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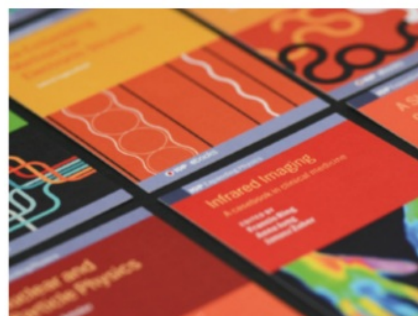
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Scientific reconstruction of indigenous knowledge of batik natural dyes using ethno-STEM approach

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Abstract: This research intended to analyze the community's knowledge scientifically of batik process and types of local plants used as natural dyes for batik colouring. The study took place at one of local batik manufactories, Zie Batik, situated in Malon Gunungpati, Semarang, Indonesia. The research instrument was observation and interview sheets. The observation of the batik making process and interview with the manufactory owner unveiled the batik techniques, tools, materials, and creative ways to produce good quality batik motifs, dyes, and calculate profit and loss. The obtained data were then analyzed scientifically through the stages of verification, reduction, validation, and conceptualization based on the Ethno-STEM approach. The analysis results revealed that there are numerous plants used in making batik that could produce color substances. Moreover, the steps of the batik process were also explained. The scientific knowledge reconstruction based on the STEM aspects showed that owners and artisans possess the proper batik techniques and methods, have creative ideas on how to produce high-quality colors and batiks, and get traditional as well as modern sales management. Scientifically, the natural dyes contain secondary metabolite compounds. Scientific knowledge in chemistry about the process of fixation, extraction, solution, alum compounds, anthocyanin, and pigments were also found in the Batik process

1. Introduction

Batik is not only one of the nation's treasures but also an attractive ethnosience subject. The word "Batik" refers to patterned fabrics that resulted from "Malam" (wax) painted on it to hold the dyes [1]. Historically, batik derives from a Javanese word "mbatik" which means painting dots using wax on a fabric. It also means as fabrics decorated with drawings painted using resist technique-wax forming lines and dots [2]. Canting is the tool to paint batik patterns. It is a kind of pen with a trapezoidal wax container at its edge, made of bamboo as the holder and brass as the vessel [3]. Every batik motif has its philosophical value and specific meaning [4]. The existence of batik has been closely related to the development of ancient empires and Islamic proliferation throughout Indonesia [5]. By the time being, batik is not only a cultural mean but also an economical drive of Indonesians.

Indonesia is rich in natural resources in which many types of plants are utilized as natural dyes besides artificial colouring [6]. There has been a change in the use of synthetic to natural colours. Recently, the



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use of natural colouring agents has been a common choice considering its minor effects on the environment, which is also in line with encouraged conservational concepts. This activity is also a sign of people's awareness of the environment, health, and market demand [7]. Natural dyes are also used by one of the batiks manufactories in Malon, Gunungpati, Semarang. Zie Batik has been employing natural dyes taken from various plants found in Gunungpati. In addition to its harmless effect, the use of natural colouring has stimulated the presence of a new business, i.e., natural dyes provider.

Other than that, the use of natural dyes for batik is also an effort to conserve Indonesians' indigenous knowledge in batik making, which has ever been nearly lost due to the existence of synthetic dyes. Since the ancient times, people have known colour-producing plants which, chemically, contain a colouring pigment such as chlorophyll, carotenoids, curcumin, anthocyanin, tannin, and flavonoids as secondary metabolites [8]. On a Natural Product subject, one of the courses in the Chemistry Department, these compounds have been the main topic to be studied. In other words, the people have had their indigenous knowledge about the local name plants and colour, extraction technique, and the preservation [9].

Batik Zie, the research site, has been using natural dyes for about ten years. An interview with Mrs Zalzila, the owner, revealed the steps of batik making starting from motif painting (or stamping), mordanting, dyeing, fixation, *pelorodan* (melting down the wax), packing, and marketing. The interviewee also stated that the dyeing process is the one that determines the quality and saturation of colour. Thus, it needs great carefulness and caution. The method, according to the interviewee, should be done in room temperature as the wax, the colour barrier is reluctant to high heat. Once the wax is melted, the colour would fuse and ruin the motif painted.

