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Determination of Color Properties of Dyed Textile Products Using Different Mordanting Methods

Adem ÖNAL*, Neslihan ÖZBULAT, Sama NACHED, Miray YILMAZ

Tokat Gaziosmanpaşa University, Tokat, Türkiye.

Abstract: In this research, we investigated the dyestuff properties of dwarf elderberry (Sambucus ebulus), which has many pharmacological functions. Dyeing of cotton fabrics and wool yarns was carried out using Sambucus ebulus L. fruit extracts. Textile products were processed to pre–, meta–, and post–mordanting methods in the presence of iron sulfate (FeSO4), copper sulfate (CuSO4) and alum (AlK(SO4)2) mordants. Color analyses of dyed textile products were performed and, the results were examined in terms of washing, rubbing, and light fastness. According to the results, it was determined that wool yarns showed better dyeing potential than that of cotton fabrics in terms of washing fastness. While the highest K/S value was measured as 6.55 in cotton fabrics with the pre-mordanting method, the highest K/S value was measured as 14.90 in wool yarns. In addition, the highest color strength values were obtained in each three mordanting methods. While gray, beige, and cream color tones were obtained in dyeing cotton fabrics, beige, green, and gray color tones were obtained in dyeing wool yarns.

Keywords: *Sambucus ebulus*, dwarf elderberry, dyestuff, natural dyes, textile products.

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***Corresponding author. E-mail:** adem.onal@gop.edu.tr.

1. INTRODUCTION

Sambucus ebulus L. is one of the medicinal plants known since ancient times (Jabbari et al., 2017). *Sambucus ebulus* L., commonly called dwarf elder, elderberry, or danewort, belongs to the Adoxaceae family. It is known to have about 190 species and grows mainly in southern and central Europe, northwest Africa and southwest Asia (Shokrzadeh and Saravi, 2010). *Sambucus ebulus* L. has been reported to have anti-ulcerogenic, anti-microbial, anti-inflammatory, anti-parasitic, anti-viral, and anti-oxidant properties (Cumhur 2022; Jiménez et al., 2015; Salehzadeh et al., 2014; Yesilada et al., 2014). Plant extracts are used in many fields due to their versatile applications as well as their important biological activities. Extracts obtained from various parts of plants are widely used in dyeing textile products (Önal et al., 2021a; Önal et al. 2021b). Since natural products are environmentally–friendly, biodegradable, non–allergenic, non–toxic, they can be considered as a very important alternative to synthetic dyes (Önal et al., 2020).

Metal salts that strongly bind the dyestuff to the fiber are called mordant. Mordants are metal salts used to derive more than one color. Generally, mordants such as $FeSO_4$, $CuSO_4$, and $AlK(SO_4)_2$ are widely used. Mordants have been used in natural dyeing since ancient times, as plants have low affinity for fiber in dyeing (Önal, 1996).

In the literature, it has been reported that the compound with dyestuff properties in *Sambucus ebulus* L. is (*S*)–sambunigrin (Figure 1) (Kayabası and Etikan 1998). It is known that the fruits and leaves of the elderberry plant are used as natural dyes (Özdemir, 2018). In this study, cotton fabrics and wool yarn were dyed using three different mordanting methods by using extracts from elderberry fruits. Color analyses of dyed textile products were performed.

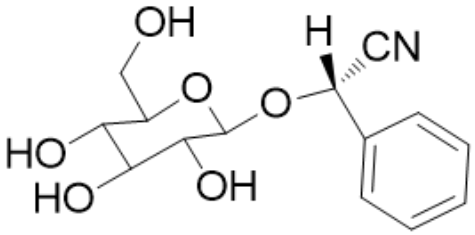

Figure 1: Structure of (*S*)-sambunigrin.

2. EXPERIMENTAL SECTION

2.1. Chemicals and Apparatus

Sambucus ebulus L. fruits were collected in July from the Tokat province, Türkiye. $CuSO_4.5H_2O$, $FeSO_4.7H_2O$, $AlK(SO_4)_2.12H_2O$ were obtained from Sigma Aldrich. Textile products were obtained from Toga Textile Ltd. company, Tokat province, Türkiye. The color properties of the dyed samples were evaluated by Premier Colorscan SS 6200A Spectrophotometer in terms of CIELab values (*L**, *a**, *b**, *C**) and color strength (K/S) values. Color codes were determined by Pantone Color Guide. The light fastness, washing fastness, and rubbing fastness values of all dyed samples were determined according to ISO 105–C06 and International Color Standardization (CIS) were tested with Atlas weather–ometer, Launder–ometer and 255 model crock–meter, respectively (Eser et al., 2015).

