Prospects of biomass wood wastes as natural dye stuffs for batik clothes and other woven fabrics

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Abstract. The undertaking of abundantly biomass wastes generated from forest-related timber industries, e.g. wood slabs, bark, leaves, sawdust, and other waste form is still limited. Attempts are necessary to utilize those wastes into useful renewable products for example natural dyes for batik cloths and woven fabrics, which implement environmentally friendly technologies. Relevantly, this scrutiny aims to elaborate on the exploration, processing, and utilization of those wastes into natural, easily produced, and applicable dyestuffs. Biomass wastes are converted into dyes in liquid, paste, and powder forms. Dye production commences with a chemical investigation of biomass wastes in those three forms. All wastes were sorted, dried, grinded, and extracted. The resulting dyes, before being applied to the batik cloth and other woven fabrics, were fixed using inorganic chemicals, e.g. lime (CaCO3), alum (Na2Al2O4), and ferro-sulphate (FeSO4) to strengthen the color. These results are applicable as basic as well as complimentary colors for batik cloths and weaving yarns. Expectedly, in qualities, the dye products could compete with or even partially substitute the imported synthetic pigments. The positive impact is this technology could improve economic welfares of forest-surrounding communities.

1. Introduction
In Indonesia, the management and undertaking of biomass wastes abundantly generated from forest wood extraction associated with timber-processing activities, such as wood slabs (pieces), wood bark, branches, and twigs, roots, leaves, and sawdust are so far still very limited; and instead just abandoning them on sites to decay or rotting themselves, stacked, and merely burned uncontrollably. Such manner can cause negative environmental impacts, thereby endangering ecosystem balances, releasing greenhouse gases, creating unbearable heats, hence causing environmental pollution, upsetting nature amenities, and disturbing human or other living creatures’ health (e.g. their respiratory systems). Among the effective attempts to deal with that biomass wood wastes are the so-called alternative technology for their utilization into useful products, such as compost, active charcoal, charcoal briquettes, and wood crafting items, which are easily socialized to the community and afford value-added economy. Another creative technology manner for those wastes with their value-added products, which is worth of direct community socialization is the manufacture (production) of natural dyes (coloring agents) for batik cloths and other woven fabrics.

The wood wastes generated from the tree felling or cutting, such as leaves, wood bark, branches/twigs, and roots; all inherently organic materials, have been known to be rich in particular chemical compounds, among others tannin, flavonoid, saponins, and anthocyanins [1, 2]. These
compounds are essential to serving as basic materials for their further synthesis into natural dyes (pigments) seemingly potential for Indonesia’s batik cloths and other woven fabric products. Those pigments, besides naturally already existed in those biomass wastes, could also be formed through the internal heating action as well as during the biomass storage, which further induces the waste chemical changes. Such changes could occur due to biomass degradation, respiration, remediation, and other physiological processes, commonly accompanied by the heat release. Usually those changes, moreover induced by the heat, commence from the compounds with more complex structures and higher molecular weight in stages dwindling to simpler compounds with lower molecular weight [3].

For small-scale as well as medium-scale wood/timber-processing industries, which in number could reach a thousand units; and in locations are scattered throughout the country’s villages, usually they have not yet been well managed in integrated manners. This situation can bring about negative consequences, among which most of the wood waste those industries generate, such as leaves, wood pieces, tree bark, branches/twigs, sawdust, and other waste shapes have not been fully utilized. Accordingly, the introduction of simple and environmentally friendly technologies to convert those wastes into useful products with added-values is urgently needed, especially those with easy-to-apply implementations. Moreover, such simple technology could provide additional incomes for the community who reside in the vicinity of production forest areas as well as timber industries.

Relevantly, this paper looks into and scrutinize scientifically the potentiality of Indonesia’s biomass wood wastes for their conversion (manufacture) into useful and renewable products (i.e. natural dyes or coloring agents) together with the transfer of the ingenuously proper manufacturing technologies, which further can be benefited by the batik-crafting and fabric-weaving communities. In addition, the development of such technologies could prospectively serve as the downstream industries, whereby the produced natural dyes are able to partially substitute for the imported synthetic pigments.

