigments as Natural Dye for Batik Textiles

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Abstract

Mangrove, or bakau as it is known in Indonesia, is one of the vegetations commonly found along the shallow coasts, estuaries, deltas and protected coastal areas and are still influenced by rising tides. After the Aceh tsunami disaster, mangrove restoration was intensively conducted in coastal areas all over Indonesia and was made into a special conservation program by the government. Mangrove is distinguishable by its big, wooden stilt roots, sharpening tip in the form of supporting leaves. The roots of the mangrove tree are morphologically distinguishable into heart root which grows into the ground and the stilt root which appear to grabs onto the surface of the ground. Mangrove forests serve several important ecological roles: they act as filters which turns saline water into fresh water, buffer from seawater intrusion, prevent erosion and abrasion, hold sediments to form new habitats, feeding ground, nursery ground, and spawning ground for a number of aquatic wildlife. Mangrove forest also possess economical functions such as as source of income, industrial ingredients for the locals and as source of new mangrove seedlings. Mangunhardjo Village, Urban Community of Mangunhardjo, Mangkang Area, Kecamatan of Tugu, Semarang City, Indonesia was an area dotted with brackish water pond. However, the area had been suffering from the effects of climate change, being inundated by overflow of river and seawater intrusion (rob). These disasters caused decline in the productivity of the ponds in the area. In an effort to combat the adverse effect of environmental change in the area, the locals of Mangunhardjo village decided to shift their livelihood by restoring the surrounding mangrove forest. Mangrove conservation at Mangunhardjo Village was conducted through activities of the program such as mangrove planting, mangrove-based food production, and mangrove waste management by applications of bioactivator bacteria for mangrove composting and production of mangrove-based natural dye for batik fabric. Mangrove-based natural dye for batik fabric from *Rhizopora mucronata* mangrove waste is a quite promising product and increases people's income.

Keywords: batik, mangrove, natural dye, *Rhizopora mucronata*, waste

1. Introduction

One of the most valuable and potential natural resources in coastal areas of Indonesia is the mangrove forest. With a coastal line exceeding 80,000 km, Indonesia possesses 4.2 million ha total area of mangrove forest [1]. In 2014, the total coverage area of mangrove forest in Indonesia is 4,227,800 ha, which comprises approximately 25.79% global coverage area of mangrove forest [2]. However, mangrove forests in Indonesia continue to be threatened albeit relatively more protected as private sectors, NGOs, and environmental protection communities strive to preserve what is left.

There have been efforts to restore ecological, socio-cultural and socio-economical functions of mangrove forest, particularly in the northern coast of Java Island. One of most common restoration efforts is the replanting of mangrove trees.

Mangunhardjo Village, Urban Community of Mangunhardjo, Mangkang Area, Kecamatan of Tugu, Central Java Province, Indonesia was an area which mostly consisted of brackish water ponds. This area had been impacted by climate change, which caused yearly flood from the overflow of Beringin River and seawater intrusion (rob), reducing the production capacity of the brackish water ponds. The community in this area was affected by this condition, considering the brackish water ponds were the main source of income for many people in the area, as presented in **Figure 1**. To cope with this adversity, many people in the Urban Community of Mangunhardjo shifted their livelihood.

Most of the brackish water fish farmers became motorcycle taxi drivers, fragrant oil sellers, drinking water refill providers, fish-based food producers, mangrove tree seeders, etc. Today, what was once brackish water pond area has been turned into a mangrove forest restoration site. The existence of mangrove in the area has met the criteria of mangrove ecosystem. The ecosystem is protected from waves and currents as to support conservation of coastal areas in Semarang [3]. The shift in the socio-economic landscape of the community in Mangunhardjo Village came along with the progress of mangrove forest restoration. Once the restoration has shown viability, many in the community changed their focus on utilizing mangrove as a source of income. The restoration of the mangrove forest has had positive impact to the welfare of its surrounding community. In addition to enhancing the natural beauty and livability of the area and mitigating the negative impact of climate change, mangrove forest can provide a source of income to the surrounding community. Mangrove can provide economic benefit as the mangrove restoration project provide employment opportunity by sustainable planting and selling mangrove seedlings, producing and selling mangrove-based food, sourcing mangrove as basic materials for bioactivator in compost, and processing mangrove waste into natural textile dye.

