The development of the effect of fixation using jamaican cherry leaves on the direction of hue

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Abstract. One type of the considerable potential of Indonesia is its natural resources, specifically plants, and Jamaican cherry is one example, a type of tall-growing flora easy to live and grow profusely in the country. However, only a few people get its best benefit, for example, from its leaves containing flavonoid and tannin useful in textile dyeing. This research contributes to ecofashion development, presented to determine the effect of fixation substances on ecoprint dyeing using Jamaican cherry leaves (Muntingia calabura L.) with steaming technique in terms of the hue directions investigated through three different color test results. The study was conducted with an ecoprint dyeing experiment whose results were then tested by using hue difference tests in the laboratory. The dyeing experiment employed medium-aged cherry leaves steamed together with the selected textiles. The fixation substances used to display and lock colors were iron (ferrous sulfate), alum, and calcium carbonate. The steaming process was carried out twice, 30 minutes for each, and the fixation process was done by submerging the fabric for 5-10 minutes. The results show that fixation substances affect the fabric’s hue directions. With alum, the results of the dyeing are leafy and brownish-yellow, while with alum, black green dominates, and with the calcium carbonate the color is brownish-green. The results are applicable in environmentally friendly textile manufacturing and inspire further research with other types of plants.

1. Introduction

Indonesia is the country with the second-largest biodiversity in the world after Brazil. There are natural resources in the form of 25,000 plant species [1]. One of the species is M. Calabura L. or commonly called Jamaican cherry plant, or Kersen in the Indonesian language. This is a type of shrub that is easily found in Indonesia [2]. Although it is abundant and easy to cultivate, the cherry plant is still not optimally utilized, and even for the community, the plant is considered to have no selling power so the plant is only used for animal feeds, especially for goats. The plant is known as medicine for curing gout, antiseptic, anti-inflammatory, anti-tumor, and anti-bacterial. It grows in tropical areas with an average tree height of 3-6 meters. It has flowers with (1-3-5) buds located in a leaf axil. The type of fruit is a red berry at maturity and 1.5 mm in diameter, containing thousands of small seeds in the fruit's flesh and tastes sweet [3]. In plant classification, Jamaican cherry (Muntingia calabura L.) is in the kingdom of Plantae, Spermatophyte division, Angiospermus sub-division, Dicotyledoneae class, Dicytledoneae sub-class, Malvales/Columniferae order, Elaeocarpaceae division, Muntingia L. genus, and species of Muntingia calabura L [4].

The plant contains alkaloids, tannins, saponins, flavonoids, polyphenols, flavonols, proanthocyanidins, cyanidins, and myo-inositol. In addition, there are also chemical flavonoid types with many types of flavonons, flavans, biflavones. The cherries contain nutrients of 76.3 grams of
water, 2.1g protein, 2.3g fat, 17.9g carbohydrates, 4.6g fiber, 1.4g ash, 125mg calcium, 94mg phosphorus, 0.015mg of vitamin A, 90mg of vitamin C, and energy 380 kj/100 g. [5]. In addition to these ingredients cherry plants also have trichome cells. The formation of plant secondary metabolites is found in all tissues and cells, but biosynthesis occurs in certain tissues or cells and is influenced by the level of differentiation and development. The observation of the anatomical structure of cherry leaves has a secret-producing glandular trichomes containing sap when touched [6]. The green pigments and chemical contents contained make cherry leaves possible to become textile dyes.

Textile dyes comprise two types, namely synthetic and natural ones. Synthetic dyes have many advantages compared to the latter, as they are readily available, guaranteed in color availability, have diverse color types, and lastly are more practical and cheaper. Besides, the colors produced by synthetic dyes are more stable, resistant to environmental conditions, durable, bright, and wide-ranging. However, they are not environmentally friendly as they can cause health and environmental problems. For example, Rhodamin B, Methanyl Yellow, and Amaranth in food and beverages are dangerous for health because they can lead to cancer and kidney and liver damage [7]. While in the textile use, synthetic coloring substances can cause environmental pollution caused by textile industry waste, which is full of color and organic chemicals. Besides, mixing colloidal material with dye waste can increase water turbidity and make the water look bad, smell, thus preventing sunlight penetration. The next terrible impact would be the depletion of dissolved oxygen, decreased water quality, and the death of living creatures living in it because of lack of oxygen or contaminated with toxic compounds [8]. Unlike the case in natural dyes, these consequences would not happen as the natural ones are more environmentally friendly.