Seen from the above explanation, this research on natural batik dyes is a suitable topic for Natural Products course. An analysis of the Semester Program Plan on the subject revealed that the main issues are phenol and flavonoids. The study consists of the definitions, examples, isolation methods, colour identification, structure testing, component numbers, natural colouring agents, flavonoids manipulations, how to produce favourable natural dyes, and how to calculate the dyes' yield.

This study focused on a descriptive-qualitative analysis of the indigenous knowledge reconstruction of natural dyes through Ethno-STEM approach. Such an approach is the integration between ethnoscience and STEM (Science, Technology, Engineering, and Mathematics). The data were collected through interviews and observations conducted at Zie Batik. The data of plant species, natural dyes, isolation process, colour extraction, and batik process were drawn to be reconstructed into scientific knowledge viewed from Ethno-STEM approach.

2. Methods

This was a descriptive qualitative study analyzing people's indigenous knowledge of natural batik dyes to be reconstructed in scientific knowledge using Ethno-STEM approach. This research is an effort to supply expertise to students about people's traditional knowledge and show them how to see it from a scientific point of view. Data were collected through interviews and observations performed at Zie Batik, Malon Gunungpati, Semarang. Purposive sampling was done to select the research subjects, i.e., Mrs Zalzilah and her husband. During the interview, characteristics of natural dyes, local names of plants and the produced colours, techniques in creating tones, creative ideas to generate high-quality colours, and economic aspects were unveiled. Then, verification, reduction, validation, and conceptualization were performed to obtain proper scientific knowledge that is suitable for students' learning sources.

3. Results and Discussion

3.1. The Observation Results

The research began with collecting indigenous knowledge about natural batik dyes including the plant types and the extraction process. Further, the data obtained were scientifically examined. Figure 1 shows the observation activities to gather the data which took place in Zie Batik and the surrounded environment located in Gunungpati, Semarang.



Figure 1. (a) Research location, (b) Research Team and Mrs. Zalzilah (owner), (c) natural dyes, (d) & (e) true indigo plant, (f) the dyeing result (source: private)

The interview results informed that there are several colour-producing plants (or part of the plant) employed which include shame plant (*Mimosa pudica*), mahogany (*Swietenia mahagoni L.*) Jacq), bahera rind (*Terminalia bellirica*), sappan (*Caesalpinia sappan L.*), rambutan rind (*Nephelium lappaceum*), mangosteen rind (*Garcinia mangostana*), wild mangosteen (*Sandoricum koetjape*), mango leaves (*Mangifera indica*), avocado leaves (*Persea americana*), copper pod (*Peltophorum pterocarpum*), Javanese turmeric (*Cucurma xanthorrhiza*), noni root (*Morinda citrifolia L.*), black mangrove leaves (*Lumnitzera littorea*), true indigo (*Indigofera*), *Soga tingi* bark (*Ceriops candolleana Arn.*), *tegeran* (*Cudrania javanensis*), turmeric (*Curcuma longa*), tea (*Camellia sinensis*), jambal soga bark (*Peltophorum ferruginum*), achiote (*Bixa orellana*), teak (*Tectona grandis*), pomegranate rind (*Punica granatum*), lotus (*Nymphaea lotus*), and guava leaves (*Psidium guajava*).

According to Mrs Zalzilah, yellowish-brown is obtained from mahogany rind (*Swietenia mahagoni L.*) Jacq) while brownish-red is obtained from mahogany bark (*Swietenia mahagoni L.*) Jacq) or young teak leaves (*Tectona grandis*). Outer *Soga tingi* bark (*Ceriops candolleana Arn.*) and sappan wood (*Caesalpinia sappan L.*) produce the red colour. Reddish-purple is generated from mangosteen rind (*Garcinia mangostana*) while blue indigo is obtained from a true indigo plant (*Indigofera tinctoria*). Reddish-brown is extracted from copper pod (*Peltophorum pterocarpum*), and black is derived from lotus (*Nymphaea lotus*). Light brown is generated from died mahogany wood, and yellow is obtained from bahera (*Terminalia bellirica*) and pomegranate (*Punica granatum*) rind. Natural textile dyes are commonly derived from extraction of part of plants such as root, wood, leaf, seed, of a flower [10]. The interview results also informed that colour mixing is needed to get excellent colour.

