Formulation of Curcumin as Natural Dye on Polyester

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Abstract. Turmeric is perennial herbs that has been used for centuries as natural dye in the Asia. It contains curcumin that generate yellow to orange color. Unfortunately, curcumin is considered as fugitive dyes because its color strength will diminish within times. In order to strengthen the color of curcumin, some additives are added into dye formulation. In this research, turmeric juice was extracted from turmeric without adding any organic solvents. The juice was then mixed with mordant and emulsifier to produce dye solution. Alum and lime juice were used as synthetic and natural mordant, respectively. Tween 80 was used as emulsifier. The polyester was soaked in the dye solution for overnight. The color strength (K/S), the color wash fastness, and the color coordination of the dyed polyester were investigated. The research shows that the ratio of turmeric juice to mordant of 2:1 (without any emulsifiers) gave the best color strength and color fastness.

1. Introduction
Textile industry is one of the fundamental industry, where the products can be easily found in the daily life. Between 2011 and 2015, the development of textile industry expanded by 45% [1]. These increment may be caused by fast-fashion phenomenon, where ready-to-wear clothes are sold in cheaper price in the shorter cycle. However, this phenomenon has negative consequences to ecosystem. The extensive amount of unrenewable products (e.g: synthetic dye and fabrics) are produced, provoking devastating waste pollutions.

These environmental issues have ignite some researchers and industrial practitioner to acquire real solution. Natural dye is one of the solution to replace the synthetic dye. Currently, research about natural dye receives attention due to its sustainability. Natural dye contains natural colorant and is sourced from plants, animals, and minerals. Natural colorant is able to produce color due to its chromophore that can absorb visible light, it has conjugation system and electron resonance to stabilize organic components [2]. Natural dye might also contain color helpers (auxochrome) that defines color gradation and colorant’s solubility in the dye.

Currently the market share of natural dye is only 1% of the total market [3]. This might due to several limitations of natural dye, such as tedious extraction of raw materials, weak color fastness thus mordant is required [4], availability of raw materials depending on the season, technology limitation, and limited range of color gradation [5].

Curcumin is the main colorant of turmeric and produces yellow to orange color. It has been used for century as natural dye. Curcumin is classified as diferuloylmethane polyphenol and considered as disperse dye due to its ability to fixate on the fabrics without mordant as fixative. However, like most of natural dyes, curcumin is fugitive dye because it will fade over time. Thus, mordant is added to the dye to enhance curcumin fixation on the fabric.
Several studies has been focusing in the development of natural dye. Different mordant will result different color gradation and strength [6]. Dyes for polyester tend to be disperse dye and designed to be hydrophobic in nature [7]. Thus, some researchers have formulate natural dyes with additive such as surfactant to produce emulsion. Water-in-oil (W/O) natural dye emulsion is successfully produced from sappan wood and generates vibrant red color [8]. Sonication during the dyeing process can also improve the dye adherence and fastness properties on the cotton fabric [9].

This research is conducted to understand the influence of concentration of mordant and emulsifier on the color strength, the color fastness, and the color gradation or coordination of curcumin on the polyester.

2. Methodology

Material used in this research was synthetic cotton with 80% Polyester obtained from local textile market. Fresh turmeric (Curcuma domestica Val) was obtained from local market. The mordant used were lime juice and alum. Alum was obtained from PT. Brataco Chemika Bandung, while lime juice was obtained from local market. Tween 80 was used as emulsifier and obtained from PT. Brataco Chemika Bandung.

2.1. Curcumin extraction and analysis

The extraction process was conducted with zero used of chemical solvent. Turmeric was washed and cleaned, then cut to smaller pieces and crushed with food processor. Crushed turmeric was filtered and centrifuged at 10,000 rpm at 5 minutes until obtaining turmeric juice. The concentration of curcumin in the turmeric juice was analysed using UV-VIS Spectrophotometry at 420 nm.