However, the development in clothing, food, cosmetic and pharmaceutical industry and the limited amount of natural dyes have somewhat exacerbated the increasing use of synthetic dyes. These conditions, if happen in a long time, will slowly but surely contribute to greater environmental damage, and thus urge the need for natural dyeing substances for textiles as an alternative to the synthetic ones. Textile dyeing in Indonesia is very diverse in techniques, materials, and types. Among the coloring techniques rapidly developing in Indonesia are dyeing and printing [9], contemporary found in the early 20th century. Ecoprinting technique, or ecoprint, is transferring colors to the fabric by direct contact [10]. The technique uses natural materials such as flowers, stems, leaves and roots that do not produce harmful waste to the environment, and the ecoprint dyeing technique is in the category of the printing technique. The color produced from the ecoprint is in the form of motives that resemble the shape of the coloring material used. The materials used include the leaves, flowers, stems, and roots that have certain criteria. To produce quality colors, ecoprint coloring techniques, the type of the textile, the type of the fixation substance, the mass of the fixation agent, and the duration of the steaming process should be taken into account.

2. Research Method

2.1. Preparation
The preparation stage is preparing tools (a pan, stove, mattress thread, scissors, stopwatch, plastic bag, thermometer, stirrer) and the materials (mori/cotton fabric/calico, silk/sutera, and satin cloth, iron or tunjung, alum (tawas), calcium carbonate or limestone/kapur, Jamaican cherry or Kersen leaves, hot water, pure water, and Turkey Red Oil or TRO ). What prepared in this stage are cherry leaves on the fourth stalk in each branch of the plant. These leaves are known to have the best condition and are neither too old nor too young.

2.2. Mordanting
Mordanting on textile aims at opening the pores of the fabric. The materials needed in this process are listed in Table 1. The mordanting procedure for silk and satin starts from preparing tools, materials, and the chemicals, followed by weighing the textile materials and substances according to the formula. After all of the materials are prepared, the TRO is dissolved with water in the pan and alum is added into the TRO solution. Water is then added according to the liquor ratio and
heated for 1 hour at a temperature of 60ºC. The textile material is put into the mordant solution, heated while stirred for 1 hour. The final step is submersing the textile in the mordant solution for 24 hours at room temperature, and finally it is rinsed thoroughly and dried. Meanwhile, the mordanting process in mori is done as that in silk and satin, but in calico mordanting, sodium carbonate is added together with the alum.

### Table 1. Mordanting Materials for Satin, Silk, and Mori fabrics

| Mordanting materials for | Satin and silk fabric | Mori or calico fabric |
|--------------------------|-----------------------|-----------------------|
| Liquor Ratio             | 1:20                  | 1:20                  |
| Weight of material (textiles) | 200 grams             | 200 grams             |
| TRO                      | 2 gram/liter          | 2 gram/liter          |
| Alum                     | 20 gram/liter         | 20 gram/liter         |
| Sodium Carbonate         | -                     | 5 gram/liter          |
| Heating Temperature      | 60°C                  | Boiling (100°C)       |
| Time                     | 1 hour                | 1 hour                |
| Submersion               | 24 ours at room temperature | 24 ours at room temperature |

2.3. Ecoprint dyeing

In this study, the ecoprint dyeing process is carried out by steaming technique. The fabric is stretched on a flat surface and then folded into two parts. The first part is laid some leaves on its surface and then covered with the second part of the cloth. Next, the surface of the textile material which has folds of cherry leaves needs to be pressed, folded back into small elongated lappet, and rolled up. The roll that has been made is laced with mattress thread and steamed in a steamer pan for 30 minutes (steaming 1). After 30 minutes, the steamed roll in stage 1 is removed and dipped in the alum, iron, or calcium carbonate fixation. The cloth is soaked for 5-10 minutes and drained until it stops dripping. It is then steamed for the second time for 30 minutes in the steamer pan. After that, the cloth is removed, leaves are cleaned, and the cloth is rinsed.

2.4. Colorfastness and Hue difference tests

Different colors resulted from dyeing are tested using a sample size of 5x5 cm cloth for each type of fabric and a UV-PC spectrophotometer. The value generated from this test is L*a*b* and dE*ab, where the hue difference values are calculated and obtained from the total reflection of light on the object carried out by radiation as dE*ab.

