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Investigation of Dyeing Properties of Red Cabbage to Cotton Fabrics in Different pH and Mordanting Conditions

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Natural dyeing,
Mordanting,
Cotton

Abstract: In this study, dyeing properties of cotton fabrics with red cabbage extract as a natural colorant and by mordanting materials like potassium aluminumsulphate and tannic acid were investigated. Pre-mordanting, simultaneous mordanting and post-mordanting methods were used for mordanting of cotton fabric and natural dyeing process was carried out by exhaustion method. Moreover, since it is known that red cabbage presents different colors in different pH values due to its indicator property, the trials were renewed for three pH conditions as acidic, basic and neutral. After dyeing processes, color measurement, washing and rubbing fastness tests were applied to the samples. As a result of the study, it was observed that red cabbage extract can be used to dye cotton fabrics and the most permanent colors can be obtained in neutral pH conditions. When mordanting methods and mordanting materials were compared to each other, it was determined that various color shades were provided according to the mordanting materials and methods. In terms of general, it was concluded that uniform dyeings with high color yield can be obtained by tannic acid mordant and pre-mordanting method and high mordant concentration should be used to get dark color shades. In addition, washing and rubbing fastness values were determined to be in acceptable limits for natural dyeing.

Kırmızılahananın Farklı pH ve Mordanlama Koşullarında Pamuklu Kumaşları Boyama Özelliklerinin Araştırılması

Anahtar Kelimeler
Kırmızılahana,
Potasyumalüminyumsülfat,
Tannik asit,
Doğal boyama,
Mordanlama,
Pamuk

Özet: Bu çalışmada, doğal boya kaynağı olarak kırmızılahana ekstraktı ve potasyumalüminyumsülfat ve tannik asit olmak üzere iki çeşit mordan maddesi ile pamuklu kumaşların boyanma özellikleri araştırılmıştır. Mordan maddelerinin pamuklu kumaşlara aktarılmasında ön mordanlama, birlikte mordanlama ve sonradan mordanlama yöntemleri kullanılmış ve doğal boyama işlemleri çektirme yöntemine göre gerçekleştirilmiştir. Ayrıca kırmızılahananın indikatör özelliği sayesinde farklı pH koşullarında farklı renkler verdiği de bilindiğinden denemeler asidik, bazik ve nötr olmak üzere üç farklı pH koşulunda da tekrarlanmıştır. Boyama işlemlerinin ardından numunelere renk ölçümü, sürtme ve yıkama haslığı testleri uygulanmıştır. Çalışma sonucunda, kırmızılahana ekstraktının pamuklu kumaşların renklendirilmesinde kullanılabileceği ve en kalıcı renk tonlarının nötr pH koşullarında elde edilebileceği görülmüştür. Mordanlama yöntemleri ve mordan maddeleri birbiri ile kıyaslandığında ise mordan maddelerine ve yöntemlerine göre pamuklu kumaşların farklı renk tonları verdiği belirlenmiştir. Genel olarak bakıldığında, ön mordanlama yöntemi ve tannik asit mordanı ile daha yüksek renk verimine sahip düzgün boyamaların yapılabildiği ve koyu renk tonları elde etmek için yüksek mordan konsantrasyonu kullanılması gerektiği sonucuna varılmıştır. Ayrıca, yıkama ve sürtme haslığı değerlerinin de doğal boyamalar açısından kabul edilebilir seviyede olduğu belirlenmiştir.

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1. Introduction

Natural dyeing by plant sources has been applied in Middle Asia and Anatolia since ancient times [1-9]. Natural dye plants can be used to colourize textile, medicine, cosmetic and food due to their features like being abundant, providing color variety and not causing ecological and health problems [1-11].

Red cabbage is a kind of red/purple colored cabbage with leaves layer by layer and belongs to Brassicaceae family (*Brassica oleracea var. capitata f. rubra*). In natural dyeing of textile materials, generally the extract from the leaves of red cabbage has been used [8, 12-15]. In the structure of the red cabbage, cyanidine that is an anthocyanin pigment from flavonoids exists and this compound exhibits good dyeing property via chromophore and auxochrome groups [5, 8, 12-18]. Moreover, the anthocyanin in red cabbage has also been proved to have antimicrobial properties [8]. The molecular structure of cyanidine compound is given in Figure 1.