2. Exploration method of natural dyes

2.1. Recycling

Recycling or reutilization of biomass (organic) wastes nowadays has turned into the paradigms of modern life, including those in the so-called world of coloring matters (back to nature). Exploration and research associated with the reutilization of organic wastes into useful and value-added products (e.g. natural dyes/coloring agents/pigments) have proliferated very rapidly in various hemispheres of the world. Natural dye products now become one of the eminent complements in substituting for synthetic pigments in food coloring, dyeing of batik cloths, and coloring of woven fabrics; such that the fabrics and their related accessories become the partial lifestyle of the community.

Natural dyes from wherever they come are preferred a lot by consumers (users) because of their superiority. These dyes are inherently exclusive; and their color characters as appeared look very typical, distinct, and ethnic, thereby exerting high selling values. Natural dyes can become potential superior products regionally in the global market. For the development in the use of natural dyes, it is necessary to conduct researches in order to get even better results of dyestuffs as well as dyed products (e.g. dyed/colored fabrics).

Many ethnic groups throughout the world have utilized particular parts of the plants as natural dyes (coloring matters), including those in Indonesia. Those Indonesia’s ethnic groups utilize specific plant parts, such as indigo (Indigofera tinctoria L.), night wood (Pterocarpus indica L.), ketapang roots (Terminalia catappa L.), teak leaves (Tectona grandis Lf.), annato seeds (Bixa orellana L.), tea leaves (Camelia sinensis L), and betels nuts (Areca catechu L) [4, 5]. Intensive related researches have been conducted by certain countries, who responded to the international markets. Meanwhile, several countries such as India, Singapore, Malaysia, and China have begun performing the transaction with consumers (users) of renewable natural dyes, especially those who feel very concerned with environmentally friendly and renewable products.
Several examples of natural dyes, which originate from particular tree portion (other than wood portions) in special tree species, comprise consecutively mahogany (Swietenia macrophylla L., acacia (Acacia mangium L.), teak (Tectona grandis Lf.), ketapang (Terminalia catappa L.), black wood (Diospiros celebica Bakh), and angsana (Pterocarpus indicus L.). The use of such non-wood portions in those tree species for natural dyes is attributed to the situation, where their wood portion has been already utilized for specific purposes (e.g., construction work). Unfortunately, the non-wood portions of those tree species, such as branches/twigs, sawdust, leaves, roots, wood barks, and other related shapes, which otherwise indicate potentiality as natural dyeing agents, are mostly just discarded or wasted, and then abandoned to decay on sites, or in other words, only little amount already utilized into dyes. Assessing the total volume of those wastes, it turned out that such total was far greater than the total volume of the already-utilized wood portion. Those wastes with their varying shapes (e.g., wood pieces/slabs, branches/twigs, wood bark, roots, leaves, and sawdust) indicate their significant potentiality for their use as dyeing agents which afforded high economy values [6].

2.2. Identification of pigments

Scrutinizing the recent study results, there were numerous shapes of biomass wastes with particular tree species origins that can serve as one of the rich sources for natural dyes (pigments), among others flavonoid, saponin, tannin, and anthocyanin compounds [5]. Those compounds signify as a group of wood extractives that impart distinctive colors to the body of their host plants, either partially or mostly. For example, flavonoids give red, yellow, brown, or yellow colors to plants; while tannins provide citrus yellow color on woods. Roots, bark, stems, and leaves of mangrove trees from Avicennia sp. are very rich in tannins, phenolics, and flavonoids [6, 7]. Research results by [8] revealed that from the extraction on the wastes from teak leaves using water solvent, it could be obtained aqueous extract which typically appeared brownish-red color. In teak woods, their specific color is known brought about by the presence of anthraquinone compounds (2-methyl anthraquinone). Testing results on the extract of teak wood sawdust revealed that it exhibited the potency of anthraquinone compounds with as much as 13.54% content. The teak sawdust was obtained from the sawing of old-aged teak woods [9, 10].