2.2. Methods

Extraction was carried out using cold press method. 100 g of fresh fruits of *Sambucus ebulus* L. were pressed and diluted with distiled water up to 2 liters. This procedure was continued until it reached 4 liters, and finally all of extracts were collected to get stable color tone (Önal et al., 2021a; Önal et al. 2021b). All dyeing processes were applied as in our previous studies (Eser et al., 2015; Önal et al., 2021a).

2.2.1. Pre-mordanting

The cotton fabric/wool yarn was heated in 0.1 M mordant solution for 1h at 70 ºC. After cooling of the sample, it was rinsed with distilled water and put into dye-bath solution (100 mL). It was heated at 70 ºC for 1h. The dyed material was rinsed with distilled water and dried.

2.2.2. Meta-mordanting

Mordant (in solid state which is equivalent to 0.1 M mordant solution), dyestuff solution and cotton fabric/wool yarn was put into the flask and heated at 70 ºC for 1 h. After cooling, it was rinsed and dried.

2.2.3. Post-mordanting

The cotton fabric/wool yarn was first treated with the dyestuff solution for 1h at 70 ºC. After cooling, it was rinsed with distilled water and put into 0.1 M mordant solution and heated for 1h at 70 °C. Finally, the dyed material was rinsed with distilled water and dried.

3. RESULTS AND DISCUSSION

3.1. Dyeing Mechanism

Mordants provide better bonding of the dyestuff to the fiber molecule. In this study, color properties were investigated by using three different mordants ($CuSO_4$, $FeSO_4$, and $AlK(SO_4)_2$). Metal cations in mordants can form stable complexes. The complex between dyestuffs and metal cations can be explained as follows:

- Metal cations form complexes between the free amino ($–NH_2$) and carboxyl groups (–COOH) of the wool yarn and the –OH molecules of the dyestuff ((*S*)–sambunigrin), thus displaying dyestuff properties (Figure 2).
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The metal complex formed between the $–CH_2O$ groups in the cellulose molecules in the cotton fabric and the –OH groups in the dyestuff ((*S*)–sambunigrin) shows dyestuff properties (Figure 3).

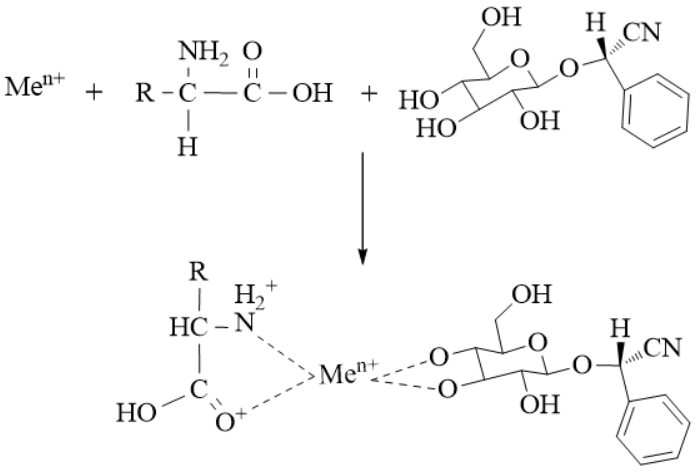

Figure 2: Proposed dyeing mechanism of wool yarn with (*S*)–sambunigrin (M^{n+}: Cu^{2+}, Fe^{2+}, Al^{3+}).