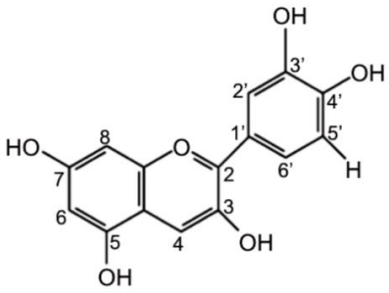

Figure 1. The molecular structure of cyanidine [14-16].

The organic compounds in complex structures that change color in accordance with pH conditions are called as indicator [17]. From the past studies, it is known that the cyanidine in red cabbage also shows indicator property depending on the changes in pH value. Thereby, when the pH value of the solution is changed, the structure of the cyanidine changes as well and causes the molecule to absorb other beams in different wavelengths of light spectrum. So, red cabbage gives different colors in different pH values (Figure 2). For instance, red cabbage gives red-pink in acidic medium, dark blue-green in basic medium and lilac-purple in neutral medium that its real pH value [8, 12-14, 17, 18].

Figure 2. The colors of the red cabbage in different pH values [19].

In order to improve fastness properties of natural dyes and provide color variety, mordanting process has generally been applied by inorganic and organic materials. As mordanting materials, mineral salts are generally preferred and mordanting can be applied in three methods. In pre-mordanting method, mordant materials are applied before dyeing, in simultaneous mordanting method, mordant materials are applied during dyeing and in post-mordanting method, mordant materials are applied after dyeing [2, 3, 5, 8, 9, 10, 20-23]. Mordant materials form coordinative bonds between fiber and dyestuff by complexing dyestuff molecules [2, 3, 5, 8, 9, 11, 24, 25]. Potassium aluminumsulphate ($KAl(SO_4)_2.12H_2O$) that is an important and common mordanting material has been used to give brightness and clarity to natural dyed materials. It has generally been used in light colors since it does not affect the actual color of the dyestuff due to be colorless [2, 3, 6, 24]. In addition, it is also safe for environment and human health [2, 22, 24]. Tannic acid ($C_{76}H_{52}O_{46}$) is another mordanting material known as tannin and is a polyphenolic compound found in tea, gall oak, acorn, colza and bean. Tannic acid crystals are amorphous materials like powder or flake in light yellow-brown color and generally used in coloring and leather finishing processes [26-29]. Likewise to potassiumaluminum sulphate, tannic acid is also known to be eco-friendly mordant [22].

In the literature, there are many studies about natural dyeing of textiles, mordanting process and mordanting methods. But, there are limited studies about the use of red cabbage in textile dyeing and the effects of different pH conditions on the colors of textile materials. In the first study about this matter, purplish red extract was obtained from red cabbage and wool, cotton and linen samples were dyed by pre-mordanting, simultaneous mordanting and post-mordanting with various mordant materials [12]. But, in this study, colors were visually evaluated and detailed colorimetric measurement by spectro photometer was not made. In addition, fastness properties of dyeings in different pH conditions were not studied. In another study, Ben Ticha et al., improved dyeing and fastness properties of cotton with red cabbage by cationization treatment, however not studied the effects of mordanting methods [13]. Benli studied the dyeing properties of red cabbage in different pH conditions on wool fabrics [14]. Similarly, Haddar et al., carried out a study on wool and silk fabrics [15]. Therefore, in the light of past studies, dyeing properties of red cabbage to cotton fabrics in different pH conditions and by different mordanting methods were investigated in detail in this study. Moreover, potassiumaluminum sulphate and tannic acid were selected to compare the effect of colorless and colorful mordant materials on color yield.

2. Material and Method

2.1. Material

Singed, desized and bleached 100% cotton fabric weighing 230 g/m^2 (warp: 44 thread/cm, weft: 25 thread/cm) was used in this study. Red cabbage was supplied from local store as a natural colorant. As mordanting materials, potassiumaluminumsulphate and tannic acid were supplied from Merck. In order to adjust different pH conditions, acetic acid and sodium hydroxide were supplied from Tekkim laboratory chemicals.

