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UV Protection Properties of Cotton, Wool, Silk and Nylon Fabrics Dyed with Red Onion Peel, Madder and Chamomile Extracts

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Abstract

Red onion peel, madder, chamomile and red onion/chamomile mixture (40 g/l, 50%wt) are extracted using aqueous solution at different temperatures (80-100°C). Cotton, wool, silk and nylon fabrics are dyed using a traditional method at pH 4 (except cotton at pH 8) using 25-40 g/l colorant extract, at specified temperature and time, without or with potash alum or $FeSO_4$ (1.5 g/l). Colorimetric data (L*, a*, b*), Color strength (K/S) and ultraviolet protection factor (UPF) are measured. Fastness properties of control and mordanted fabrics are assessed. UPF measurements reveal excellent UV protective properties for different fabrics colored with red onion, madder, chamomile and red onion peel/chamomile mixture (50% wt, 40 g/l) with or without mordants. Dyeing of fabrics without or with mordants gives excellent UPF factors (50+), except nylon which has an insufficient UPF with madder. These natural colored fabrics are suggested to prevent skin cancer and their colorants are recommended for textile coloration industry.

Keywords: Red onion peel; Madder; Chamomile; Dyeing; Fabrics; UV protection

Introduction

Recently, a great attention for application of natural colorants is survived for agriculture availability, ease and safe production. Synthetic colorants produce different shades which are available in low price, but cause environmental pollution, so natural dyes are a good alternative for textile coloration. Many researchers studied the functional finishing of textiles using natural dyes [1-4]. Also, extraction of colouring matter from Flos Sophorae and UPF values of silk were investigated [5].

Many researches have been conducted to determine the influence of the UV rays on different living organisms, particularly humans [6-14] as there is a strong correlation between skin cancer and UV dose. Hurtful UV radiation can be absorbed by Skin cells through sunlight, then the body gets red of these radiation by excretion. However, an extra dosage of UV radiation has some repercussions as it can cause skin cancer, damage of cells and inflammation of human skin which are considered the clear outcomes of erythema or sunburn [15].

Related work about UPF of natural colored yarns with mordants and its biological efficiency was reported [16]. Similar work about natural colorants and their application on selected fabrics, which provided antibacterial and ultraviolet protective level [17,18]. A study for colorimetric determination and antimicrobial analysis of colored fabrics using "Peony, Pomegranate, Clove, Coptis Chinenis and Gallnut extracts" was performed against different micro-organisms [19,20]. Fastness and UPF properties of colored fabrics using EucaLyptus were studied [21].

The following are some natural dyes which are studied in this article and their chemical structure (Tables 1-3)

Red onion peel: is a natural by-product waste from food industry. It gives bright reddish brown color in textile coloration. It is grown all over the world. The outer layer was known as a red onion peel which is a by-product waste of the food industry. The color of red onion peel extract is reddish brown. Previous studies on red onion peel [22,23] investigated the flavonoids which contain large amounts of flavonols, flavones, and anthocyanidins (flavylium cations dyes). The most known of the last compound is cyanidin dyes derivatives (Table 3).

Figure 1 shows the relationship of absorbance/wavelength of colorant at different pH was studied [24]. The absorbance of red onion colorant extract has two peaks; at 290 and 363 nm in UV region. The colorant shape and stability is similar in acidic medium and maximum absorption is achieved at wavelength 363 nm. At pH 8 the curve has different shapes and maximum absorption is achieved at wavelength 376 nm. High UV absorption of the colorant reveals that it could be extracted at the boil in acidic conditions. Figure 1 shows the colorant absorbance radiation in the UV-B region (290-320 nm) and UV-A region (320-400 nm) (Table 4).

Madder: It is an important natural colorant, as it is recognized in Egyptian pharaonic textile. Its constituents are anthraquinone compounds containing hydroxyl auxo-chromic groups [25]. Madder roots were reported to contain about 35 anthraquinone compounds (Table 4). The major components of Indian madder (Rubia cordifolia) are purpurin 66%, 1% munjistin and 10% nordamnacanthal. The major component of European madder (Rubia tinctoriun) is alizarin. The auxochromic groups (OH, COOH) in madder colorants are able to form complex compounds, so they are called mordant dyes depending on the appropriate groups which are capable of forming complex with the metal ion (Table 5).

Chamomile: It is an Egyptian crop [26,27]. The duration of cultivation is 1-2 years and the structure of chamomile is illustrated in Table 5. Terpenoids and flavonoids are found in the dried flowers of chamomile, which have a healing effect. Many human diseases can be cured by the chamomile preparations such as; insomnia, gastrointestinal disorder, inflammation, menstrual disorder, rheumatic pain, ulcers, muscle, spasms, hemorrhoids, wounds, and hay fever.

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Plant	Botanic name	Colour index CI	Components of colors	Family
Red onion peel	Allium cepa L	Red, yellow or, orange	Red, yellow or orange colours	Flavonoid (flavonols flavones) and cyanidin
Madder genus (European)	Rubia tinctoriumL	Natural Red 8	Natural Red	Alizarin
Madder genus (Idian)	Rubia Cordifolia L	Natural Red 16	Natural Red	-Rubladin -Purpurin -Nardamna canthal - Lucidin
Chamomile	Composite	Yellow	Flavonoid	Anthemins tinctorial

Table 1: Characteristics of red onion peel, madder, and chamomile.