Scientifically, those plants could result in colours since each of them has a unique organic compound which could not be found in non- colourant organic compounds. Dyes are organic compounds with double bonds in their molecular structure. This double bond causes dyes to have colour as electrons absorb energy from light in the visible spectrum, that is at the intermediate wavelength of 400-700 nm. These substances carry shades because they have one chromophore group structure (colour carrier group). The chemical structure of dyes also has a conjugated system, that is, structures with double and

single conjugated bonds. Electrons can resonate, and this is the strength of stability in organic compounds. When one of these features is lost, the colour will disappear (unstable). Besides chromophore, most dyes also contain groups known as auxochromes (colour assistants), for example, carboxylic acid groups (COOH), sulfonic acid, amino, and hydroxyl (OH) groups. This auxochrome is not responsible for the colour agent yet can shift its original colour and act as a substance affecting the polarity of the dye. Electron resonance causes dyes to absorb light and produce colours that can be detected by human eyes.

Table 1 informs the relationship between wavelength and visible light that can be observed by the colour substance.

Table 1. Color Wavelength Absorption, Absorbed Color, and Detected Color

Color Wavelength Absorption (nm)	Absorbed Color	Detected Color
400-435	Violet	Green-Yellow
435-480	Blue	Yellow
480-490	Green-Blue	Orange
490-500	Blue-Green	Red
500-560	Green	Purple
560-580	Yellow-Green	Violet
580-595	Yellow	Blue
595-605	Orange	Green-Blue
605-700	Red	Blue-Green

Chromophore groups of dyes include anthraquinone, emetine, phthalocyanine, azo, and triaryl methane compounds. The Chromophore group in the dyestuff is shown in Figure 2.

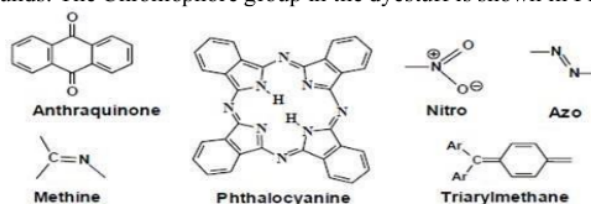


Figure 2. The Chromophore cluster serves to provide electrons for double bonds that can absorb light at certain wavelengths.

Table 2 shows several chromophore's chemical structures contained in local color-producing plants.

Table 2. Names and Chemical Structures of Chromophore

Name	Chemical Structure
1 Nitroso	NO or (-N-OH)
2 Nitro	NO ₂
3 Azo	-N=N-
4 Ethylene	-C=C-
5 Carbonyl	-C=O
6 Carbon Nitrogen	-C-NH or C-H=N-
7 Carbon Sulphur	-C=S or -C-S-C-S-

3.2. The Batik Process at 'Zie Batik'

The making of batik starts with preparing plain fabrics. Almost always the original cloth is white or beige. Motifs are drawn using a pencil. After finishing drawing, each cloth is hung on *gawangan* (two

poles connected by wooden bars at the end). Melt the wax over low heat. Once the wax has been melted, use canting to draw on the cloth by following the initial pencil sketch. This process is intended to keep the drawing from dyeing as the motifs will have different colours. The wax-drawing has to be done carefully so that no drip falls on the fabric as it will affect the final result. After all the motifs are covered by wax, the colouring process is carried out.

The dyeing process begins with preparing the colouring agent in a bucket. Dip the fabric in it. In this first dye bath, the area of the cloth where the wax was applied will remain white. Then, the second application of wax is applied. Poorer quality of wax is usually used to cover larger areas of the cloth. The darker colour helps to differentiate it from the first wax applied. Any parts that are covered with this wax application will be in colour got from the first bath. Next, the cloth is dyed in the second dye bath. After that, all the wax that has been applied thus far is removed. This can be done in several ways; heating the wax and scraping it off, applying hot water and sponging off the remaining wax, boiling the fabric in water-soda ash, or smearing petrol and ironing the cloth to remove wax. Among those ways, the boiling and smearing have been the two most common removals done by traditional batik artists. The wax covering, dye bath, and wax removal is done repeatedly until the desired colouring is obtained. The more various the colours, the longer the dyeing process. For instance, if batik cloth is expected to have five different colours; the process will be repeated five times. Once it all finishes, the last step is washing and drying the fabric. This process takes a quite long time, i.e., about 2-3 months depending on the motif complexity.

