Study on East Sumba-originated natural pigments for coloring woven fabrics

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Abstract. East Sumba Regency has long been renowned as the production site for tightly woven items. These woven items afford high economy values, since they are produced with natural-coloring stuffs (renewable-pigments). Pigment-producing plants serve as one of valuable natural sources, which afford beneficial potency for coloring textiles in Indonesia, especially in developing products that sound “back-to-nature”. Relevantly, this research aimed to conduct technical assessment and processing of pigment-producing plants associated with natural coloring-agents for fabrics in East Sumba. The methods employed in-depth interviews with various parties, who played essential roles in processing of natural pigments from plant sources; pigment extraction; and chemical tests. Results revealed that utilization of natural pigments still kept going on nowadays by the community in East Sumba to produce tight-woven items. Extraction technique of natural renewable-pigments was still very simple by immersing pigment-producing plants in water. Likewise, so was the technique for coloring threads/yarns with natural pigments by dipping and immersing methods. There were three kinds of plant-derived natural pigments utilized most by the community, with their plant species origins comprising Wora/Nila (Indigofera erecta Thunb), Kambu (Morinda cf.citrifolia L.), and (Symlocos cochinchinensis (Lour.) S. Moore). Further, extraction technique using hot water brought out higher yields of extracted pigments and better fabric-coloring qualities. Activities of tight weaving were commonly used as additional income source. Besides taking considerable time for pigment production process, recipient markets were still not appropriately available. Moreover, currently raw material source for natural pigment became more difficult to obtain. Accordingly, a part of the community began mixing natural pigments with synthetic pigments. In future, pigment-producing plants should be cultivated more seriously to maintain natural-pigment stocks.

1. Introduction

Forests can provide various essential necessities for persons, beginning from food items to board products and clothes. One of the related supporting sources in producing clothes is coloring agents (pigments). Renewable natural pigments could be obtained from plants/trees; and unfortunately, most of the pigments have been produced synthetically. About natural pigments in accordance with the Regulation by Forestry Minister (No. 35/Menhut-II/2007) [1] regarding Non-Timber Forest Products, it was mentioned that there were 21 kinds of natural pigments originated from forests [2].

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Natural pigments from plants could serve as renewable natural resources, which afford valuable potency in their uses as coloring agents for textiles in Indonesia particularly in developing products, associated with the motto “back to nature”. Generally, products derived from renewable natural sources perform better than those produced synthetically, with respect to product qualities, yields, and environmentally friendly impacts [3].

In another side, the use of synthetic pigments in the coloring process for textiles/fabrics could bring about environment problems, because several synthetic pigments contain heavy metals which are harmful, dangerous, and severely polluted. Those metals are among others Cu, Ni, Cr, Hg, and Co [4]. Those pollutants finally might be just discarded to the public effluent stream, thereby contaminating the environments, particularly water-stream environments [5,6].

Natural pigments for textile items are usually obtained by extracting various parts of plants such as roots, woods, barks, leaves, and seeds as well as flowers, which further brings out the so-called extract results. Processing or removing natural pigments is usually conducted through two methods, which consist of extraction and fermentation [7].

One of pigment-producing plant species, from the natural pigments has been extracted and then utilized a lot by local community is the so-called Nila (*Indigofera tinctoria*). This Nila derived natural pigment is already popular and used as coloring agent for tight-woven fabrics in Sumba Island, as batik-fabric coloring in Jogyakarta, and as ulos coloring in North Sumatra. Despite those conveniences, unfortunately use of plant-derived natural pigments currently tends to be abandoned due to the presence of synthetic pigments as coloring agents. Actually, use of renewable natural pigments could bring several advantages, as they were more secure in their uses, more attractive to worldwide markets, and more environmentally friendly [8].

Amutha et al. [9] have identified two natural dyes extracted from the fruits of *Terminalia arjuna* and *Thespesia populnea* trees. Both the dyes gave bright yellow colour in silk and nylon fabrics and pale yellow shade in cotton. The dyes exhibited good fastness properties on silk and nylon fabrics even without mordant [9].

Among other kinds of plant-derived natural pigments are flavonoid, saponin, and tannin, which all belong to a group of wood extractive pigments. Flavonoid compounds can impart red, yellow, brown, or blue colors to particular wood species. Tannins are inherently complex organic compounds with their amorphously textured crystals, and soluble in water forming colored liquid. Such liquid colors and their color intensity (weak or strong) could be affected by acid, alkali or salt treatments [3].