Kinds of pigments prevalently present in plants are chlorophyll, carotenoid, anthocyanin, and xanthophyll compounds [11]. Those pigments are used a lot as basic colors. Meanwhile, other pigment compounds in plants that could serve as complementary colors are flavonoids, tannins, and quinones. In particular microorganisms such as Phaffia rhodozyma bacteria and Monascus sp fungi, they could synthesize astaxanthin pigment molecules which exhibits reddish-pink color. Yellow-colored ankaflavin pigment and reddish orange-colored torularhodin pigment molecules are brought to appear by the yeast of Rhodotorulaesp. and Rhodotorulaaglutinispecies. Quinone groups cover several heterocyclic compounds. Member of quinine group is inherently 1,4-benzoquinone or cyclohexadienion, frequently called as “quinone”.

Chlorophyll, xanthophyll, carotene, and anthocyanin pigments are present not as granular shapes on the surface of leaves, but instead they dissolve in the leaf-cell liquid. In particular plants, such as Coleus sp. (red-colored plants) and red cabbage, their anthocyanins always appear to give a purplish red color. Meanwhile, in some other plant species, anthocyanins are not always formed in the life cycle of their leaves [12].

Flavonoids, tannins, and anthocyanins belong to the extractive substances that impart a distinctive color to their host plants. Flavonoids can be grouped into six major classes which differ chemically from each other, i.e., flavonols, flavanones, flavones, isoflavones, flavonols, and anthocyanidins. The colors that result from those pigments depend on plant species and particular portions in the plants. As such, flavonoids give yellow color [13]; or impart red, yellow, brown or blue color [12]. Tannin exhibit a brown color [13]; or brownish yellow and reddish-brown colors [12], or citron yellow color [12]. Meanwhile, the anthocyanin pigment provides blue, brown, red, orange, and purple colors on the leaves [10].
Roots, bark, stems, and leaves of mangroves from *Avicennia* sp. as described before are very rich in tannins, phenolics, and flavonoids [8, 9]. When particular parts of those mangrove plants are dissolved in water, then the watercolor becomes very concentrated (thick colored or strongly turbid), which appears blackish-brown like the color of aqueous tea. The presence of tannins and flavonoids with high content in mangroves allows their extracts to be used as natural dyes (coloring matters) for fabrics or other woven materials.

2.3. Color changes and quality testing of natural dyes

The color of flavonoids can fade away under exposure to strong-intensity light; but conversely, the flavon color seems more permanent, despite becoming somewhat paler. The essential pigment compounds in the flavon are consecutively apigenin, kaempferol, quercetin, myricetin, luteolin, tricin, and isorhamnetin [13]. Quercetin with the molecular formula C_{15}H_{10}O_{7} belongs to one of the essential flavonoids. Meanwhile, luteolin with the molecular formula C_{15}H_{10}O_{6} is also one of the flavonoid compounds that can bring the yellow color to appear. Accordingly, the distinct yellow color as emerged from the biomass-based natural dyes could be attributed to the flavonoid presence [13].

Changes can occur in the tannin compounds during the fruit growth and fruit ripening process in particular plants. Tannins and other various substances in biomass-based organic wastes (e.g. plant litters, leaves, branches/twigs, and sawdust) during the rain can dissolve out and then get carried away to the water body. This condition causes the color of the water body at the stagnant or enclosed sites (e.g. marshes, swamps, and peat swamps) to become blackish brown, known as the so-called black water. The tannin present in the water causes also it to taste tart and rather bitter.

Color changes frequently occur to the dyes during their storage, especially in the forms of extract liquid. The causes of the dye discolorations are associated with several influencing factors, such as decay, contamination, oxidation, and acidity (pH) changes that occur to the biomass-related matters (including natural dyes). Color changes could also be affected by the proportion between chlorophyll and other color-carrying pigments. The color of green-colored biomass during the storage could gradually turn yellow and then brownish, brought about by the decreasing ability or inability of chlorophyll pigments to absorb light for the photosynthesis. Meanwhile, the carotene pigments are known to be more stable (endured) compared to chlorophyll.

The chlorophyll pigments in plant biomass are not stable; and their color quickly turns brown when in physical contact with acids. This situation is due to the presence of Mg atoms which can be replaced by H atoms, caused by acid actions. Those structural changes result in the formation of specific compounds called pheophytin. These compounds will trigger the discoloration of leaves from yellow to brown colors [14].