3. Result and Discussion

3.1. Result

The ecoprint dyeing by the steaming technique produces leaf motifs with various colors according to the type and character of fixation substances used. The results of the dyeing are presented in Figure 1. From Figure 1, it is apparent that fixation substances affect the results of the ecoprint dyeing using Jamaican cherry leaves on hue directions as proven by the results of the hue difference tests in Table 2, Table 3, Table 4, and Table 5.

### Table 2. Lightness Value/L*

| Ecoprint Dyeing Technique | Fixation Substance | Mori Primissima(a) | Test | Test | Test Mean | Test | Test | Test Mean | Test 2 | Test Mean | Satin(c) | Test | Test | Test Mean | Test 2 | Test Mean |
|---------------------------|--------------------|---------------------|------|------|-----------|------|------|-----------|-------|-----------|----------|------|------|-----------|-------|-----------|
| Steaming (X)              | Alum(A)            | 73.7570 0.98125 75.03 | 72.10 | 76.55 | 77.15 | 75.26 | 99.32 | 97.63 | 95.35 | 97.43 |
|                           | Iron (B)           | 63.5354 5861.44 59.85 | 31.03 | 21.26 | 27.79 | 26.69 | 68.55 | 59.10 | 53.15 | 59.93 |
|                           | Calcium            | 68.2970 2863.08 67.21 | 39.01 | 41.14 | 40.23 | 40.12 | 64.44 | 64.18 | 64.32 | 63.31 |
The results in Table 2 show that the highest $L^*$ value of the hue difference test in the ecoprint dyeing using the steaming technique occurs in satin coloring using alum fixation agent with a mean of 97.43. Based on the tests, the brightest results in the steaming technique, therefore, are produced in satin ecoprint dyeing with alum as its fixation substance.

![Figure 1. The Results of Ecoprint Dyeing Using Jamaican Cherry Leaves with the Steaming Technique](image)

### Table 3. Hue and Saturation Value of the Red-Green Direction/\(a^*\)

| Ecoprint Dyeing Technique | Fixation Substance | Fabric Hue Difference Value (Hue and Saturation Value of the Red-Green Direction/\(a^*\)) |
|--------------------------|-------------------|------------------------------------------------------------------|
|                          |                   | \(Mori\) Primissima\(a\) | Silk \(b\) | Satin \(c\) |
|                          |                   | Test | Test 2 | Test 3 | Mean | Test 1 | Test 2 | Test 3 | Mean | Test 1 | Test 2 | Test 3 | Mean |
| Steaming (X)             | Alum \(A\)        | 0.43 | 0.38   | -0.060 | 0.29 | -0.32 | -2.16 | -2.44 | -1.64 | -2.60 | -2.42 | -1.64 | -2.22 |
|                          | Iron \(B\)        | -0.30 | 0.41   | 0.72   | 0.27 | 0.19  | 0.42  | -0.33 | 0.31  | 1.12  | 1.07  | 1.39  | 1.19  |
|                          | Calcium C.        | 0.19  | 0.81   | 1.77   | 0.92 | -0.60 | -0.16 | -0.92 | -0.56 | 3.27  | 3.10  | 3.69  | 3.35  |

Besides, the results as depicted in Table 3 indicate that the highest hue and saturation value of the red-green direction in the ecoprint dyeing with the aforementioned technique occurs in satin with calcium carbonate fixation substance, with a mean of 3.35. This also means that from the hue difference tests conducted, a greenish-red hue mostly appears as the color of the motif in satin ecoprint dyeing with the steaming technique and limestone fixation substance.
Table 4. Hue Coordinate Value in the Blue-Yellow Direction/b*

| Ecoprint Dyeing Technique | Fixation Substance | Fabric Hue Difference Value | Mori Primissima(a) | Silk (b) | Satin(c) |
|---------------------------|---------------------|-----------------------------|--------------------|---------|---------|
| Steaming (X)              | Alum (A)            | Test 1 | 16.2 | 21.10 | 5.15 |
|                           |                     | Test 2 | 18.44 | 53.23 | 37.13 |
|                           |                     | Test 3 | 28.6 | 53.03 | 24.60 |
|                           |                     | Mean  | 21.10 | 37.13 | 25.40 |
|                           | Iron (B)            | Test 1 | 6.56 | 5.97  | 10.2  |
|                           |                     | Test 2 | 10.94 | 8.69  | 8.91  |
|                           |                     | Test 3 | 10.2  | 9.27  | 3.91  |
|                           |                     | Mean  | 8.91  | 11.45 | 4.76  |
|                           | Calcium (C)         | Test 1 | 9.86 | 11.99 | 16.5  |
|                           |                     | Test 2 | 13.03 | 17.71 | 18.28 |
|                           |                     | Test 3 | 13.1 | 17.51 | 17.51 |
|                           |                     | Mean  | 11.99 | 15.18 | 16.51 |