Anthocyanins is one of the natural dyes which is a subclass within the class of flavonoids and, which are responsible for red till bluish colors in most flowers, higher plants, fruit and vegetables. Anthocyanins consist of a typical C6–C3–C6 aglycon, which is often glycosylated. Within plants, these sugar moieties are acylated. The most frequently occurring anthocyanidins are cyanidin, delphinidin, malvidin, pelargonidin, peonidin and petunidin. Anthocyanins are very prone to pH-fluctuations [10].

Relevantly, technical assessment and processing of pigment-producing plants/trees associated with the utilization of natural coloring agents for fabrics in East Sumba deserved carrying out to look into their related current situation as well as development potency. The practical detailed results are forthcoming [11].

2. Materials and Methods

2.1. Materials

The main research materials were inherently natural pigments derived (extracted) from particular plant/tree species, which grow well and abundantly in East Sumba. The chemical stuffs which were used comprised among others methanol, ethanol, and distilled water. Meanwhile, the related devices and instruments consisted of beaker glasses, heating oven, analytic balance, GCMS (Gas Chromatography Mass Spectrometer) pyrolysis, pipettes, pyrex tubes, and other assisting devices/instruments.
2.2. Methods

2.2.1. Interview with the related parties
In-depth interview and discussion were performed with various parties who supposedly played essential roles in processing (extracting) natural pigments from plant sources. The targeted parties comprised farmers/crafters, enterprisers, self-assisting institutions, and regional government. From this discussion with those parties could then be obtained beneficial information especially about various kinds of renewable natural pigments commonly utilized for coloring fabrics and other woven items by the community.

2.2.2. Technical assessment on processing of plant-derived natural pigments
This assessment was conducted through the observation and recording (taking note) of every process which was carried out throughout the entire production of natural pigments.

2.2.3. Testing on the produced natural pigments
Natural pigments which were consecutively produced by the community; and also produced through the laboratory scale trial were then tested for comparing the properties of resulting-pigments between those produced by the community manner and through laboratory scale trial technique. The tested properties comprised natural pigment yield and coloring qualities.

2.2.4. Pigment extraction and testing of phytochemical properties
Treatment that implemented several various extraction techniques could expectedly produce the pigments with satisfactory high yields and better qualities. In the pigment extraction process (in the laboratory scale trial), initially parts of the trees/plants indicatively potential to produce natural pigments were ground/milled to very small sized pieces using hammer mill or blender. Afterwards, the milled/ground tree parts (with their known oven dry weight equivalent) were sieved using staged screens such that the particles that passed through 40-60 mesh screen in sufficient amount could be obtained. The obtained screened particles were then extracted by refluxing in hot water and separately immersed (macerated) in methanol. The methanol immersed particles were screened; and then the obtained filtrate was concentrated using rotary vacuum evaporator. After all the methanol evaporated out, it left behind the concentrated extract (regarded/called as natural pigment), further put into the oven under mild heating (±50-60°C) for short duration, then and in this way its dry weight could be known. The yield (Y) of concentrated extract/natural pigment then could be calculated using the formula, as follows:

\[ Y(\%) = \frac{\text{Dry weight of concentrated extract (natural pigment), grams}}{\text{Oven dry weight of milled/ground tree parts}} \times 100 \]  

Meanwhile, a part of the concentrated extracts (natural pigments) was taken and then tested for phytochemical properties.

3. Results and Discussion

3.1. Technical and economy assessment on processing of natural pigments

3.1.1. Kinds of plant-derived natural pigments
Natural pigments of various kinds for coloring the woven fabrics were taken (extracted) by the community from their producing-plants, which grew well and abundantly in the forest vicinity. The forests which were explored a lot located around the National Park under the Region II in Wanggameti village. Kind of main natural pigments in the forest which was sought the most by the community was the one originated from Loba tree species, and the tree parts which were taken and extracted (for natural pigments) comprised leaves and barks.
Information obtained from the Industry and Trade Service at East Sumba regency mentioned that there were at least three main centers for production of tight-woven fabrics, among others in Raja (Rindi), Lambanapu, and Kaliuda villages. The data from the Office of Center for Statistics Bureau there listed that there existed 2548 units of tight-weaving enterprises with 4768 workers, which spread out at 12 subdistrict [12].