In addition to the plant species and plant portions that could affect the colors of natural dyes, the use of fixation chemicals can enrich, strengthen or weaken the original color of particular matters (including the biomass and pigments). For example, use of fixation materials such as chalks (lime), alum, and tunjun (ferri-sulphate) could bring about the varying colors (weak, medium, or strong) on particular dyes, such as causing the brown color of tannin pigments (Table 1). Particular parts of mangrove plants (*Lumicera* sp.), such as roots, stems/branches/twigs, and leaves are confirmed to exert different colors, despite being fixated afterward using the fixating chemicals with the same colors as those originally at those plant parts. The possible causes are due to the different tannin contents in any of those plant parts.

Several factors that could affect the stability of pigments or coloring matters are among others acidity degree (pH), cations, oxygen, sulfur dioxide (SO$_2$), protein, and enzymes. The specific colors that appear caused by anthocyanin pigments depend on pH of the surrounding environment, thereby enabling these pigments to be used as a pH indicator. The anthocyanin colors as emerged are consecutively red (at pH =1), reddish-brown (pH = 4), violet (pH = 8), green (pH = 12), and yellow (pH = 13). In order to obtain the desired colors, anthocyanins should be stored using the appropriate pH buffer solution. Part of the cations, particularly divalent and trivalent cations, should be avoided, because those cations could change the anthocyanin pigments to blue color, thereby causing their
precipitation (sedimentation). Besides, the pigment in contact with copper, lightweight steel, and iron should be avoided. Oxygen, especially when dissolved in a mixture of solution that also contains anthocyanins, will oxidize them gradually. \( \text{SO}_2 \), when reacted with anthocyanins, will yield the colorless reaction products (without colors). However, the reaction is reversible, thereby by just heating the \( \text{SO}_2 \), the color will revert back to its origin. Further, when the anthocyanin sources react with protein, then it will give off vapor or create sediment. This situation is affected more by non-phenolic pigments, such as gelatin, which react with protein. Enzymes, especially those which are used in the processing of food that contains anthocyanins can have their content lost or greatly reduced. This situation owes in part to the glucosidase enzymes which is present in the stage of enzyme preparation.

Testing on qualities of dyestuffs (pigments) or colored products (e.g. dyed fabrics) in biomass matters is urgently needed, as it aims to test their resistance against the destruction by microbes as well as against the treatment by coloring agents. Another aim is to keep the enzymes in such biomass working on the active ingredients, thereby not causing unwanted-decomposition to the desired compounds (e.g. the pigments in this regard). The enzymes that play great roles on such decomposition are among others oxidase, peroxidase, hydrolase, and isomerase. Those enzymes are essential especially in the process of decomposing particular compounds, such as phenols, polysaccharides, and alkaloids, which have already existed as natural compounds. Accordingly, conducting research is necessary to complete such quality requirements (e.g. for the pigments and the dyed fabrics).

Testing on qualities of fabrics or any materials after being dyed with natural dyes originated from biomass wastes should afterward be compared with the standard specification for the coloring agents (dyestuffs) and with the color characteristics of synthetic pigments. The standardization as well as comparison is urgently needed in order that the consumers (users) feel sure of the natural-dye performance or do not feel disappointed; and the qualities of the dyed materials can be kept well maintained. The dyed materials which are tested cover several prototype items, after being dyed using coloring solution either in liquid form or in dry extracts, which refer to the procedures standardized by ISO and Indonesia’s National Standard (SNI).