2.2. Method

2.2.1. Preparation of red cabbage extract

The preparation method of red cabbage extract was adapted from a preceding study [12]. Red cabbage leaves (3000 g) were cut in small pieces and put in a large pot. Then, the leaves were scrubbed with sodium chloride (300 g) for about 45 min and pure water about 9000 mL was added. After waiting for 12 h, purplish red extract was obtained and filtered. The pH value was found to be 6.5 for the extract and used for neutral medium trails. For acidic medium, acetic acid was added to extract and the pH value was adjusted to 4.5. For basic medium, sodium hydroxide solution was added to extract and the pH value was adjusted to 8.5. Likewise, pH value was readjusted after the addition of mordant materials to the dyeing baths.

2.2.2. Dyeing and mordanting processes

Dyeing and mordanting processes were carried out in laboratory type dyeing machine (SandoLab SUPERMAT 6) at 80°C for 60 min and in the liquor ratio of 1:20. All the samples were cut in the same weight (5 g). So, the used dye/fiber ratio was 6.6/1. The trials were separately made for three mordanting methods (pre-mordanting, simultaneous mordanting and post-mordanting) and for three pH conditions (acidic, basic and neutral). In addition, unmordanted dyeings were also carried out in acidic, basic and neutral pH conditions for comparison.

For pre-mordanted dyeing process, potassium aluminumsulphate and tannic acid were taken in the concentration of 1% and 5% for each pH condition and dissolved in hot pure water. Then fabric samples were added and mordanted. After mordanting, the samples were washed and dyed with red cabbage extracts prepared in acidic, basic and neutral pH conditions. After dyeing, the samples were washed and allowed to dry in room temperature.

For simultaneous mordanted dyeing process, potassiumaluminumsulphate and tannic acid were taken in the concentration of 1% and 5% for each pH condition and added to red cabbage extracts prepared in acidic, basic and neutral pH conditions. Then, fabric samples were added and dyed. After dyeing, the samples were washed and allowed to dry in room temperature.

For post-mordanted dyeing process, the samples were dyed with red cabbage extracts prepared in acidic, basic and neutral pH conditions. After dyeing, the samples were washed. Then, potassium aluminumsulphate and tannic acid were taken in the concentration of 1% and 5% for each pH condition and dissolved in hot pure water. Dyed samples were added to mordanting solutions and mordanted. After mordanting, the samples were washed and allowed to dry in room temperature.

In dyeing and mordanting processes, salt or any other additives were not added to the bath in order to observe the pure colors of red cabbage on cotton samples.

2.2.3. Color measurement

Colorimetric data of the samples were measured in accordance with CIELAB standards (Figure 3) in spectrophotometer (Datacolor 600TM).

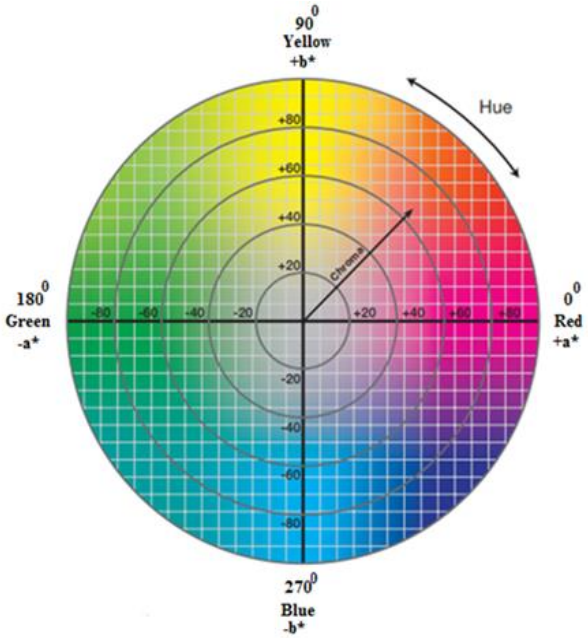

Figure 3. CIELAB color chart [30].

Dyed samples were separated into three groups as acidic, basic and neutral dyeings and the unmordanted samples of each group were selected as references. K/S values were calculated using the Kubelka–Munk equation as follows;

$$K/S = (1 - R)^2/2R \qquad (1)$$

where (K) is the adsorption coefficient, (R) is the reflectance and (S) is the scattering coefficient.

In addition, CIE L*, a*, b*, C*, h°, dE* values were also determined where L* is lightness, a* is redness (+ve) or greenness (−ve), b* is yellowness (+ve) or blueness (−ve), C* is chroma, h° is hue angle and dE* is total color difference. For each sample, five measurements were made and mean values were calculated.