3.3. *The Analysis of Batik Process based on the Ethno-STEM Aspects*

The data of batik process were reconstructed scientifically from Ethno-STEM context [11]. The analysis results are as follows:

- Aspect of Science.* There are several points of the science aspect observed during the batik process.
- Fabrics. Cotton are the standard choices. Scientifically, fabric consists of polymer compound [12]
 - Wax. The wax applied on the fabric comprises paraffin, nitro and animal fat which are non-burning substance [13]
 - Dyestuffs. Natural colors are obtained from the extraction of root, leaf, wood, bark, flower, seed, fruit, or rind. Scientifically, all those natural materials have pigments like chlorophyll, carotenoids, tannins, anthocyanins [14].
 - Batik process. The knowledge of batik making has been inherited for decades and widely known as one of the national's treasures.

Aspect of Technology. The tools and materials used in making batik are all traditional. Both painting and stamping technique do not require advanced tools yet preserve the hereditary essence of batik.

Aspect of Engineering. The drawing, stamping, dyeing, wax covering, and wax removal are techniques in batik making process.

Aspect of Mathematics. To save the production cost, the interviewee stated that she plants true indigo by herself as it can survive for five years. Other than that, the owners have cooperated with surrounding residents to grow, produce, and sell indigo coloring/ true indigo seed. 1 kg of true indigo costs IDR 1.000.000. In other words, the batik manufactory has stimulated the establishment of other businesses.

3.4. *The Reconstruction of Scientific Knowledge of Natural Dyes*

This part focused on the scientific reconstruction of knowledge contained in the dyeing process.

3.4.1. *Mordanting*

Mordanting is the giving of metal elements so that the dyestuff is firmly bonded to the fabric fibers. The materials used are a mixture of alum, soda ash and water.

3.4.2. *Extraction*

The extraction process depends on the materials used whether it is leaf, bark, seed, fruit, rind, or root. However, Mrs Zalilah, the interviewee, stated that the process could be done through boiling. The steps

are as follows: (1) prepare 1 kg of leaf/bark/seed/fruit/rind/root in a big vessel; (2) add 5-10 liters of water; (3) heat to boiling; (4) keep it bubbling for about 1 hour; (5) rest the mixture for about 1 hour; (6) strain the mix; (7) the dye liquid is ready to use. This process covers scientific knowledge of isolation and extraction process, i.e., the taking of natural compound of secondary metabolite using solvent, dissolution, heating, and filtration which highly depend on temperature [15].

3.4.3. Dyeing

In the process of batik, the steps of dyeing are: (1) wet the mordanted using TRO solution (Wetting Substance); (2) prepare water solution of natural dyes in a dip of \pm 2-5 liters for dyeing 2-3 meters of cloth; (3) do dyeing cloth in natural dyestuff solution; (4) dry the cloth; (5) repeat at least 3 times or until the desired colour saturation level is obtained.

3.4.4. Fixation

The fixation aims at locking the colour substance, reinforce colour, and give different effect according to the fixation substance. The steps are: (1) solve 70 gr of alum ($KAl(SO_4)_2$) in 1 liter of water, stir, and set for 24 hours; (2) solve 2 gr of calcium ($CaCO_3$) in 1 liter of water, stir, and let for 24 hours; (3) solve 30 gr of iron ($FeSO_4$) in 1 liter of water, stir, and set for 24 hours; (4) soak the dried fabric in the desired fixation solution. Alum will give a yellowish tone, and calcium will result in a darker-bluish tone. Similar to this, iron will strengthen a dark colour.

4. Conclusion

The observation and interview results revealed that there are numerous plants that could result color substances. Furthermore, the steps of batik process were also unveiled. The scientific knowledge reconstruction based on the Ethno-STEM approach showed that the batik manufactory owners and craftsmen know the proper batik techniques and methods, have creative ideas on how to produce high quality colors and batiks, and possess traditional as well as modern sales management. Scientifically, the natural dyes contain secondary metabolite compounds. Scientific knowledge in chemistry about the process of fixation, extraction, solution, alum compounds, anthocyanin, and pigments were also found in Batik process.

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