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UV protection and color constants of cotton fabrics dyed with natural dyes

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Abstract: In this research, cotton fabrics were dyed with various dye solutions obtained from natural materials, including turmeric, hibiscus and spinach, as well as mixtures of them. Pre-mordanting was applied using three metal salts. After the dyeing process, color constants were determined using the imageJ program, and the UVB/UVA transmission ratio for the dyed fabrics was measured. The results show that fabrics dyed with natural dyes, as well as those dyed with mixtures of natural dyes and different mordants, produced a variety of colors; additionally, the UV transmission values were found to be different and lower than those of the undyed fabrics.

Keywords: color, cotton fabrics, natural dyes, photo analysis, ultraviolet.

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1. Introduction

There are many steps toward using natural materials in textile dyeing due to their properties, where natural dyes are renewable, environmentally eco-friendly, and nontoxic, used in dyeing different fabrics and do not cause pollution (Ali et al., 2022). Also, natural dyes give a broad range of colors, and a slight change in the dyeing technique or mordant can modify the color of fabrics or get a new color. Natural dyes can be extracted from plants, insects or minerals (Chungkrang et al., 2020); they could give fabrics functional properties like antibacterial, flame resistance and UV protective properties, among others (Che & Yang, 2022).

Ghaheh et al. (2014) dyed wool fabrics with green tea, henna, turmeric, madder and saffron petals to obtain fabrics with antibacterial activity against some bacteria types with low color resistance. The Bar and Bar (2020) dyed silk fabrics with Bauhinia vahlii bark with banana peduncle extract, good fastness color properties were obtained with promising results for flame retardancy, Rungruangkitkrai et al. (2020) dyed Eri silk fabric with different natural dyed extracts from Neem bark, Andaman satinwood leave, Burma padauk bark, Gloden shower pods, Sappan and Acacia bark, and the results show very good fastness property and excellent UV protection.

In this research turmeric, spinach, and hibiscus were used as natural dyes to obtain UV protective fabrics.

2. Materials and methods

2.1. Material

Plain cotton fabric (135) g/m^2 from the local market, ethanol (Honeywell Lab 99.8 %,), aluminum potassium potash alum (LOBACHEMIE 474.38 g/mol), ferrous sulphate (LOBACHEMIE 278.01g/mol), cupric sulphate (LOBACHEMIE 249.68g/mol). Spinach, turmeric and hibiscus from the local market.

Spectrophotometer device (Jasco 530 (190-800) nm) to measure UVA and UVB transmission, and ImageJ program to measure (R, G and B) color constants that refer to red, green and blue.

2.2. Dyeing method

Before dyeing, the fabric was treated with a pre-mordanting process using three mordants; alum (ALM), ferrous sulphate (Fe) and cupric sulphate (Cu), with a concentration of 10 g/l at a temperature of 80°C for an hour, after that fabrics transport to the dyed solution, the bath ratio (1:50) (fabric weight: dyeing solution weight), at boiling temperature for one hour. After that, the fabrics were washed with water and dried at room temperature.

Dyeing solutions were extracted from three plants: turmeric (T), spinach (S), and hibiscus (H), by dissolving 50 g of the plant in (1) L of (1:1) water-ethanol solution at 60°C for one hour. Then the solutions were filtered to obtain the dye solution that was ready for the dyeing process. In addition to the three solutions obtained from the extraction process, the previous solutions were mixed in equal volumetric proportions to obtain four additional dyeing solutions; spinach-hibiscus (SH), spinach-turmeric (ST), hibiscus- -turmeric (HT), spinach-hibiscus- turmeric (SHT), and thus it were 7 dyeing groups: (T, S, H, SH, ST, TH and SHT).

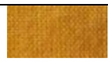
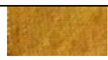
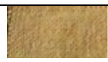
3. Result and discussion

3.1. RGB of dyed fabrics

The RGB of samples was determined by the image J program, fabrics were scanned and then analyzed with the program in RGB form. Table 1 shows R, G, and B values, as (UF) is undyed fabric.

Table 1. Color constants of dyed fabrics.

Sample name	sample	R	G	B
UF		254.876	254.937	254.937
S-ALM		217.987	219.444	197.925
S-Fe		186.21	180.21	155.031
S-Cu		199.512	199.925	161.5
T-ALM		227.838	170.856	8.854
T-Fe		133.028	74.898	34.369
T-Cu		183.094	99.36	16.778
H-ALM		188.313	136.119	154.19
H-Fe		126.826	127.888	137.437
H-Cu		112.537	121.96	132.619
ST-ALM		217.197	160.515	6.173
ST-Fe		167.381	126.142	81.916
ST-Cu		163.292	80.013	11.821

HT-ALM		188.704	122.065	30.273
HT-Fe		121.262	92.45	42.484
HT-Cu		94.783	82.433	16.225
SH-ALM		166.033	134.769	144.199
SH-Fe		149.604	134.698	134.792
SH-Cu		171.957	169.665	166.422
SHT-ALM		188.806	132.375	39.306
SHT-Fe		173.369	139.746	83.644
SHT-Cu		168.143	137.526	41.489

It was noted from Table 1 that:

- The mordants provided the fabrics with pure dyed solution with a different color, and when a mixed solution was used, a new color was obtained.