2.2.4. Washing fastness test

Washing fastness test was carried out according to ISO 105:C06 A2S standard method at 40°C for 30 min. with 4 g/L standart detergent (ECE) in SDL ATLAS M228 Rotawash machine. The change in colour and staining were evaluated using a grey scale between 1 and 5.

2.2.5. Rubbing fastness test

Rubbing fastness test was carried out according to ISO 105:X12 standard method as dry and wet in James Heal machine and evaluated using a grey scale between 1 and 5.

3. Results

3.1. Colorimetric data results

Red cabbage extracts were prepared in different pH conditions and applied to cotton fabrics with the aim of coloring in the study. In addition, the effects of potassiumaluminumsulphate and tannic acid mordants were also investigated. The colors of the samples are given in Table 1.

According to the Table 1, it was seen that cotton fabrics dyed with red cabbage were in purplish grey color in acidic conditions, greenish yellow color in basic conditions and bluish grey in neutral conditions.

Actually, the color shades in acidic conditions were more pinkish right after dyeing but their colors changed after washing processes. This color change was thought to be due to the inconstancy of the complexes between cyanidine and metal ions in acidic pH values [8].

Table 1. The colors of the dyed samples

Sample	Acidic	Basic	Neutral	Sample	Acidic	Basic	Neutral
Unmordanted				Unmordanted			
1% M1 Pre-Mordanting				1% M2 Pre-Mordanting			
1% M1 Simultaneous Mordanting				1% M2 Simultaneous Mordanting			
1% M1 Post-Mordanting				1% M2 Post-Mordanting			
5% M1 Pre-Mordanting				5% M2 Pre-Mordanting			
5% M1 Simultaneous Mordanting				5% M2 Simultaneous Mordanting			
5% M1 Post-Mordanting				5% M2 Post-Mordanting			

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

Almost all the colors were in light shades and this fact was attributed to the fact that natural dyeing of cotton was harder than wool or silk fibers due to its chemical structure [10, 13, 22, 24] and the dyeing process was applied without salt addition that improves substantivity and dye fixation [9].

As known, natural cotton fibers have negative surface charge even if just a bit due to the carboxyl groups formed as a result of the oxidation of hydroxyl groups in their chemical structure. These negative charges on the cellulosic fibers repel anionic dyestuffs and cause low uptake of dyestuffs [13, 24].

Generally speaking, tannic acid mordant was found to be better in terms of color yield when compared to potassiumaluminumsulphate mordant and mordant concentration was very crucial on the darkness. The fact that the increase in the concentration of the mordant material provided dark color shades was also reported in another study, so this study verified that [22].

Different mordanting methods were found to be advantageous since they enabled color variety.

The high color yields and uniform dyeings were obtained by pre-mordanting method. Although the color yields were also high in simultaneous mordanting as well as pre-mordanting, uneven dyeings were generally observed. So, simultaneous mordanting was thought to be more suitable for batik dyeings. In post-mordanting method, the samples were dyed in different shades (yellow-brown shades) with tannic acid while they were barely dyed with potassium aluminumsulphate. In other words, tannic acid converted the actual color (purple-blue) of red cabbage observed in acidic and neutral pH conditions on cotton to different color like yellowish brown and potassiumaluminumsulphate was found to be useless in post-mordanting. Therefore, the post-mordanting method was not determined to be available.

Since the samples were in different color shades depending on the pH conditions, color measurement were made separately for acidic, basic and neutral pH dyeings and the unmordanted samples for each group was selected as reference samples.

Colorimetric data for acidic pH dyeings are given in Table 2.

According to the Table 2, it was observed that color yields with tannic acid mordant were found to be higher than the color yields with potassium aluminumsulphate mordant. However, the color strength (K/S) values of the samples post mordanted with potassiumaluminumsulphate were determined to be lower than that of the reference sample. L* values decreased depending on the increase in color strength (K/S) values. Only, in the samples post mordanted with potassiumaluminumsulphate, L* values were higher than the reference and this fact was attributed to the low color yields of the samples. In all dyeings made with potassiumaluminum sulphate a* values were negative while in all dyeings made with tannic acid were positive. From this result, it was understood that potassiumaluminumsulphate made the color greenish and tannic acid made the color reddish in comparison to reference. In