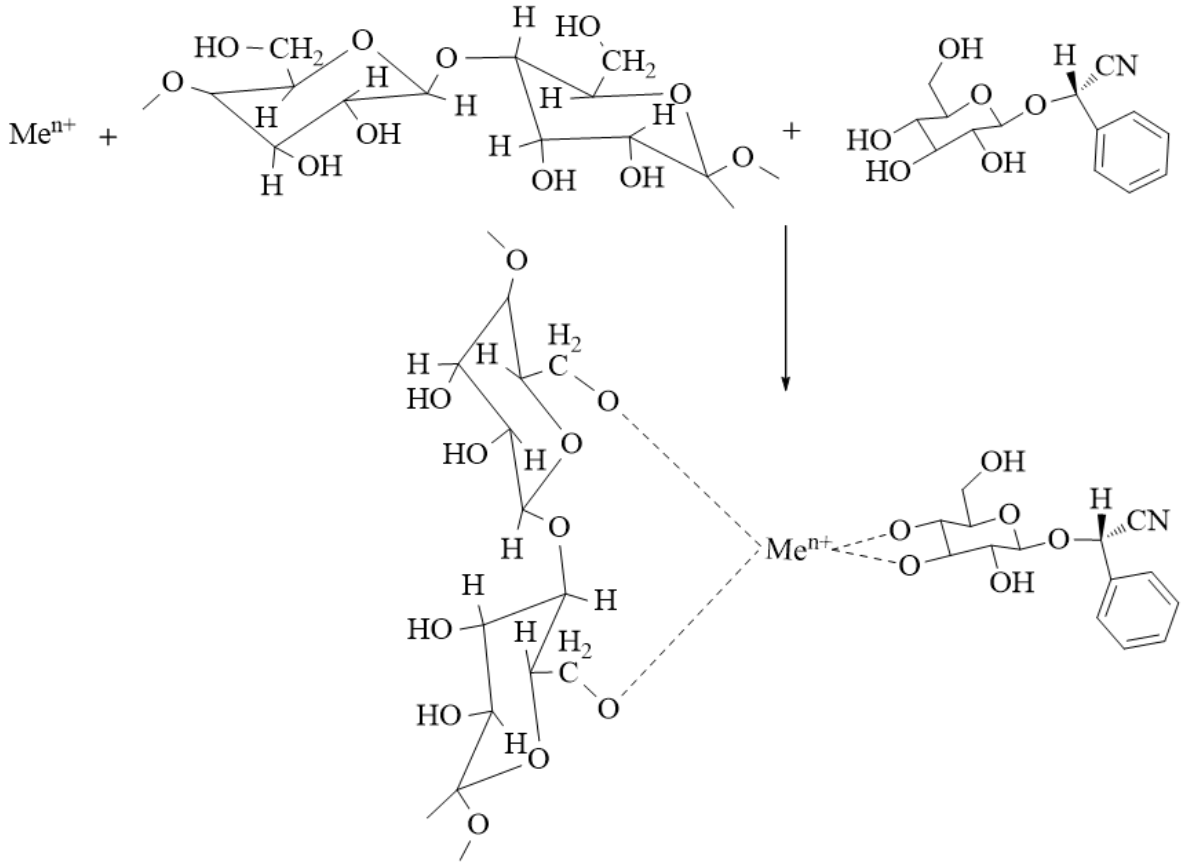

Figure 3: Proposed dyeing mechanism of cotton fabric with (*S*)–sambunigrin (M^{n+} : Cu^{2+}, Fe^{2+}, Al^{3+}).

3.2. Fastness Values and Color Codes

Fastness values and color codes for dyed wool yarns and cotton fabrics were presented in Tables 1 and 2.

Table 1: Fastness values and color codes of dyed cotton fabrics.

Method	Mordant	Wash fastness[a]	Rubbing fastness[b] (wet–dry)	Light fastness[c]	Color code (Pantone)
Pre–	$FeSO_4$	3–4	5–5	3/4	7535 CS
Meta–	$FeSO_4$	4–5	5–5	4	5665 CS
Post–	$FeSO_4$	5	5–5	4/5	400CS
Pre–	$CuSO_4$	3	5–5	4	427 CS
Meta–	$CuSO_4$	4–5	5–5	4/5	406 CS
Post–	$CuSO_4$	4–5	5–5	4/5	5527 CS
Pre–	$AlK(SO_4)_2$	5	5–5	4	5527 CS
Meta–	$AlK(SO_4)_2$	5	5–5	4/5	5665 CS
Post–	$AlK(SO_4)_2$	5	5–5	5	7527 CS
	N/A	5	5–5	3-4	5507 CS

[a]Wash and [b]rubbing fastness 1 = poor, 5 = very good, [c]Light fastness 1 = very poor, 8 = outstanding.

When Table 1 is examined, dry and wet rubbing fastnesses in cotton fabric dyeing are very good for all mordants and mordanting methods. Washing fastness is slightly lower for iron sulfate in pre– and meta–mordanting. In dyeings made with copper sulfate mordant, the value obtained in the pre-mordanting is partially lower than in the meta– and post–mordanting. Light fastnesses are lower in pre–mordanting with iron sulfate, and generally below the medium value (4) for all mordants and mordanting methods. Light gray with alum, beige with iron sulfate, and cream with copper sulfate were obtained. According to the fastness results, the order of mordant activity can be given as alum > copper sulfate > iron sulfate.