- With different mordants, the three constants (R, G and B) varied in the range (0-255), but these differences had no one behavior for each sample, because of the varying complex formed between dyed group mordant and fabrics, where:

Dyeing with (S and H) dyes group, using (F) mordant caused decreasing (R, G and B) values which meant darker values; the same behavior was found in dyed fabrics with mixed dyed groups that contained spinach and hibiscus. On the other hand, the (F) mordant, used in dyed fabrics with turmeric, made (R and G) decrease but B increase, and this behavior repeated with mixing dyed groups containing turmeric. Although the use of (ALM) mordant gave fabrics that were dyed with spinach and hibiscus and their mixing higher values for (R, G and B), that changed for the dyeing with turmeric and its mixing.

These three constants made the comparison between samples difficult; the grayscale for the samples was found by applying Equation 1 (Benedetti, 2009):

$$Grayscale = 0.299R + 0.587G + 0.114B \qquad (1)$$

Grayscale results are shown in Figure 1 where samples that moved toward 255 displayed a lighter color.

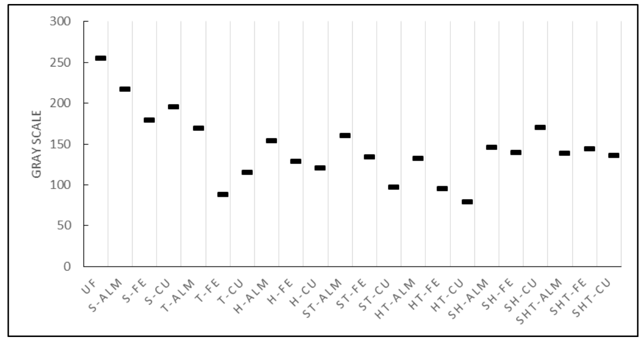


Figure 1. Grayscales of dyed fabrics.

Mordants provided different colors to each dye group because of the different behavior of the matrix dye mordant, which is shown in Fig. 1, where:

- For (S, T and SH) groups, ferrous sulphate gives darker shade, compared to alum and cupric sulphate.

- For (H, ST, HT and SHT) groups, cupric sulphate gives a darker shade, compared to alum and ferrous sulphate.

- Alum gave the lightest shade for all groups, apart from (SH and SHT).

- (S-ALM) The dyed fabric was the lightest color among all dyed fabrics, and (SH-Cu) dyed fabric was the lightest color among the mixing dyeing group. (T-Fe) dyed fabric gave the darkest color among all fabrics, and (HT-Cu) the darkest color among all mixed-dyed fabrics.

-Fabrics dyed with spinach gave a lighter color but when mixed with turmeric, hibiscus (ST or SH) or turmeric with hibiscus (SHT), the color shifted to a darker shade.

- Turmeric turned all dyed fabrics into darker colors.

3.2. UVA and UVB protection properties of dyed fabrics

To determine UV protection for dyed fabrics, the UVA average, the UVB average and the ratio (UVB/UVA) of dyed fabrics were calculated by using the following equations (Gambichler et al., 2002):

$$UVA_{average} = \frac{1}{n}\sum_{320}^{400} T(\lambda) \qquad (2)$$

$$UVB_{average} = \frac{1}{n}\sum_{290}^{320} T(\lambda) \qquad (3)$$

$$UVB/UVA = \frac{UVB_{average}}{UVA_{average}} \qquad (4)$$

Where T (λ) is the spectral transmittance at wavelength λ that was obtained by a spectrophotometric device.

Figure 2 shows the UVB average transmission values that were obtained by applying Eq. 2.

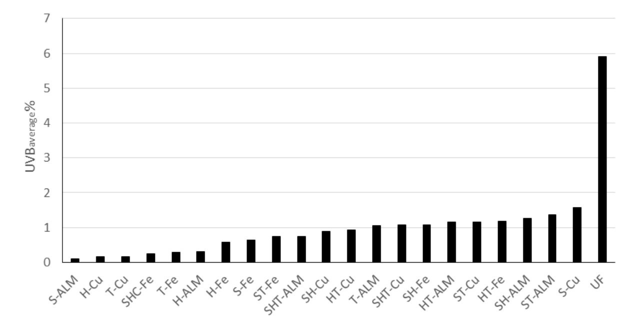


Figure 2. UVB average of dyed fabrics.