Figure 1.
The site of Mangunhardjo Village, Urban Community of Mangunhardjo, Mangkang Area, Kecamatan of Tugu, Cental Java Province, Indonesia before mangrove forest restoration (a) and after mangrove forest restoration (b).

2. Mangrove tree planting

Due to the decrease in productivity of brackish water pond, the community of Mangunhardjo, Semarang, took part in mangrove forest restoration project. This activity involved almost everyone from all ages in the community. In addition to plating the mangrove used to alleviate ecological stress through enhancing biodiversity by conservation activities, the local community also nurse seedlings to be sold all over the country. Today, ecosystem of mangrove forest and its diverse plant and animal life strives in Mangunhardjo village. Healthy mangrove ecosystem provide shelter and feeding ground for various marine life, such as fish, prawn and crab, which in turn provides additional source of income for the surrounding community.

3. Mangrove-based food

Mangrove fruit can be processed into snacks and food, such as chips, syrup, brownies, klepon, sticks and other kind of snacks. The species used in making food are Lindur (*Bruquiera gymnorrhiza*), Api-api (*Avecennia sp*), and Pidada (*Sonneratia sp*), (*Rizhopora sp*) Lindur fruit is rich in carbohydrate, higher than that of rice. Mangrove fruit has tannin content, which gives it a bitter taste. To lower its tannin contents, the fruits are boiled or immersing overnight, before they are processed. Boiling or immersion has proven to reduce the tannin content of mangrove fruits by 40%. The fruits are also made into flour, to preserve its quality. Storing mangrove fruits as flours halts its metabolism and giving it a longer shelf life due to the lack of water, making it a viable ingredient for various food.

R Mangrove-based food made and marketed by women of the fishing community of Mangunhardjo village are chips, syrup, sticks, klepon, and cakes, as presented in **Figure 2**.

Figure 2.
Cookies made from Avecenia mangrove fruit.

4. Mangrove-based bacterial bioactivator for composting

Microorganisms associated with mangrove waste synthesize secondary metabolites similar to their host. These microbes are viable source of new compounds. Symbiont bacteria of mangrove waste are bacteria which thrive in association with mangrove waste. These associated bacteria contribute in the cycle of nutrition of its host and are decomposing agents for the waste. Compounds produced by symbiont bacteria has the potential to be used as precursors for the biosynthesis metabolism of immunity against pathogenic bacteria and other predators [4]. Microbes are the most numerous of all the organisms living on water, and as symbiotes of other organisms [5]. One way that bacteria contributes to its ecosystem is to act as a decomposer in breaking down organic materials such as dead leaves around mangrove plants. Due to bacterial activities, dead mangrove leaves are eventually broken down into nutrition. One of the processes in mangrove ecosystem which significantly contribute to the biodiversity in the water is decomposition, or specifically, the disintegration of mangrove leaves into nutrition. Disintegration is a step in the decomposition process, which in turn will produce important nutrients within the food chain, through the productivity of the surrounding waters [6]. Decomposition bacteria are groups of bacteria with the capability of decomposing other dead microorganisms into its basic building blocks, all of which will return to the environment. These decomposition bacteria are categorized into saprophytic organisms, due to its ability to break down organic compounds in nature. Saprophytic bacteria break down dead plants or animals and remains or waste of other organisms [7, 8]. Mangrove waste is a supply of organic materials to mangrove ecosystems, which maintains the carrying capacity of the surrounding area [9].