Table 2: Fastness values and color codes of dyed wool yarn.

Method	Mordant	Wash fastnes[a]	Rubbing fastness[b] (wet–dry)	Light fastness[c]	Color code (Pantone)
Pre–	$FeSO_4$	5	4.5–5	4	417 CS
Meta–	$FeSO_4$	5	5–5	4	404 CS
Post–	$FeSO_4$	5	5–5	4–5	402 CS
Pre–	$CuSO_4$	5	5–5	4	5625 CS
Meta–	$CuSO_4$	5	5–5	3–4	5635 CS
Post–	$CuSO_4$	5	5–5	4–5	5655 CS
Pre–	$AlK(SO_4)_2$	5	5–5	4	401 CS
Meta–	$AlK(SO_4)_2$	5	5–5	4	414 CS
Post–	$AlK(SO_4)_2$	5	5–5	4–5	415 CS
	N/A	5	5–5	3–4	5645 CS

[a]Wash and [b]rub fastness 1 = poor, 5 = very good, [c]Light fastness 1 = very poor, 8 = outstanding.

According to Table 2, dry and wet rubbing fastnesses in wool yarns dyeing are very good, that is, 5 for every three mordants and mordanting methods. Washing fastnesses for iron sulfate mordant are 4–5 in pre–mordanting and 5 in others. Light fastnesses are generally medium and below. The light fastnesses detected in the final mordanting were slightly higher than the meta– and pre–mordanting. The effectiveness of mordants in wool dyeing is close to each other. Beige and shades of beige are obtained for alum mordant, matte green and grey tones for iron sulfate mordant, grass green and beige tones are obtained for copper sulfate.

3.3. Determination of Color Performance

Color strength was determined as K/S values of the dyed samples using the Kubelka–Munk equation (Džimbeg-Malčić et al., 2011). K/S and L^*, a^*, b^* values of wool yarns and cotton fabrics are given in Table 3.

Table 3: K/S and *L* a* b** values of cotton fabrics and wool yarn.

Fabric	**Mordant**	***L****	***a****	***b****	**K/S**
Cotton	$FeSO_4$	34.20	3.75	8.46	6.55
	$FeSO_4$	29.92	2.99	5.99	4.48
	$FeSO_4$	32.60	1.08	6.45	7.01
	$CuSO_4$	32.09	0.92	20.56	6.40
	$CuSO_4$	33.45	0.78	19.28	5.32
	$CuSO_4$	31.90	1.45	21.12	6.00
	$AlK(SO_4)_2$	40.21	4.23	15.12	4.99
	$AlK(SO_4)_2$	41.08	4.56	10.02	4.48
	$AlK(SO_4)_2$	43.20	5.01	9.14	5.01
Wool	$FeSO_4$	38.36	4.95	17.90	14.55
	$FeSO_4$	37.90	3.26	16.77	14.90
	$FeSO_4$	39.76	3.90	15.62	13.80
	$CuSO_4$	35.01	–0.99	21.50	9.90
	$CuSO_4$	35.05	0.80	21.67	7.27
	$CuSO_4$	39.66	-0.77	21.40	6.09
	$AlK(SO_4)_2$	43.95	5.79	17.66	9.76
	$AlK(SO_4)_2$	41.24	5.70	16.05	9.20
	$AlK(SO_4)_2$	42.20	5.99	15.97	8.05
unmordant–cotton	–	36.23	7.76	15.22	3.96
unmordant–wool	–	58.12	8.89	17.44	4.92

As seen in Table 3, it was obtained in different shades of color intensity for cotton fabrics. Grey and beige color tones were obtained for cotton fabrics, in a general manner. The highest K/S value was measured as 6.55 for ıron sulfate with pre-mordanting method for dyed cotton fabrics. In addition, it was obtained in different shades of color intensity for wool yarns. The highest K/S value was detected as 14.90 for iron sulfate mordant. Examples of cotton and wool yarn dyed with *Sambucus ebulus* L. fruit extract are as in Figure 4.