Fig. 2 shows that:

All dyed fabrics gave UVB transmission protection higher than undyed fabrics.

The best UVB protection was for the dyed fabric with a group (S-ALUM), while the lowest UVB protection was for the dyed fabric with a group (S-Cu).

The mixed dyed group gave the highest UVB protection (SHC-Fe), and the mixed dyed group gave the lowest UVB protection (ST-ALM).

Figure 3 shows the result of the UVA average transmission value that was obtained by applying Eq. 3.

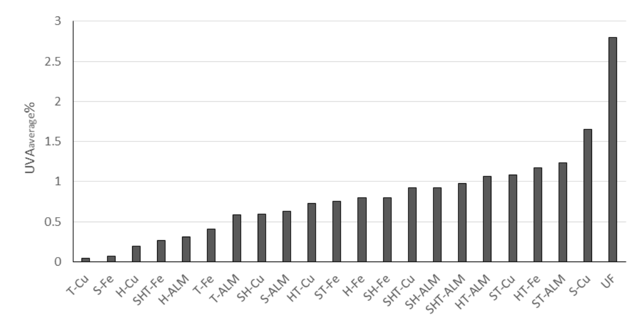


Figure 3. UVA average of dyed fabrics.

As Fig. 3 shows:

All dyed fabrics provided UVA transmission protection higher than that of the undyed fabric.

The best UVA protection was for the dyed fabric with group (T-Cu), while the lowest UVA protection was for the dyed fabric with group (S-Cu).

The mixed-dyed group gave the highest UVA protection (SHC-Fe), and the mixed-dyed group gave the lowest UVA protection (ST-ALM).

Dyed fabrics with spinach and cupric sulphate gave the highest transmission values for UVA and UVB. On the other hand, it was found that mixtures with spinach reduced the transmission values for (UVA and UVB) in the same order as follows: S-Cu> ST-Cu>SHT-Cu> SH-Cu.

Fabrics dyed with spinach and alum gave the lowest UVB transmission values; but it was not the best for UVA, for which the lowest transmission values were for the (T-Cu and S-Fe) groups.

The matrix that gave the lowest UVA and UVB transmission values was for the (SHT-Fe) group.

Figure 4 shows the ratio (UVB/UVA) that was obtained by applying Eq. 4; if the value of (UVB/UVA) is below (1) that means UVA is higher from UVB.

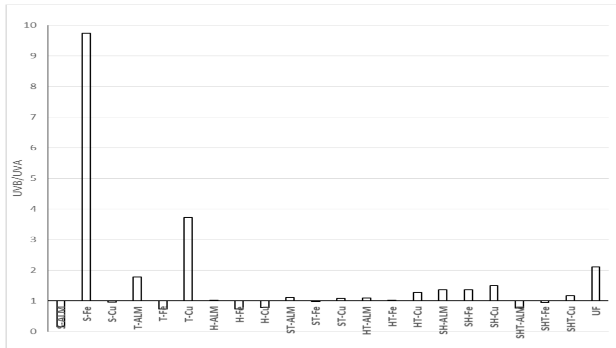


Figure 4. UVB/UVA ratio of dyed fabrics.

Fig. 4 illustrates that the UVB average was greater than the UVA average for more than half of the fabrics, and the sample (S-Fe) gave UVB higher than UVA about 10 times. If (UVB/UVA) is higher than (1) that means the fabrics give better protection against UVA than UVB and vice versa. For all of the above, it was observed that most samples exhibited better UVA protection than UVB protection.

The pure dyed group (S-Cu and H-Cu) gave the best UVA and UVB protection, and (H-Cu) gave a UVB/UVA ratio less than (1).

The mixed solution (SHT) with mordant (Cu) gave best UVA and UVB protection with UVB/UVA ratio lower than (1). The ideal UVB/UVA ratio is more than 1 or less, depending on the sensitivity of the patient, as both UVA and UVB radiation can cause damage. Thus, it could be determined which is the best dyed fabric from the (21) prepared samples that could be suitable for the specific situation.

4. Conclusions

This study involved 21 fabrics dyed with various dye solutions obtained from three plants: turmeric, spinach and hibiscus, as well as mixtures of them; three mordants were applied before dyeing. The (S-ALM) dyed fabric exhibited the lightest color, while the (T-Fe) dyed fabric displayed the darkest color. All dyed fabrics offered better protection against UVA and UVB rays compared to the undyed fabric. The (S-ALM) dyed fabric provided the best UVB protection, whereas the (T-Cu) dyed fabric offered the best UVA protection.

Conflict of interest

The authors have no conflict of interest to declare.

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