Microbes isolated from plants with bioactive compounds have been known to have similar compound to its host and, in some cases, even indicate greater activity than that of its host [10]. A study on symbiont microbes with bioactivator potential found four viable species, namely Pseudomonas sp., Flavobacterium sp., Acinetobacter sp., and Bacillus subtilis. The consortium of the 4 species can act as organic waste decomposer and restore the color and odor of fresh water [11]. The symbiont bacteria from mangrove waste have seen application in bioactivator products which has been used by the community in Urban Community of Tembalang, Semarang, Central Java to process organic waste into compost, as presented in **Figure 3** below.

Figure 3.
Liquid Bioactivator products from symbiont bacteria of mangrove waste, which are used in making compost.

5. Using mangrove waste as natural textile dye

The latest development in fashion industry sees a demand for breakthrough from designers and scholars to create textile materials and clothes that are creative, innovative and marketable. Batik, as one of the most sought after fashion products in Indonesia, are mostly made using synthetic dye. Synthetic dye has its advantages, namely its availability, range of colors and the practicality of its application. However, the use of synthetic dye pose health risk of consumers, and even greater threat to the environment. Due to its carcinogenic nature, the use of these dyes in fabric may trigger allergy reaction. The process by which these dyes is made also presents environmental hazards. Therefore, there is an opportunity to reintroduce natural dye as a safer, more environmentally friendly alternative. Batik clothes and fabric made using natural dye have high commercial value because of its artistry, unique colors and the sustainability by which they are made and sourced. The use of natural dye in batik also give impressions of ethnic-look and exclusiveness.

Rhizophora mucronata is one of the potential mangrove species to be used in the production of natural dye. Other than being an important species for the mangrove restoration project in Mangunhardjo village, Semarang, *R. mucronata* still sees limited utilization by the surrounding community. Yet, parts of mangrove have been known to be used as natural dye in several other areas in Indonesia such as Papua and Takisung. [12] mentioned that *R. mucronata* is a natural tanning agent commonly used in textile industry and can produce color variation depending on the mordant used. A number of studies also indicate the potency of *R. mucronata* as dye material. In Bontang, Borneo, fruit of *R. mucronata* is used as a material in dye production for the local industry [13]. One study also found that natural dye made from *R. mucronata* passed the quality test with a predicate of 'fine' [14]. Although color pigments of *R. mucronata* parts can be sourced as a material for natural dye, there are more color variation and and ways to retain colors that has yet to be tested.

Pigments of *R. mucronata* is a unique potential of this species of mangrove. The pigment content can become an asset through effective and efficient utilization, which can provide economic value to the community around mangrove ecosystem. Therefore, further studies on pigments of bark, propagules, and leaves of *R. mucronata* in relation to their application in batik as dye materials.

Batik has experience a rise in popularity among both the locals and foreigners in the last few decades. The increasing demand of batik products also creates increasing demand for and use of synthetic dye. This is due to the fact that synthetic dyes are marketed at a lower price point and have better color retention compared to natural dyes. However, as more and more consumers become more aware of environmental issues, fabrics with natural dyes becomes more popular in the market. Synthetic dye has been known to be carcinogenic, and the waste from its production poses danger for the environment. [15] mentioned that synthetic dye is mutagenic and non-degradable in nature. Orange II is one example of the most prevalent artificial dye in the industry. This artificial dye has been known to not easily broken down by natural means. The waste from production and use of synthetic dyes has also been known to contain high levels of heavy metals such as chromium, zinc, copper, etc. [15, 16] wrote that waste water from textile production activity was found to pose health hazard to the surrounding community in Palembang, due to its high content of corrosive chemicals, organic pollutants, and high levels of acidity in its waste. Pollutants from synthetic dye production and use contains high leves of heavy metals, and intermediate dyes which are mutagenic in nature [17]. Not only does this damage the environment, it also pose health hazard to the community.