2.2. Natural dye formulation and dyeing of polyester

The turmeric juice was formulated with two different type of mordants (alum and lime juice) with volume ratio of turmeric juice (TJ) and mordant 1:0, 2:1, 1:1, and 1:2. The mixture of turmeric juice and mordant was agitated at high speed and room temperature for 30 minutes.

Polyester with the size of 3 x 3 cm was dyed and soaked overnight at room temperature. The dyed polyester must be dried before proceeding into the analysis step.

The formulation with the best color fastness was formulated with emulsifier Tween 80.

2.3. Analysis of dyed polyester

The color strength of dry dyed polyester was analyzed. Color strength analysis was conducted using Spectrophotometer Datacolor 600TM where K/S values follows Kubelka-Munk Theory of Reflectance:

\[ \frac{K}{S} = \frac{(1-R)^2}{2R} \]  

Where K is absorption coefficient of dyed fabric, S is scattering coefficient, and R is reflectance coefficient. Illuminant D65 and 10° observer were used. The color coordination of dyed polyester was also analyzed based on CIELAB color space.
The color wash fastness was investigated by washing dyed polyester in the water bath (500 ml) for 10 minutes. Each washing process is repeated five times. The washed polyester was dried, afterwards the color strength and the color coordination were measured. The concentration of curcumin in each of the water bath was measured using UV-VIS Spectrophotometry at 420 nm.

The color fastness was analyzed by Grey Scale (GS) method by comparing GS value of dyed polyester before and after washing.

3. Results and Discussion
The concentration of curcumin in the turmeric juice was 7.38 mg/L. The turmeric juice was then formulated with mordant and emulsifier with different volume ratio of turmeric juice, mordant, and emulsifier as follows: (1) 1:0:0, (2) 2:1:0, (3) 2:1:1, (4) 1:1:0, and (5) 1:2:0.

3.1. Evaluation of color coordination
The color coordination of each formulation can be seen on Table 1. The coordination using CIELAB color space with three coordinates letter L*, a*, and b*. L* represents the lightness from black (0) to white (100), a* represents green (-) to red (+), and b* represents blue (-) to yellow (+).

The dyed polyester without using any mordant and emulsifier generated orange color. Adding mordant alum into the formulation produced lighter orange on the polyester. Alum created lower pH in the dye solution. In acidic condition, curcumin emits brighter color gradation [10]. Compared to alum, lime juice is natural mordant because it contains minerals. Additionally lime juice creates acidic condition in the dye solution, thus it emits brighter color. However, in comparison with alum, lime juice generated light yellow color, while alum more into light orange. This might cause by citric acid contained in the lime juice, which is natural anti-oxidant and natural bleach [11].

Adding emulsifier to the formulation will generate dye emulsion. Tween 80 has natural light yellow color, mixing it with curcumin would lighten the dye color.

| Mordant Alum | Before Washing | After Washing |
|--------------|----------------|---------------|
| TJ:M:E*      | L* a* b*       | L* a* b*      |
| (1) 1:0:0    | 50.611 33.393 23.077 | 58.561 -0.404 4.132 |
| (2) 2:1:0    | 62.144 2.88 55.333 | 60.682 5.964 52.920 |
| (3) 2:1:1    | 65.896 -9.812 52.223 | 57.132 8.093 24.408 |
| (4) 1:1:0    | 50.513 17.938 44.282 | 48.645 16.012 37.762 |
| (5) 1:2:0    | 66.672 2.600 56.236 | 55.886 7.047 35.394 |

| Mordant Lime Juice | Before Washing | After Washing |
|--------------------|----------------|---------------|
| TJ:M:E*            | L* a* b*       | L* a* b*      |
| (1) 1:0:0          | 50.611 33.393 23.077 | 58.561 -0.404 4.132 |
| (2) 2:1:0          | 71.874 5.331 62.078 | 70.451 8.158 60.581 |
| (3) 2:1:1          | 76.038 0.621 65.543 | 57.045 -1.847 14.908 |
| (4) 1:1:0          | 71.040 9.726 61.415 | 58.908 -2.099 14.140 |
| (5) 1:2:0          | 63.204 12.021 57.373 | 61.664 4.687 19.941 |