Table 2. Colorimetric data for acidic pH dyeings

Sample			K/S	L*	a*	b*	C*	h°	dE*
Reference			0.123	83.04	1.80	-3.36	3.81	248.14	-
Mordant Type	Mordanting Method	Concentration							
M1	Pre-Mordanting	1%	0.141	80.83	-0.83	-6.13	6.19	252.30	4.41
		5%	0.154	78.77	-0.44	-8.16	8.17	266.92	7.80
	Simultaneous Mordanting	1%	0.139	81.69	-0.31	-7.58	7.58	262.33	5.59
		5%	0.146	79.12	-0.49	-7.79	8.12	263.64	7.19
	Post-Mordanting	1%	0.076	90.20	-0.94	-1.50	1.77	118.85	5.82
		5%	0.079	87.68	-0.66	-0.86	1.88	232.65	4.58
M2	Pre-Mordanting	1%	0.588	73.17	3.95	2.30	13.28	269.87	14.30
		5%	0.685	69.26	3.27	0.18	13.90	278.76	15.22
	Simultaneous Mordanting	1%	0.292	77.02	4.65	-3.03	5.55	226.89	9.41
		5%	0.469	74.81	5.76	-0.06	8.76	259.43	9.71
	Post-Mordanting	1%	0.288	79.38	5.04	6.12	4.93	50.53	10.66
		5%	0.606	72.12	8.57	10.77	13.76	51.48	16.10

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

potassiumaluminumsulphate mordanted samples, b* values changed according to the mordanting method. Namely, in pre-mordanting and simultaneous mordanting b* values decreased showing that the samples were bluer than the reference and in post-mordanting, b* values increased showing that the samples were yellower than the reference. On the other hand, for tannic acid mordant, b* values of all samples increased and found to be yellower than the reference. Especially, b* values of the samples post-mordanted with tannic acid were quite high. C* values increased in parallel with color yield but for the samples post-mordanted with potassium aluminumsulphate that slightly dyed.
h° values of the samples post-mordanted with tannic acid were about 50° and in the sample post-mordanted with potassiumaluminumsulphate in 1% concentration was 118° and this fact confirmed these samples were in yellow color shades. Except these mentioned samples, h° values were found to be close to each other and between 200° and 280°. In terms of dE* values, they were found to be lower for potassium aluminumsulphate than for tannic acid and meant that color difference was low in case of potassiumaluminumsulphate mordant was used.

Colorimetric data for basic pH dyeings are given in Table 3.

According to the Table 3, it was observed that color yields with tannic acid mordant were found to be higher than the color yields with potassium aluminumsulphate mordant. All the color strength (K/S) values were found to be higher than that of the reference sample and showed the increase in color yield. L* values decreased due to the increase in color yield. a* values of the samples mordanted with tannic acid increased showing that the colors were redder than the reference. In the samples mordanted with potassiumaluminumsulphate, a* values differed depending on the mordanting method. Thereby, in pre-mordanting and simultaneous mordanting method a* values decreased while in post-mordanting increased that meant the samples mordanted with pre-mordanting and simultaneous mordanting method were greener and the samples mordanted with post-mordanting method were redder than the reference. b* values showed increase in all dyeings particularly in the samples mordanted with tannic acid that meant yellower colors than the reference. C* values increased in parallel with color yield and significant difference was observed for the samples mordanted with tannic acid. h° values were determined between 50° and 100° and verified the color shades were in yellow-red region. dE* values indicating the color difference were also high for the samples mordanted with tannic acid.

Colorimetric data for neutral pH dyeings are given in Table 4. Similarly to the other samples, higher color yields were obtained with tannic acid than potassiumaluminumsulphate. Moreover, some of the potassiumaluminumsulphate mordanted samples were slightly dyed and very light colors were obtained. In these samples, L* values were found to be higher than the reference.