Compared to stock of sythetic dyes, the availability of natural dyes is more limited since artificial dyes are mass produced and have better distribution chain whereas natural dye often see limited production and must be sourced directly from its native area. Yet, not all sythetic dyes in Indonesian market is produced within the country. *R. mucronata* with its application potential as a material for natural dye can be found all over Indonesia, yet there has been limited commercial exploitation for this use. Studies of *R. mucronata* parts to be used as dyes for batik fabric are expected to contribute to the novelty of *R. mucronata* as an alternative source for dye in batik textile industry.

6. The biology of *R. mucronata*

R. mucronata is a species prevalent in the Indo-Pacific region. In Indonesia, *R. mucronata* is known locally as "Bakau Hitam" (lit. Black Mangrove), "Bakau Korap", "Bakau Merah" (lit. Red Mangrove), "Angka Hitam", "Belukap", "Dongoh Korap", "Jankar", "Lenggayong", and "Lolaro". This mangrove often become the choice plant in mangrove restoration programs [18].

R. mucronata is classified into the genus Rhizophora. One distinguishing feature of this species is its broad leaves. There are two other species within the Rhizophora genus, namely *Rhizophora apiculata* andRhizophora stylosa along with two hybrids, namely Rhizophora lamarckii (a hybrid between *R. apiculata* and R. stylosa) and Rhizophora annamalayana (a hybrid between R.apiculata and *R. mucronata*) [19].

The tree of *R. mucronata* can reach a height of 30 meters. The trunk diameter can grow up to 70 cm with bark which is dark, mostly black and a horizontal crevice. Stilt roots and aerial roots grow on the lower branches of the tree. The stilt roots can be quite sizable and are woody. The stilt roots of *R. mucronata* are usually abortive, whereas the lateral roots can be quite numerous in one tree and extend from the tip of the branch as well as possessing numerous branches on itself, which are also known as stilt roots/hoop/pile-like which supports the tree. Aerial roots can sometimes be found in the lower branches. The trunk itself is enclosed cylindrical in form, with bark that are black or dark red, has a coarse, scaly texture, and with horizontal crevices formed around the bark [20].

The leaves of *R. mucronata* has layers with green stalks. The leaves can reach a length of 23 cm. They are typically elliptical with narrow tips. The propagules of *R. mucronata* have an egg-like shape. The color of the fruit varies from green to brownish. The base of the fruit has a coarse texture and typically monocots. When ripe, the cotyledon neck will turn yellow.

R. mucronata is a species with the highest tolerance for sandy environment, compared to other Rhizophora species. This species is commonly found in tidal area with sand substrates [21]. *R. mucronata* thrives in mud with fine, grainy soil and is believed to be one of the mangrove species capable of surviving during inundation by high tide [22].

7. Chemical composition of *Rhizophora mucronata*

Mangrove commonly contains compounds such as alkaloid, flavonoid, phenol, terpenoid, steroids, and saponins [23]. Proximate analysis of *R. mucronata* fruit by [24] found that there were 46.63% of water, 1.96% of fat, 0.41% of protein, 1.25% of ash and 22.29% of carbohydrate. [25] identified the phytochemical contents of *R. mucronata* bark, and found Positive results on phenolic compounds (including flavonoid and tannins), and believed that the tannins are drawn in the methanol extract with testing using FeCl3. In addition to phenolic group compounds, secondary metabolites such as terpenoids/steroids, alkaloid and saponins were also found in the bark of *R. mucronata*, only in this study the results were obtained by the use of multiple solvents (ethyl acetate and methanol) and varying reagents.

The leaves of *R. mucronata* was indicated as the most effective part to be used in extraction process [26]. It was found that the leaves of *R. mucronata* are rich in phenolic compounds, consisting of several flavonoid, phenolic acids, and tannin [27]. *R. mucronata* leaves contains dihydroflavonol with free 5-OH and 7-OH, with restored raffinose at 3-OH, caffeic acid, vanillic acid, p-hydroxybenzoate acid, and tannin, believed to be catechin tannin. [28] elaborated that the extract of *R. mucronata* leaves, both fresh and dried, and extracted using sterilized distilled water contains the following phytochemical constituents: alkaloid, carboxylic acid, coumarin, flavonoid, phenol, protein, amino acid, quinone, resin, saponin, steroids/phtyosterols, tannins, xanthoprotein.