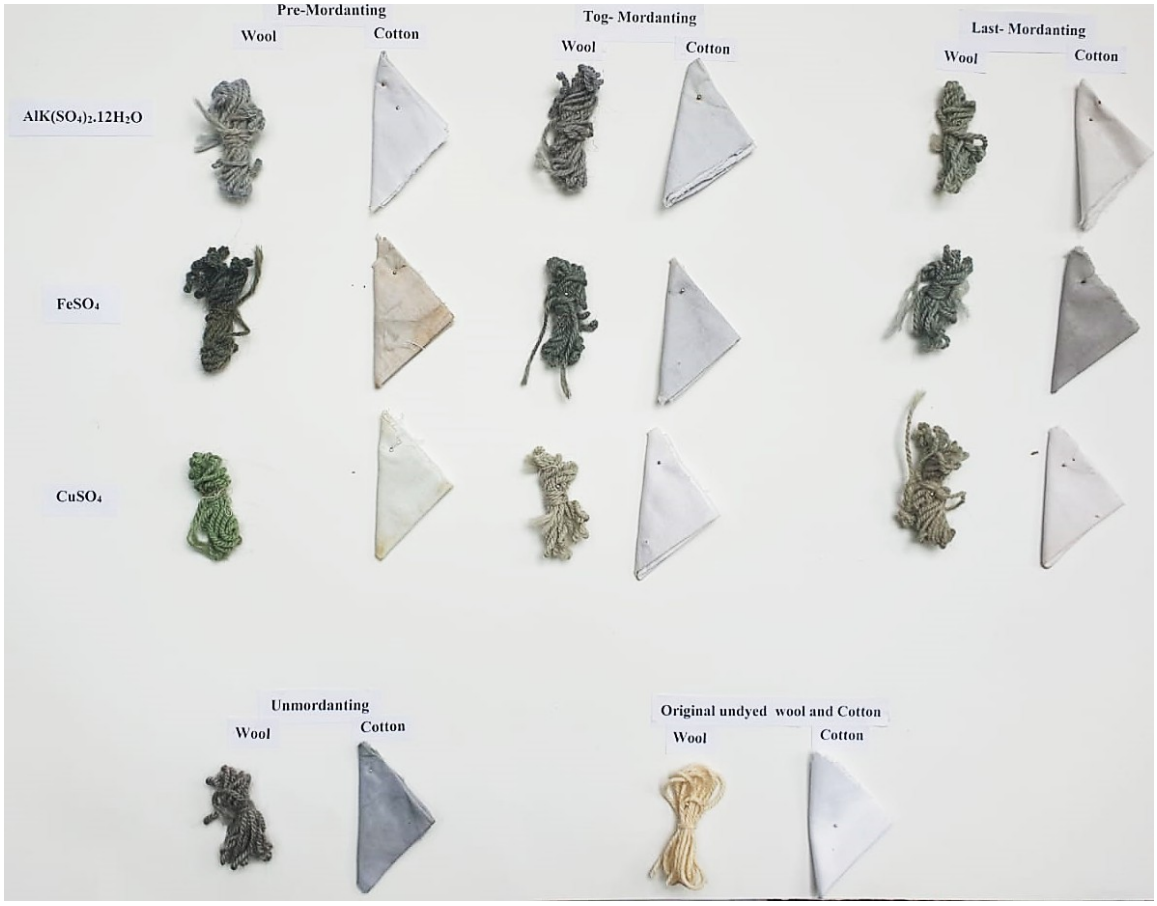

Figure 4: Cotton fabric and wool yarn samples dyed with *Sambucus ebulus* L. fruit extract.

4. CONCLUSION

In the present work, the *Sambucus ebulus* L. fruit extract was used for dyeing of cotton fabric and wool yarn. Fabrics and threads were dyed using three different mordants. According to the fastness results, it was determined that the mordanting efficiency was alum > copper sulfate > iron sulfate. Grey, beige, and cream color tones were obtained in dyeing of cotton fabrics. Beige, green, and grey color tones were obtained in the dyeing of wool yarns. Generally, very high fastnesses were obtained in both cotton fabric and wool yarn dyeing. The light fastnesses were at middle and below middle value in wool yarn and cotton fabrics. It is important that dwarf elderberry (*Sambucus ebulus* L.), which is widely used in medicine and pharmacy, is used in dyeing textile materials. In this study, this issue has been proven experimentally. Further investigations are underway.

5. CONFLICT OF INTEREST

There is no conflict of interest between the authors.

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