Table 3. Colorimetric data for basic pH dyeings

Sample			K/S	L*	a*	b*	C*	h°	dE*
Reference			0.146	88.53	0.76	5.91	5.95	82.70	-
Mordant Type	Mordanting Method	Concentration							
M1	Pre-Mordanting	1%	0.233	87.49	-1.01	6.63	6.51	78.64	2.17
		5%	0.278	86.10	-1.20	9.33	9.33	91.22	4.58
	Simultaneous Mordanting	1%	0.266	87.21	-1.87	6.82	7.91	97.94	4.36
		5%	0.269	86.49	-2.79	7.40	8.91	100.66	4.44
	Post-Mordanting	1%	0.203	87.54	1.17	5.96	5.19	76.94	1.37
		5%	0.225	87.58	1.52	6.35	6.53	76.55	2.22
M2	Pre-Mordanting	1%	0.737	74.25	6.32	12.06	13.61	62.36	16.51
		5%	0.929	69.61	9.69	12.68	17.83	58.75	24.38
	Simultaneous Mordanting	1%	0.684	74.68	6.13	11.61	13.13	62.16	15.92
		5%	0.903	70.50	9.47	12.51	17.33	57.85	23.48
	Post-Mordanting	1%	0.355	80.10	6.05	10.17	11.84	61.24	10.84
		5%	0.801	71.14	8.66	12.33	15.07	54.92	20.15

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

Table 4. Colorimetric data for neutral pH dyeings

Sample			K/S	L*	a*	b*	C*	h°	dE*
Reference			0.159	83.77	-1.50	-1.55	2.16	225.90	-
Mordant Type	Mordanting Method	Concentration							
M1	Pre-Mordanting	1%	0.141	84.11	-4.52	-3.35	5.63	206.54	4.97
		5%	0.226	77.59	-5.44	-4.94	8.35	222.19	8.12
	Simultaneous Mordanting	1%	0.197	80.92	-2.47	-6.22	7.51	210.26	6.91
		5%	0.213	77.94	-4.43	-6.07	8.18	213.88	7.92
	Post-Mordanting	1%	0.093	85.42	-1.97	1.32	2.85	173.69	2.71
		5%	0.192	83.70	-1.67	0.79	4.63	194.60	4.98
M2	Pre-Mordanting	1%	0.454	74.77	2.94	4.62	5.48	247.55	11.58
		5%	0.602	70.95	3.87	3.55	9.71	239.36	13.90
	Simultaneous Mordanting	1%	0.393	74.33	2.98	2.41	5.30	234.73	12.12
		5%	0.580	72.93	5.16	2.66	6.76	240.21	13.72
	Post-Mordanting	1%	0.543	74.96	8.26	12.02	5.59	55.51	18.60
		5%	0.715	69.27	8.55	10.79	10.22	51.62	21.25

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

a* values showed that the samples mordanted with potassiumaluminumsulphate were greener and the samples mordanted with tannic acid were redder than the reference. b* values increased in the samples mordanted with tannic acid particularly in the post-mordanted ones and verified the yellow color shade. In the samples mordanted with potassiumaluminum sulphate, b* values differed depending on the mordanting method. Thereby, in pre-mordanting and simultaneous mordanting method, the colors were bluer and in post-mordanting method, the colors were yellower than the reference.

C* values showed change in accordance with color yield. Depending on the color shades, h° values differed and the colors were observed to be in yellow-red region for the samples post-mordanted with tannic acid while generally in blue-grey region in the other samples.

dE* values verified the higher color difference with tannic acid than potassiumaluminumsulphate.

3.2. Washing fastness test results

Washing fastness test results of acidic pH dyeings are given in Table 5.

According to the Table 5, it was seen that there was distinct color difference after washing and the dyestuff did not adsorb sufficiently. This was predictable result because cotton fabrics were generally dyed in basic conditions [12, 13]. Dyeing of cotton should be carried out at basic pH values due to the hydrolysis of cellulose units in hot acidic conditions [13]. So, the insufficient bonding of dyestuff in acidic pH conditions was attributed to partly hydrolysis of monomeric glucose units. On the other hand, color change was found to be low in some samples and this was estimated to be due to very light color shades of these samples. In terms of staining, all the samples were resulted in quitely good.

Washing fastness test results of basic pH dyeings are given in Table 6.

In terms of color change, the results were found to be medium and good level. Since the most considerable color loss was in the reference sample, it was evaluated that mordanting process affected positively. In general, washing fastness test results were better with tannic acid than potassium aluminum sulphate. This fact was attributed to the strong hydrogen bonding between cotton fiber and phenolic hydroxyl groups of tannin [24]. In terms of staining, all the samples were resulted in quitely good.

Washing fastness test results of neutral pH dyeings are given in Table 7.