8. The use of *Rhizophora mucronata*

In Madagascar, the wood of *R. mucronata* is extensively used in making boats and fishing nets for fish and shrimps, and is domestically used as a construction material for fences, housings and cooking fuel [29]. The indigenous people of Papua has also been using *R. mucronata* as materials for fence poles, walls and boats. In addition, fruits if *R. mucronata* has been used to treat diarrhea. Whereas in general, parts of the Rhizophora tree are brewed into alcoholic drinks in the Wondama Bay area [30]. In the field of biochemistry, bark from *R. mucronata* containing polysaccharides has been used as an in-vitro treatment for human immunodeficiency virus (HIV) [31].

[32] stated that *R. mucronata* is one of eight types of sources for natural dye used by the people of Papua. This species is used for several purposes such as a material for dye, food ingredients, and cosmetics [33]. *R. mucronata* bark from Takisung area has been used for dyeing batik cloth [34]. [35] wrote that *R. mucronata* bark, which has a natural brown pigment, is used as a textile dye because its tannin content reaches 30%. [36] successfully used the stem and leaf waste of *R. mucronata* as a natural dye for batik on cotton and silk fabrics.

9. Batik

Batik is a form of textile product that are generally used in the form of various crafts, tablecloths, sheets, and clothing. In 2009, UNESCO awarded Indonesian Batik as an Intangible Cultural Heritage of Humanity. The uniqueness of batik products are often found in their style, use, and design which are not only attractive to the local market, but also to the international market. In the period between January to June 2014, Batik became one of the commodity groups that had the highest export value in Central Java, compared to the other two commodities, namely textiles and textile goods. Textile and textile goods have the largest contribution of 36.84% of total export value or approximately US$189.01 million. This export value shows that textiles and textile products in Central Java have a huge potential as a contributor to the country's foreign exchange.

10. Textile dye

Color becomes visible to the eye when there is absorption of a portion of the color spectrum in the visible area by molecules. The molecular structure is responsible for the presence of compounds that absorb visible light, which will be interpreted as colors. Molecules in plants consist of chains of carbon, oxygen, and hydrogen as main compounds and a few additional heteroatoms such as nitrogen. Molecules that absorb visible light are filled by chains of alternating and single carbon bonds that are alternating or conjugated. The longer the double bond, the more vivid the colors will appear. This bond can absorb visible light in certain areas, which provides coloration to the compounds [37].

Textile dyes, based on the materials from which they are sourced, are classified into two namely Natural Dyes (ZPA) and Synthetic Dyes (ZPS). ZPA is a dye obtained from natural ingredients, which generally comes from the extracts of plants or animals. ZPS is artificial dyes or syntheses made by chemical reactions using the basic ingredients of charcoal, coal, or petroleum which are the result of aromatic hydrocarbon derivatives such as benzene, naphthalene, and anthracene [38].