Further, by conducting a lot of explorations and experiments, not only will this undertaking get to know the pigment qualities, but it can also enrich the broadness of pigment sources. The characters of several pigments (dyeing agents) that could be obtained from biomass wood wastes are illustrated in Table 1.

| Pigment group  | Number of pigments (ug/gr) | Original color (as appeared) | Soluble in | Level of stability       |
|----------------|----------------------------|------------------------------|------------|--------------------------|
| Anthocyanin    | 120                        | Orange, red                  | Water      | Sensitive to pH & heat   |
| Flavonoids     | 600                        | Colorless, yellow            | Water      | Rather heat resistant    |
| Á-anthocyanin  | 20                         | Colorless                    | Water      | Heat resistant           |
| Tannin         | 20                         | Colorless, Yellow            | Water      | Heat resistant           |
| Betalain       | 70                         | Yellow, red                  | Water      | Heat sensitive           |
| Quinon         | 200                        | Yellow-black                 | Water      | Heat resistant           |
| Xanton         | 20                         | Yellow                       | Water      | Heat resistant           |
| Carotenoids    | 300                        | Colorless                    | Animal fat | Heat sensitive           |
| Chlorophyll    | 25                         | Green, chocolate-like color (brown) | Water, fat | Heat sensitive |

Source: [7,10]
3. Implementation of Technology and Application

3.1. Technology of production enhancement

A breakthrough to produce or manufacture natural dyes (coloring matters) from biomass wastes implies as an attempt to reduce and replace dependency on the imported synthetic dyes. The use of materials or whatever genetic sources including biomass wastes should take into account their continuity as well as sustainability. Several plant species have been utilized as raw material for natural dyes; however, only particular parts of those plants are already done so, such as noni shrubs, red fruits, areca nuts, and other plant parts (e.g. fruit skins, roots, and leaves).

Table 2. Biomass wood wastes; and parts of their host tree origin, which exhibit potentiality as natural dyes.

| No | Tree parts (as sources of biomass wastes) | Species of host tree origin | Specific dye color |
|----|--------------------------------------------|----------------------------|-------------------|
| 1  | Leaf                                       | Marsdenia tinctoria        | Black             |
| 2  | Leaf                                       | Dracaena angustifolia      | Green             |
| 3  | Leaf/wood                                  | Pterocarpus indicus        | Chocolate-like color (brown)-yellow, red |
| 4  | Leaf, twigs                                | Uncaria gambir             | dark red – cocco   |
| 5  | Root                                       | Morinda citrifolia         | Red-chocolate-like color (brown) |
| 6  | Rind                                       | Garcinia mangostana        | Blue, purple, red  |
| 7  | Bark                                       | Peltophorum pterocarpum    | Red, black        |
| 8  | Leaf, bark, wood                           | Terminalia catappa         | Black, Yellow- chocolate-like color (brown) |
| 9  | Young leaf                                 | Tectona grandis            | Red-chocolate-like color (brown) |
| 10 | bark, rind                                 | Baccaurea racemosa         | Green             |
| 11 | Seed, oldfeuit                             | Areca catechu              | Red               |
| 12 | Seed                                       | Bixa orellana              | Red, yellow       |
| 13 | Bark                                       | Acacia mangium             | Dark brown        |
| 14 | bark, wood                                 | Rhizophora apiculata       | Black brown       |
| 15 | Wood                                       | Xylocarpus granatum        | Brick-like color, red |
| 16 | Bark                                       | Ceriops candolleana        | Red-yellow        |
| 17 | bark, woods                                 | Peltophorum ferruginum     | Reddish brown     |
| 18 | wood, bark                                 | Caesalpinia sappan         | Bluish red        |
| 19 | Root terrace                               | Cudrainia javanensis       | Yellow            |
| 20 | Wood                                       | Artocarpus sp.             | Yellow            |
| 21 | bark                                       | Aporosa frutescens         | Black             |
| 22 | Flowers                                    | Butea monosperma           | Yellow            |
| 23 | Leaves                                     | Camellia sinensis          | Chocolate-like color (brown) |
| 24 | Bark                                       | Ceriopseptagial            | Black             |
| 25 | Wood                                       | Macroloebium bijugum       | Brownish red.     |
| 26 | Bark                                       | Swietenia mahagoni         | Brownish red.     |
| 27 | Young leaf                                 | Peristrophe bivalvis       | Red               |
| 28 | Wood/leaf                                  | Mangieta indica            | Green             |
| 29 | Flowers                                    | Nyctanthes arbotristis     | Yellow, creamy-gold-like color |
| 30 | Leaves                                     | Symlocos lucida            | Yellow            |