From the assessment results about natural-coloring technique for woven fabrics could be obtained beneficial information. The information mentioned that several pigment-producing tree (plant) species from which their pigments were utilized consisted of among others Wora (Nila) species as source for blue/violet color, Kambu species as pigment source for red color; and Loba species as source for strengthening the color, aided by the assisting chemical agents, such as lime and kemiri (*Aleurites moluccana*) seeds.

![Plant/tree species from which the natural pigments were extracted and then used for coloring the fabrics](a) Wora species; (b) Kambu species; (c) Loba species

Results of identification on specimens of pigment-producing plant species which were performed by the Botany Division at the Biology Research Center, under the Indonesia’s Science Institute (LIPI) are presented in Table 1.

| No | Regional/ Vernacular names | Scientific names                  | Family         |
|----|----------------------------|-----------------------------------|----------------|
| 1  | Wora/ Nila                 | *Indigofera erecta* Thunb         | Leguminosae    |
| 2  | Kambu                      | *Morinda cf.citrifolia* L.        | Rubiaceae      |
| 3  | Loba                       | *Symlocos cochinchinensis* Lour.) S. Moore | Symplocaceae |

### 3.1.2. Coloring technique

The coloring-technique was performed by initially immersing in cold water, parts of particular pigment-producing plant species (Wora/Nila species). The immersion lasted for 24 hours to provide enough time for the natural pigment to elute out of the tree parts into the water. Afterwards, parts of the eluted plant/trees were removed from the water, leaving behind the colored aqueous solution (liquid) which appeared as black/blue/violet. The black/blue/violet-colored liquid (eluant) was let there for particular duration until it formed a precipitated mass; and the precipitated mass could further be used as natural pigments. The weaving thread/yarn was then dipped into the colored liquid (eluant) to impart it with blue/violet color. This process could overall take about 2 weeks. In the same way, to impart the weaving thread/yarn with red color, it should be dipped in the colored liquid, previously into which was immersed particular parts of Kambu plant/tree species. In coloring the thread/yarn with
Kambu natural pigment, it was usually performed by adding Loba-originated pigment to strengthen the red color at the thread/yarn.

This coloring technique of thread/yarn was performed after the tying (bundling) process finished. The tying/bundling of thread/yarn usually used raffia rope with the purpose that the tied part of thread/yarn would not be colored during the dipping process. The tying patterns could be varying, whereby it could shape figures like horses, chickens, flying-horses, etc. Usually, the first coloring process was conducted using Nira-originated pigments (affording blue color). The dipping of thread/yarn in Nila-originated pigment could last for one month, which should be performed repeatedly until the desired blue color was obtained. Afterwards, the tying of thread/yarn was opened (untied), and then colored with kemiri and Kambu-originated pigments as the sources for red color. All the tying ropes were completely removed. It then appeared that Nila originated pigment mixed Kambu-originated pigment would bring about black color. Meanwhile, Loba-originated pigment mixed with Kambu-originated pigments ended up with red color.

The preparation of natural pigments could be regarded as very time consuming, as it might take one month. For these reasons, the manufacture of tight woven fabrics became a very lengthy process. Moreover, for the weaving process itself, it could finish in the matter of one day until one week.

![Figure 2](image-url) The dipping (coloring) process for yarn, fabrics, and other woven items

### 3.1.3. Economy assessment

In general, the community in East Sumba did not rely much their main occupation on fabric-weaving activities. In fact for their main occupation, the community there at Rindi Subdistrict which served as one of the assessment locations, performed other occupation activities such as farming, raising cattle, fishing, and trading [13].

![Figure 3](image-url) Fabric materials after being colored with various plant-derived natural pigments
In one week, duration, in average the fabric weavers could produce one sheet of woven fabrics that measured 20 cm by 200 cm, with the selling price as much as IDR 300,000–400,000 per sheet. Meanwhile for larger size of woven fabric sheets (50 cm by 200 cm), the weaving activities could take about 2 weeks.

3.2. Extraction of natural pigments and testing on their phytochemical properties

3.2.1. Pigment extraction

The extraction method as performed on particular parts of plant/tree species origins (to obtain the extracts/natural pigments) implemented the so-called maceration and refluxing techniques. Maceration technique was to separate active compounds from the plant/tree parts (and then to be included in the extracts), not only based not on the effectiveness, practical consideration, safety, and economy aspects in the technique use; but also for the purpose to avoid or minimize the possible destruction (degradation) to those compounds which could be vulnerable (not resistant) to particular heat-involving treatment. Meanwhile in refluxing technique, the selecting of methanol as the extracting solvent was because methanol could perform as multipurpose solvent that was very suitable to extract expectedly almost all the plant compounds.