The intensity of the color produced in natural dyes depends on the type of coloring matter. Coloring matter is the substance that determines the hue of natural dyes and is an organic compound. The classification of natural dyes based on coloring matter is divided into four groups namely mordant dyes, direct dyes, acid/base dyes, and laver dyes. Mordant (natural) dyes in the coloring process must be combined with a metal oxide complex to form an insoluble dye. Natural dyes in mordant dyes have good color resistance potential, for example Moridin dyes from Noni roots. Direct dyes are retained to the fabric fibers based on hydrogen bonds, making the color retention low, for example Curcumin from turmeric. Acid/base dyes consist of a combination of acid and base groups, such as flavonoid pigments. The last group is laver dye. These dyes must go through the process of reduction–oxidation (redox) in the fabric dyeing process. In addition, laver dyes are also known as the oldest dyes in the world because they have the best color retention among the three other classes of natural dyes. One example of laver dyes is Indigo from torn leaves [13]. Natural dyes that have been explored from plants and have been used in fabric coloring include sengon leaves (*Albizia falcataria*) as silk fabric dyes, mangosteen rind (*Garcinia mangostana*) as natural dyes on cotton fabrics, *Morinda citrifolia* bark on *Morinda citrifolia* cotton cloth, purple sweet potato (*Ipomea batatas*), etc. [39–42]. Extraction of natural dyes is mostly carried out using polar solvents such as distilled water, ethyl acetate, methanol, acetone and n-hexane [25, 37, 43].

11. Dye extract

In general, the results of extraction from leaves, bark, and propagules show brown color with different color density variations (**Figure 4**). The brown color indicates the presence of tannin [11]. Previous studies have found that high levels of tannin produce a dense color on tea leaves [44]. Several factors such as the extraction temperature below 100°C, the type of solvent (polar) used for extraction, particle size, and extraction time are things that need to be taken into account in producing quality tannins [45]. Tannins are found in the bark, fruit (propagules), and leaves of *R. mucronata* [46].

However, there is variation in tannin content in each part of the tree. The content of tannin *R. mucronata* has similarities with tannin derived from *Ceriops tagal* bark,

Figure 4.
Batik fabric coloring from mangrove waste extraction with lime, tunjung and alum fixations.

which is soluble in distilled water that has polar properties [47, 48]. The tannin content produced from extraction using distilled water did not differ significantly compared to other solvents with similar polarity.

12. FTIR analysis and UV-Vis spectrophotometry

UV Vis spectropometry to extracts of *R. mucronata* leaves, bark, and propagules extracted at 70°C shows the maximum absorbance located at a wavelength of 412 nm. This shows the existence of conjugated C=C and C=O bonds. The maximum absorbance value obtained at wavelengths between 300 and 550 nm indicates the presence of $\pi \rightarrow \pi^*$ denoting conjugated C=C and n transitions $\rightarrow \pi^*$ in the form of chromophore C=O [49]. Tannins are classified as natural polyphenol compounds which contain phenolic hydroxyl groups and carboxyl groups. In addition, there are also chromophore groups which generally give color to a compound. The C=C conjugated bonds and C=O are included in the chromophore group, thus supporting the notion that the brown color that arises from extraction is caused by the presence of tannin content.

Subsequent testing to see the absorption pattern using an infrared spectrophotometer. Test results on the three types of dye extracts on leaves, bark and propagules showed a similar absorption pattern. Absorption in the range of wave numbers 3500 to 3000 cm^{-1} and 2000 to 1500 cm^{-1} indicates the presence of C-H groups. The C-O group is also indicated although it must be further analyzed in the fingerprint area. The C-O group forms an aromatic compound, which is part of the tannin together with the O-H and -CH2 groups [50]. The solid-shaped extract of D_{70} shows a different absorption pattern. O-H, C-H, C=O ester, and C-O-C ether groups are indicated. The existence of these four types of functional groups shows that the flavonoid compound is indicated in D_{70} extract. This is supported by research conducted by [51] who found that the flavonoid compounds from the flavonone group had the OH functional group bound, aliphatic CH, C=O, C=C Aromatic, C-O and C-H aromatics. [52] revealed that flavonoids are building blocks of proanthocyanidin compounds which are condensed tannins. Flavan-3-ols polymer compounds consisting of (+)-catechin and (−)-epicathecin are the main constituents of the group of flavonoid compounds that fall into the category of condensed tannins. To support these findings, Total Phenol Content and Total Flavonoid Content were conducted.