In terms of color change, the results were found to be medium and good level. Mordanting process improved the washing fastness like in the basic pH dyeings. In comparison to basic pH dyeings, the levels were low but the results were better with tannic acid than potassiumaluminumsulphate too as reported in the basic pH dyeings due to the same reason. In terms of staining, all the samples were resulted in quitely good as well as the other pH dyeings and this fact was related to the light color shades of the samples.

Table 5. Washing fastness test results of acidic pH dyeings

Sample			Color Change	Staining					
				Wo	PAC	PES	PA	Co	Ac
Reference			1-2	5	5	5	5	5	5
Mordant Type	Mordanting Method	Concentration							
M1	Pre-Mordanting	1%	1-2	5	5	5	5	5	5
		5%	1-2	5	5	5	5	5	5
	Simultaneous Mordanting	1%	1-2	5	5	5	5	5	5
		5%	1-2	5	5	5	5	5	5
	Post-Mordanting	1%	4-5	5	5	5	5	5	5
		5%	4-5	5	5	5	4-5	5	5
M2	Pre-Mordanting	1%	3-4	5	5	5	5	5	5
		5%	3	5	5	5	4-5	5	5
	Simultaneous Mordanting	1%	4	5	5	5	5	5	5
		5%	3-4	5	5	5	5	5	5
	Post-Mordanting	1%	3-4	5	5	5	4-5	5	5
		5%	2	5	5	5	4-5	5	5

- M1: Potassiumaluminumsulphate, M2: Tannic Acid, Wo: Wool, PAC: Polyacrylnitril, PES: Polyester, PA: Polyamide, Co: Cotton, Ac: Acetate

Table 6. Washing fastness test results of basic pH dyeings

Sample			Color Change	Staining					
				Wo	PAC	PES	PA	Co	Ac
Reference			2-3	5	5	5	5	5	5
Mordant Type	Mordanting Method	Concentration							
M1	Pre-Mordanting	1%	3	5	5	5	5	5	5
		5%	3	5	5	5	5	5	5
	Simultaneous Mordanting	1%	4	5	5	5	5	5	5
		5%	3	5	5	5	5	5	5
	Post-Mordanting	1%	5	5	5	5	5	5	5
		5%	5	5	5	5	5	5	5
M2	Pre-Mordanting	1%	3-4	5	5	5	5	5	5
		5%	3-4	5	5	5	5	5	5
	Simultaneous Mordanting	1%	4-5	5	5	5	5	5	5
		5%	4-5	5	5	5	5	5	5
	Post-Mordanting	1%	4	5	5	5	5	5	5
		5%	4	5	5	5	5	5	5

- M1: Potassiumaluminumsulphate, M2: Tannic Acid, Wo: Wool, PAC: Polyacrylnitril, PES: Polyester, PA: Polyamide, Co: Cotton, Ac: Acetate

Table 7. Washing fastness test results of neutral pH dyeings

Sample			Color Change	Staining					
				Wo	PAC	PES	PA	Co	Ac
Reference			2	5	5	5	5	5	5
Mordant Type	Mordanting Method	Concentration							
M1	Pre-Mordanting	1%	2-3	5	5	5	5	5	5
		5%	2-3	5	5	5	5	5	5
	Simultaneous Mordanting	1%	2	5	5	5	5	5	5
		5%	2	5	5	5	5	5	5
	Post-Mordanting	1%	4	5	5	5	5	5	5
		5%	3-4	5	5	5	5	5	5
M2	Pre-Mordanting	1%	4-5	5	5	5	5	5	5
		5%	3-4	5	5	5	4-5	5	5
	Simultaneous Mordanting	1%	4	5	5	5	5	5	5
		5%	4	5	5	5	5	5	5
	Post-Mordanting	1%	4	5	5	5	4-5	5	5
		5%	3-4	5	5	5	4-5	4-5	5

- M1: Potassiumaluminumsulphate, M2: Tannic Acid, Wo: Wool, PAC: Polyacrylnitril, PES: Polyester, PA: Polyamide, Co: Cotton, Ac: Acetate

3.3. Rubbing fastness test results

Rubbing fastness test results of acidic pH dyeings are given in Table 8. Dry rubbing fastness results were evaluated as quite good. Although the wet rubbing fastness levels were slightly lower than dry rubbing fastness levels, they were evaluated as medium and good in general.