In Table 2 was presented the yield of extracts (natural pigment) as obtained using two refluxing extraction techniques (in laboratory trial; using hot water and methanol solvents) and using the technique commonly performed by the community (cold water solvent). Meanwhile as described before, the maceration extraction technique was implemented to extract particular chemical compounds which were not resistant to heat.

In Table 2, it revealed that the extraction technique using hot water solvent brought out greater yield of the extract (natural pigment) than using cold water and methanol solvents. The extraction using cold water was commonly performed by the community (in East Sumba); and such lower pigment yield could expectedly be increased two times greater, if they used hot water solvent instead.

| No | Species origin of pigment-producing plants | Yield, % / Extraction techniques |
|----|------------------------------------------|---------------------------------|
|    |                                          | Cold water solvent **)          | Refluxing extraction *)         | Hot water solvent | Methanol solvent |
| 1  | Nila                                     | 9.00                           | 16.37                          | 16.05 |
| 2  | Kambu                                    | 4.04                           | 17.23                          | 14.87 |
| 3  | Loba                                     | 5.42                           | 9.69                           | 7.96 |

Remarks: *) in laboratory-scale trial; **) commonly performed by the community in East Sumba

Efficiency of extraction of natural dyes largely depends on the type of sources and various processing variables such as pH, temperature, time, liquor ratio, and particlesize. The methods of extraction of natural dyes can be classified based on the media used in extraction, such as aqueous, nonaqueous, organic, and mixture of aqueous-organic extraction [14].

3.2.2. Phytochemical tests

Results of phytochemical tests on the extracts (natural pigments) were presented in Table 3. Phytochemical contents could detect or confirm the presence of particular pigment compounds (e.g. tannin, flavonoid, and saponin) [15] in the extracts from plant species origins.
Table 3. Results of phytochemical tests on plant derived pigments

| No | Species origins of pigment-producing plants | Kinds of natural pigments as detected (confirmed) |
|----|---------------------------------------------|-----------------------------------------------|
|    |                                             | Tannin | Flavonoid | Saponin |
| 1  | Nila                                        | +++    | +         | +       |
| 2  | Kambu                                       | ++     | ++        | ++      |
| 3  | Loba                                        | +      | +         | ++      |

Remarks: + = presence, ++ = strong presence; +++ = very strong presence

Tannin compounds could be used to impart specific colors to fabrics. The tannin used as coloring agents (natural pigments) acted as mordant, and commonly in combination with particular heavy metals. Prabhu and Teli have isolated tannin compounds from java tamarind (Tamarindus indica) and then used them as natural mordant, previously mixed with copper sulfate (CuSO₄). This natural mordant (CuSO₄-mixed tannin) could then be used as natural pigments for cotton, wool, and silk fabrics. In fact, this mordant was more resistant to leaching than the natural pigment alone (tannin without addition of mordanting agent, CuSO₄) [16].

In scrutinizing Table 3, it strongly indicated that Nila originated natural pigment exhibited greatest tannin contents, compared to the content in Kambu and Loba originated natural pigments. Accordingly, Nila originated pigment seemed better for use as mordant compared to the other pigments (Kambu and Loba). Also, with economy reasons, Nila originated pigments could be combined with alum (Al₂(SO₄)₃) and ash soda (Na₂CO₃) in order that the colored (pigmented) fabric fixed the colors (pigments) more strongly, thereby not easily leached out. Meanwhile, Loba originated pigments were already known to contain aluminum (Al) and iron (Fe) metals, which could also function as mordant. The presence of these metals could be found inside the leaf, root, and bark parts of the tree stems.

3.3. Tests on total phenol in plant-derived natural pigments

Results of tests on total phenol in natural pigments originated from Nila, Kambu, and Loba plant species were presented in Table 4.

Table 4. Total phenol content in plant-derived natural pigments for coloring fabrics

| No | Species origins of pigment-producing plants | Total phenol % (w/w) |
|----|---------------------------------------------|---------------------|
| 1  | Nila                                        | 228.20              |
| 2  | Kambu                                       | 308.80              |
| 3  | Loba                                        | 232.50              |

Total phenol content (Table 4) was strongly indicated to correlate linearly and positively with flavonoid presence in natural pigments (Table 3). It is necessary to know that flavonoid compounds typify as the greatest group that existed in nature. These flavonoid compounds signify as natural pigments that impart red, violet, and blue colors, and as pigments that brought out yellow colors in the particular parts of plants/vegetations.