Next, presenting the hue coordinate value, Table 4 shows that the highest value in the blue-yellow direction on the ecoprint dyeing using the steaming technique occurs in the coloring of silk fabric with alum fixation agent, with a mean of 37.13, indicating that yellow may dominate the color of the satin fabric in the steaming of ecoprint with alum fixation.

Table 5. Total Light Reflection Value Performed by Radiation/dE*ab

| Ecoprint Dyeing Technique | Fixation Substance | Fabric Hue Difference Value | Mori Primissima(a) | Silk (b) | Satin(c) |
|---------------------------|---------------------|-----------------------------|--------------------|---------|---------|
| Steaming (X)              | Alum (A)            | Test 1 | 31.95 | 58.05 | 58.06 |
|                           |                     | Test 2 | 34.54 | 57.64 | 57.02 |
|                           |                     | Test 3 | 33.85 | 58.06 | 58.06 |
|                           |                     | Mean  | 33.39 | 57.73 | 58.06 |
|                           | Iron (B)            | Test 1 | 36.38 | 79.3  | 72.84 |
|                           |                     | Test 2 | 44.81 | 73.98 | 73.98 |
|                           |                     | Test 3 | 38.92 | 73.98 | 30.88 |
|                           |                     | Mean  | 40.03 | 72.84 | 40.68 |
|                           | Calcium (C)         | Test 1 | 32.54 | 63.24 | 62.43 |
|                           |                     | Test 2 | 31.82 | 61.51 | 62.43 |
|                           |                     | Test 3 | 38.55 | 62.55 | 62.43 |
|                           |                     | Mean  | 34.3  | 62.43 | 62.43 |

The results in Table 5 show that the results of ecoprint dyeing with the steaming technique with the highest fabric hue difference test value are in silk ecoprint dyeing with iron fixation, with a mean of 73.98. It can be seen from the data of the different color test results, that iron fixation produces the darkest color. This is proven by the highest light reflection value, while ecoprint dyeing with alum fixation produces the brightest color as evidenced by the lowest light reflection value.

3.2. Discussion

The function of the fixation substances in addition to giving rise to colors is to strengthen bonds between fibers and colors so as to prevent dehydration of color pigments [12]. This is in line with the statement that the colorfastness can be improved through the fixation process, where after the dye is diffused into the solution and then sticks to the surface of the fiber, it then absorbed and diffused to the center of the textile fiber so it is locked into the fiber [13]. These fixation substances in ecoprint dyeing, likewise, affect colors, so different colors may have resulted from the use of three fixation agents used under the study. The grayish-green color is produced by iron fixation, brownish-yellow appears when alum fixation applies, and brownish-green is dominantly seen as the result of calcium carbonate fixation. As measured with three hue difference tests, the hue directions of ecoprint dyeing in mori or cotton fabric with the steaming technique and three fixation substances (alum, iron, and limestone), in the RGB color wheel appears such colors as Antique Bronze, Black Olive, and Army Green. In silk ecoprint dyeing with the same techniques and fixation agents are generated RGB colors of Bronze Yellow, Eerie Black, and Pulman Green.
Meanwhile, in satin fabric, the same treatment produces the colors of Gold Fusion, Jet, and Raw Umber.

4. Conclusion
The study has revealed that using different types of fixation substances and textiles on the ecoprint dyeing with the steaming technique potentially results in different hue different test values on each sample taken. Based on the test results, the highest level of color lightness ($L^*$) appears when using alum fixation substance, while the darkest color has been produced by iron fixation. The hue difference test results closest to the saturation of the red-green direction ($a^*$) occur when limestone or calcium carbonate is used for fixation. Besides, hue test results closest to the blue-yellow coordinate ($b^*$) appear in alum fixation. Based on the calculation of $L^*a^*b^*$ where the value is the total value of the reflection of light on the object by radiation ($dE^*ab$), iron fixation agent applied in silk fabric has somewhat produced the highest value, indicating that silk material has a relatively high color absorption value and that iron possibly produces the most concentrated color of all fixation substances used.

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