Sources: [10,11, 14, 16]
There is numerous plant species exhibit potentiality as natural dyes (pigments), and it is minimally the chlorophyll pigment in other parts of those plants that still left unutilized. In Table 2 are presented the potentialities of biomass wood wastes for their uses as natural dyestuffs (coloring matters). The main foundation in implementing the production and development of natural dyes should abide by the so-called Convention on Biological Diversity (CBD), which regulates the biodiversity of any living creatures. Another major foundation refers to the Nagoya Protocol, which regulates the implementation of the CBD. The Laws issued by the Government of Republic of Indonesia, Number 11 in 2013, regulates the access to Genetic Resources; and the Profit Sharing with Fair and Balanced Portions from the Utilization of such Resources by any involved parties over the Convention on Biological Diversity, which was ratified on May 8th, 2013.

In Indonesia, the industries that endeavor in dye extracts have not been specifically regulated; but the stipulations released by the Ministry of Health, No. 006 in 2012 regulates how the related industries should prepare the stocks in the form of dye extracts as the final products. The endeavoring permits are principally only valid for 3 (three) years. When the permits are due (after 3 years), the industries should ask for the permissions renewals to endeavor again in biomass-based natural dye extracts.

Referring to the utilization of natural dyes (coloring matters) obtained from the biomass wood wastes, which is permitted through the endorsement as described above, the natural dyes-concerned institutions are obliged to perform the stipulated items, as follows:
1. Protecting and conserving genetic resources, and sustaining the traditions associated with natural dyes;
2. Preventing biopiracy and unauthorized or illegal use;
3. Ensuring profit sharing (financial as well as non-financial gains);
4. Passing on the legal basis for regulating access and profit-sharing;
5. Conducting the technology transfer for sustainable sources as well as continual uses and conservation.

3.2. Transfer of technology and applications
Batik crafters and fabric weavers perform the coloring on cloths and sewing threads (yarns) using the dyestuffs (coloring matters) which should be easily obtained surrounding their houses. Meanwhile, biomass wood wastes are readily and abundantly available in the vicinities of consecutively production forests, plantation estates, and timber industries (e.g. wood pieces/slabs, wood barks, branches/twigs, roots, leaves, sawdust, and other waste shapes). Concurrently, biomass wastes from the community-owned wood-processing industries are present as tree-felling or logging residues, in the forms of consecutive leaves, wood slabs/pieces, wood bark, stems/branches/twigs, and roots. So that those biomass wastes could be extracted of their dye compounds, they should at first undergo the intensive as well as rigorous size reduction actions to the tiny-sized particles (flour/powder shapes), through the cutting, chopping, grinding, and milling. Further, those waste particles (flour) are extracted using water solvent to separate the soluble dye matters (roughly as the water extract). Relevant with such, as much 500 grams of biomass wastes as leaves are cut to small-sized pieces. The leaf pieces are put into a boiling pan; and then into the pan is added water with the proportion of 1:10 (w/w). The mixture of ingredient (leaf pieces and water) in the pan is heated (boiled) for a particular duration, such that the water volume is reduced approximately to a half or a third. The boiled water is then filtered using a sheet of cloth to separate the soluble extract and residues (retained on the filtering cloth). The water together with the soluble extracts that passes through the filtering cloth is gathered (called as the solution of natural dyes), and then the collected solution allowed to cool down. Afterward, the dye solution is ready for use as natural dyes in traditional practices by the community.

The dye solution (containing soluble leaf extract) that results using such a simple extraction method could be inherently used for the dyeing (coloring) of fabrics and sewing/weaving yarns, but it should initially undergo several particular treatments by preparing the necessary tools, materials, and fixating chemicals. The prepared tools and materials comprise (1) mori cloths (could be mori, cotton, or silk);
(2) canting to aid in creating batik motives; (3) gawangan for wrapping the cloths; (4) melted wax for covering the motives; and (5) boiling pan and heating stove. Meanwhile, the fixating chemicals cover lime (CaCO₃), alum (Na₂Al₂O₃), and tunjung/Ferro-sulphate (FeSO₄/Al₂(SO₄)₃). Concurrently, the natural dyestuffs (coloring matters) are simply the leaves-extracted dye solution.