13. Total phenol content and total flavonoid content

Determination of total phenol in D_{70} extract was carried out using the Folin–Ciocalteu reagent. This reagent is sensitive in reducing compounds such as polyphenols and in its reaction will show blue when measured by spectrophotometer [53]. The test results showed that the phenol content were 2.4950 mg GAE/g. The presence of phenol in the extract can be an indication of tannin. In general tannins are high molecular weight polyphenol compounds, which naturally form complexes with protein [54]. Testing of total flavonoids was also carried out and the results obtained were 0.6516 mg QE/g. Flavonoids are still included in polyphenol compounds and usually consist of flavones, flavonols, and condensed tannins, which are secondary metabolites of plants [53, 54].

14. Fabric with mangrove-based dye

Fabric dyeing using natural dyes of *R. mucronata* was done by immersing dry, white cotton fabric with the dye and then air-drying them. This step was repeated three times. When immersing the fabric into the dye solution, the fabric undergoes swelling so that the pores of the fabric fibers will open and the dye can be absorbed into the fiber together with the dye solution. Dyes that have been absorbed into the fiber will be bound by reactive groups on cellulose fibers in the form of hydroxyl groups (OH) and form hydrogen bonds. The finished dyed fabric was then aerated with protection from sun exposure. After the cloth dries, the cloth is then immersed in alum color-fixating agent ($KAl(SO4)2.12H_2O$). When dyeing, the dye is absorbed into the fabric fibers. But in general there are substances on the fabric surface that block the process, so fixation agents such as alum are needed to help the absorption of dyes on the fabric and increase color retention by binding the dye molecules to the fibers of the fabric. The reaction between the fabric which has been dyed and fixated by alum (KAl(SO4)2.12H2O) does not produce complex salts but compounds which are ionically bonded [55].

The colors produced by the three types of dyes from *R. mucronata* after fixation with alum through qualitative observations based on [56] were shades of tawny/tenné brown. The tawny brown digital code according to [57] is AE6938. Tawny brown can be described as a light brown hue with a combination of brown and orange The tawny brown color that was obtained after fixation with alum was not much different from the color before the addition of alum. This is in accordance with the nature of alum which gives out hue according to its original color [58].

15. Color retention test

The results of the color retention test of dyed fabrics from parts of the *R. mucronata* through extraction with temperature variations and fixation using alum showed permanent color properties. The value of Gray Scale and Staining Scale in the color retention test against fabric rubbing showed almost the same results, namely in the category 4 (fine) and 4–5 (fine). In the soap washing test, the average results showed 3–4 (adequate) to 4 (fine). Leaf extracts heated at 70°C (D_{70}) and bark extract heated at the same temperature (K_{70}) consistently showed a staining scale value of 4 showing the 'fine' category at three replications of the test. In general, all test results met the minimal SNI standards of 3.

Tannin commonly used as dyes are found in *Ceriops tagal* mangrove bark and can produce a brownish red color [48]. The leaves have 15% less tannin content.

Types of tannins in *Ceriops tagal* and *R. mucronata* are tannins condensed with procyanidin types. Tannin extraction from plants is strongly influenced by the composition of the solvent used [59]. The optimal solvent will be able to produce tannins in large quantities. In addition to the dyes obtained, the color retention of the fabric also depends on the fixation agent. Staining quality test results that showed the category of 'adequate' and 'fine due to the use of alum fixation, creating strong molecular bond which in turn contributes to good color retention. According to [59], the strength of the bond that occurs between fabric fibers and dyes determines the color retention during the washing process. Dyes strongly retained in the fabric fibers will create better, more vibrant colors after being washed.

16. Conclusions

Mangroves can be used as natural dyes on batik cloth, because of their high availability and positive impact on the household economy of the local community. *Rhizophora mucronata*, a mangrove species commonly found in the coastal areas of Semarang, is used in conservation efforts and beneficial in the field of fisheries. The existence of this species of mangrove forests can improve the catch and welfare of the local fishing community.

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