3.2. Evaluation of color strength
The color strength (K/S) of the fabric indicates the depth of the color penetrate in the fabric [12]. Its value can be influenced by the type of mordant used [12]. The results of different formulations can be seen in Figure 2. Dyed polyester without any mordant and emulsifier had the weakest color strength around 8.51 and adding alum as mordant to turmeric juice would increase the color strength of the
dyed polyester. The color strength of 15.40 was generated when the alum was increased twice to turmeric juice. The affinity between natural colorant and fibers was considered very limited, thus mordant was applied to improve its affinity. Mordant can form chemical bond between fiber and colorant, hence support the fixation of colorant into the fabric [13].

In comparison to alum, lime juice produced dyed polyester with lower color strength. Increasing lime juice did not have the same effect as alum in enhancing the color strength. One of the parameter that influence the diffusion of dye into fiber is pH value [14]. Lime juice mordant creates medium acidic condition (pH 4 – 5) compared to alum (pH 2 – 3). Curcumin might diffuse better into the fabric in high acidic condition, thus higher color strength when alum was used as mordant.

![Figure 2](image)

**Figure 2.** The color strength (K/S) of curcumin on polyester for different formulations (a) using Mordant Alum, and (b) using Mordant Lime Juice

### 3.3. Evaluation of color wash fastness

The color strength of curcumin in the fabric after the washing process can be seen in Figure 2. Surely washing would decrease the color strength of curcumin in the fabric for all formulations [12]. The decrease of color strength indicates the weaker fixation rate of the dye in the fabric. In contrast to the rest of formulations, the ratio of turmeric juice to mordant of 2:1 for both alum and lime juice produced the strongest color strength after washing process.

Grey scale is one method to determine the color shading of the fabric. It has different grades with 5 being the highest. It can be used to indicate the color changes after washing process. When the grade drops significantly, it shows low resistance of color changes or weak color fastness of the dye.

Figure 3 displays the grey scale (GS) of the fabric before and after washing. It can be seen that washing process reduces the GS grade of the fabric, which indicating color changes from the initial condition. Excluding the formulation of turmeric juice to mordant 2:1, almost all formulations shows significant drops of GS value. At ratio 2:1 (turmeric juice to mordant), when alum was used as mordant the GS value dropped to 3.50 from 3.60. This change is considered small and indicated that color of fabric after washing still in the same range as initial (Table 1). The similar phenomena also occur when lime juice was used as mordant, the GS value reduced to 3.48 from 3.57. Thus implies the same color range as it is proven in Table 1.

The curcumin concentration in the water bath (washing bath) can be seen in Figure 4. The lesser the concentration of curcumin in the water bath indicates the strong fixative rate of curcumin in the fabric. Figure 4 shows that formulation of turmeric juice to mordant 2:1 diffuses low concentration of curcumin in the water bath. This shows better dye fixation in the fabric and consequently produces stronger color strength and shade of the fabric.
Adding Tween 80 as emulsifier in the formulation would worsen the color fastness in the polyester. Tween 80 can act as detergent and lift the curcumin from the fabric.

![Figure 3. The Grey Scale (GS) of polyester for different formulations (a) using Mordant Alum, and (b) using Mordant Lime Juice](image)

![Figure 4. The concentration of curcumin in the water bath from different formulations (a) using Mordant Alum, and (b) using Mordant Lime Juice](image)

4. Conclusions
This research shows that adding alum and lime juice as mordant would brighten the color of curcumin on the polyester. Increasing alum as mordant strengthened the color strength of curcumin on the polyester, while increasing lime juice gave no similar affect. The color wash fastness of the curcumin on the polyester gave the best result in the ratio of turmeric juice to mordant 2:1 without adding any emulsifier.

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