The fabrics (cloth/cotton) which previously have already been given a motive or colors must then be mordanted (chemical or natural) [15]. As such, the mordant solution is prepared by dissolving into a particular volume of water, the so-called fixating chemicals, i.e. lime (CaCO₃), alum (Na₂Al₂O₃), and tunjung (FeSO₄ / Al₂(SO₄)₃), each similarly as much as 20-50 grams (per one liter of water); and further the mixture is stirred vigorously until all the fixating chemicals are dissolved completely in the water (as mordant solution). The mordant solution is heated to boil using the stove; and then the fabrics (cloths or cotton) are immersed into the boiling solution, allowed there for one hour. Afterward, the boiling is terminated by extinguishing the stove fire; and the cloths/cotton are kept immersed in the mordant solution overnight. Thereafter, the immersed fabrics (cloths/cotton) is removed from the mordant solution by lifting it, rinsed (but without squeezing), and then allowed to dry. The dried mordanted fabrics (cloths/cotton) are further immersed in the leaf wastes-extracted dye solution for the dyeing/coloring process. Such coloring (i.e. the fabric immersion) should be repeated several times to get the dyed fabrics with satisfactory coloring results. After the coloring, the dyed fabrics could be washed using clean water to remove unwanted materials (e.g. residual dyes and slightly-carried mordant/fixation chemicals); dried in an open place under the roof (but not directly exposed to sunlight), and then ironed.

Special for the coloring (dyeing) of silk fabrics, the mordant solution is prepared by dissolving basic alum [Al₂(SO₄)₃] into water (i.e. 0.20-0.50 gram per one liter of water), and then the solution stirred vigorously until the alum dissolves completely. Similar as before, the mordant solution was boiled; and into the boiling solution are immersed the silk fabrics for one hour. Afterward, the boiling is terminated; and the silk fabrics kept immersed overnight. Thereafter, the immersed silk fabrics are lifted from the mordant solution, rinsed (without squeezing either), and then allowed to dry. The dried mordanted silk fabrics are further immersed into the leaf wastes-extracted dye solution for the coloring process. Also similar to before, the coloring (fabric immersion) could be repeated several times until achieving satisfactory coloring results [16]. Afterward, the dyed silk could be washed using clean water to remove unwanted materials; dried (but not under direct sunlight); and then ironed.

4. Conclusion and Suggestions

Assessment and scrutiny results reveal that in Indonesia, biomass wood wastes generated from forest-related timber-processing industries exhibit remarkable potentiality as the sources of natural dyes (coloring matters) for batik cloth and other woven fabric products. Such biomass wastes have been proved to contain particular pigments with varying colors (e.g. red, yellow, black, purple-brown, and weak brown); and hence potential as natural dyestuffs (coloring matters). Specifically, the red color is obtained from secang wood extraction, yellow from tegeran wood and root bark, black from mountain acacia bark, purple-brown from mahogany bark, and light brown from teak leaves. Further assessment on the shapes of biomass wastes (e.g. wood pieces/slabs, wood bark, branches/twigs, leaves, roots, and sawdust) indicates that those numerous waste shapes seem to have positive prospects, as most of them afford applicable technology that could be implemented satisfactorily in converting those biomass waste into useful products (e.g. natural dyes). Those dyes seem spectacularly useful for the coloring of batik cloths and other woven fabrics.

World regulations that stipulate the coloring chemicals should not pollute the environments and not inflict other negative impacts have placed the use of environmentally-friendly and renewable natural dyes in advantageously strategic positions. The natural coloring materials with biomass wood waste origin after being thoroughly and intensely tested strongly indicate that they are quite safe not endangering the environments as well as living creatures (e.g. human beings). This convenient situation brings many countries in urgent needs for natural dyestuffs /coloring matters. Further, the fast and prosperous expansion of batik endeavors could stimulate the business in manufacturing natural
dyes. Accordingly, such business in green products deserves the main priority; and it could only work out well if there is a thorough and mutual cooperation between the concerned research institutions to provide beneficial information particularly associated with the manufacture of renewable natural dyes from biomass wastes; and their uses for batik cloths and other woven fabrics (e.g. technology, management, and marketing).

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