As a mordanting material, potassium aluminum sulphate was observed to be better than tannic acid this time. This result was attributed to the fact that tannic acid provided dark yellow-brown color shades.

Table 8. Rubbing fastness test results of acidic pH dyeings

Sample			Rubbing	
			Dry	Wet
Reference			5	4-5
Mordant Type	Mordanting Method	Concentration		
M1	Pre-Mordanting	1%	5	4-5
		5%	4-5	4
	Simultaneous Mordanting	1%	5	4-5
		5%	5	4-5
	Post-Mordanting	1%	5	4-5
		5%	5	4-5
M2	Pre-Mordanting	1%	5	4-5
		5%	5	4-5
	Simultaneous Mordanting	1%	4	3-4
		5%	4	3-4
	Post-Mordanting	1%	4-5	4
		5%	4	3-4

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

Rubbing fastness test results of basic pH dyeings are given in Table 9. According to the Table 9, the samples mordanted with potassiumaluminum sulphate showed good dry and wet rubbing levels, while the samples mordanted with tannic acid showed medium or low dry and wet rubbing levels. This was estimated to be due to the difference in color shades and darkness values.

Rubbing fastness test results of neutral pH dyeings are given in Table 10. Generally, medium or good dry and wet fastness levels were obtained. Mordant type did not make any significant difference. Only, the samples post-mordanted with tannic acid exhibited low dry and wet rubbing levels and this was thought to be due to the difference in color shades and darkness values as reported before.

Table 9. Rubbing fastness test results of basic pH dyeings

Sample			Rubbing	
			Dry	Wet
Reference			5	4-5
Mordant Type	Mordanting Method	Concentration		
M1	Pre-Mordanting	1%	5	4-5
		5%	4-5	4
	Simultaneous Mordanting	1%	4-5	4
		5%	4	3-4
	Post-Mordanting	1%	4-5	4
		5%	4-5	4
M2	Pre-Mordanting	1%	4	3-4
		5%	3-4	3
	Simultaneous Mordanting	1%	2-3	2
		5%	2	1-2
	Post-Mordanting	1%	4	3-4
		5%	3-4	3

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

Table 10. Rubbing fastness test results of neutral pH dyeings

Sample			Rubbing	
			Dry	Wet
Reference			5	4-5
Mordant Type	Mordanting Method	Concentration		
M1	Pre-Mordanting	1%	5	4-5
		5%	4-5	4
	Simultaneous Mordanting	1%	5	4-5
		5%	4-5	4
	Post-Mordanting	1%	4	4
		5%	4	4
M2	Pre-Mordanting	1%	5	4-5
		5%	5	4-5
	Simultaneous Mordanting	1%	4-5	4
		5%	4	3-4
	Post-Mordanting	1%	3-4	3
		5%	3-4	2-3

- M1: Potassiumaluminumsulphate, M2: Tannic Acid

4. Discussion and Conclusion

Red cabbage has shown different color shades in different pH conditions via its indicator property. Mordanting process and mordanting methods can also alter dyeing and fastness properties of the samples. But there were limited studies with red cabbage dyeing in the literature. Therefore, in this study, the dyeing properties of red cabbage to cotton fabrics in three different pH conditions and with different mordanting methods and materials were investigated in detail. It was seen that, red cabbage extract could be used to dye cotton fabrics and the most stable color shades could be obtained in neutral pH conditions as reported in the similar studies [12-15]. Mordanting methods and mordanting materials gave rise to various color shades and this fact verified the claims of some studies [2, 5, 10]. As a mordanting method, pre-mordanting method was selected as available since high color yields and uniform dyeings were obtained. Mordant concentration was found to be important in terms of darkness as reported in a preceding study [22]. As a mordanting material, tannic acid was selected due to the high color yields. On the other hand, since the post-mordanting with tannic acid leaded to the significant color change from blue-purple to yellow-brown, these samples were excluded. Washing fastness levels were evaluated as acceptable for natural dyeing except acidic pH dyeings. Acidic pH dyeings were not found to be available due to the hydrolysis of cellulose units as reported [12, 13]. Rubbing fastness levels were generally evaluated as medium or good. In addition, this study was significant in terms of sustainable environment owing to the fact that natural, eco-friendly and non-toxic materials were used.

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