3.4. Tests on coloring qualities of plant derived natural pigments

The color qualities of natural pigments in this regard were expressed quantitatively as brightness values, as presented in Figure 4. From Figure 4, it mentioned that color qualities of natural pigments which were extracted using hot water solvent tended to be better (i.e. greater brightness values) than using other extraction techniques (e.g. using cold water and methanol solvents), as also confirmed through visual observation (Figures 5 and 6). This occurrence was quite interesting, because besides better coloring qualities (greater brightness) of natural pigments, their corresponding pigment yields
tended also to be greater with refluxing-extraction techniques, particularly using hot water solvent (Table 2).

![Figure 4](image)

**Figure 4.** Color qualities of natural pigments extracted from particular plant species, expressed as brightness values (color qualities, Numbers 0 - 60 refer to the brightness values)

![Figure 5](image)

**Figure 5.** Visual appearance associated with color qualities of Nila originated natural pigments obtained using various extraction techniques (a, b, c)

![Figure 6](image)

**Figure 6.** Visual appearance associated with color qualities of Kambu originated natural pigments, obtained using various extraction techniques (a, b, c)
3.5. Analysis on chemical compounds in plant-derived natural pigments

Results of chemical compound analysis were presented in Table 5. It turned out that chemical compounds in Loba Nila and Kambu originated natural pigments were dominated by particular groups of fatty acids. In addition, dodecanoic acid and hexadecanoic acid compounds were contained in all these investigated plant-derived natural pigments (Loba, Nila, and Kambu originated).

| No | Species origins of pigment producing plants | Chemical compounds | Composition |
|----|-------------------------------------------|--------------------|-------------|
| 1  | Loba                                      | - Dodecanoic acid  | 25.89       |
|    |                                           | - Hexadecanoic acid| 14.79       |
|    |                                           | - 9,12-Octadecadienoic acid | 11.15 |
|    |                                           | - 2-Propanone, 1-(4-hydroxy-3-methoxyphenyl)- | 7.79 |
|    |                                           | - 2-Furancarboxaldehyde, 5-(hydroxymethyl)- | 5.07 |
| 2  | Nila                                      | - 2-Hexadec-1-ol, 3,7,11,15-tetramethyl | 21.90 |
|    |                                           | - 8,11,14-Eicosatrienoic acid | 18.65 |
|    |                                           | - Hexadecanoic acid | 15.44 |
|    |                                           | - STIGMAST-5-EN-3-OL, OLEAT | 4.48 |
|    |                                           | - l-Limonene        | 3.17 |
| 3  | Kambu                                     | - Dodecanoic acid (CAS) | 20.57 |
|    |                                           | - 2-Furancarboxaldehyde, 5-(hydroxymethyl)| 10.23 |
|    |                                           | - Acetic acid (CAS) Ethyllic acid | 8.50 |
|    |                                           | - ISOSORBID         | 5.37 |
|    |                                           | - 9-Hexadecenoic acid | 4.76 |

4. Conclusion

Utilization of plant-derived natural pigments has long been performed by the community in East Sumba as fabric coloring agents and to produce tightly woven fabrics; and apparently such undertaking would still keep going in the future. Unfortunately, the extraction technique implemented by the community was still very simple by just immersing the supposedly pigment containing parts of the plants/trees (e.g. roots, stems, leaves, and barks) in cold water. Likewise, so was the technique for coloring the fabric/thread/yearn with natural pigments, which was conducted by just dipping and immersing methods. There were three kinds of plant derived natural pigments used most by the community and those three corresponding plant species origins comprised Wora/Nila (Indigofera erecta Thunb), Kambu (Morinda cf.citrifolia L.), and Loba (Symplocos cochinchinensis (Lour.) S. Moore). Results of technical assessment on processing of pigment producing plants revealed that extraction technique using hot water solvent brought out the extracts (pigments) with higher yield and better coloring qualities (greater brightness values).

These weaving activities were generally performed by the community just as additional income sources. Moreover, the production process of woven fabrics was very time consuming and lengthy and also, the recipient markets so far were felt still inadequately and improperly available.

Nowadays, raw material sources for natural pigments tended to be more difficult to obtain. Accordingly, to cope with those difficulties, parts of the community began mixing natural pigments with synthetic pigments. In the future, expectedly those pigment producing plants should be cultivated seriously and thoroughly to maintain the stocks of natural pigments.
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