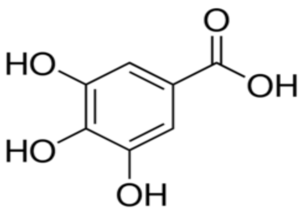
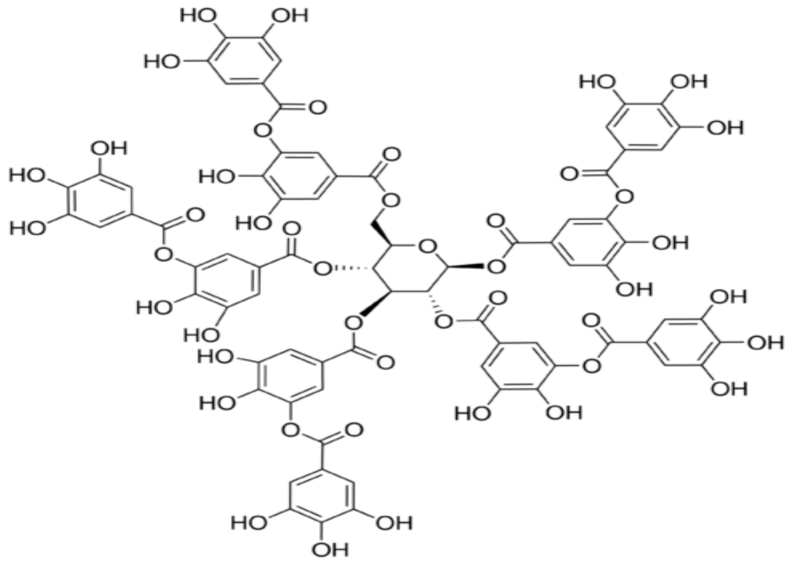
a- Gallic acid	b- Tannic acid
	

Table 2: Chemical structure of Tannic acid and Gallic acid (found in red onion peel extract, madder and chamomile).

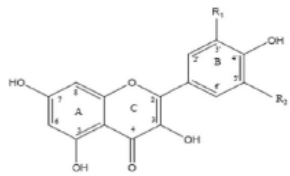
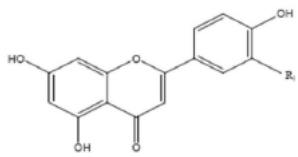
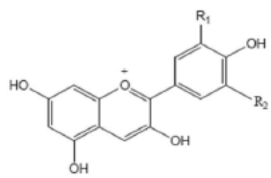
Chemical structure of phenolic compounds of red onion peel				
Compounds	**Structure**		R_1	R_2
Flavonols		Quercetin	OH	H
		Kaempferol	H	H
		Myricetin	OH	OH
Flavones		Apigenin	H	
		Luteolin	OH	
Anthocyanidines		Cyanidin	H	OH
		Delphinidin	OH	OH
		Pelargonidin	H	H
		Peonidin	OH	OMe

Table 3: Chemical composition of red onion peel extract.

The oil chamomile is paramount as it can be used in a wide scale in cosmetics and aromatherapy [28].

In the present investigation, Red onion peel, madder, chamomile (25-40 g/l) and chamomile/red onion peel mixture (50% wt.) are extracted using aqueous solution at different temperatures (80-100°C). Then these extracts are used for coloration of different fabrics. UV protective properties of the colored fabrics are studied. The coloration of fabrics using natural colorants is performed without or with mordants (1.5 g/l) to minimize pollution. Color measurements, fastness properties, and UPF properties are also determined.

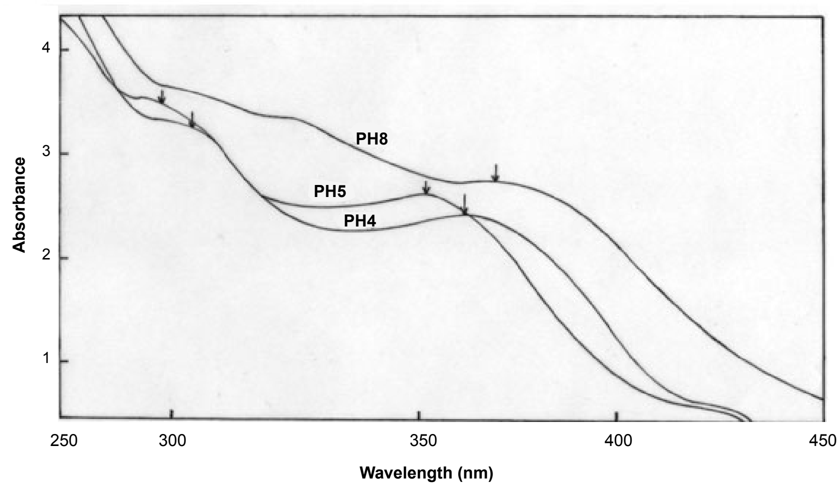


Figure 1: UV-VIS Spectrum of 12.5 gm/L of red onion peels extracted at 95°C and pH 4-8.

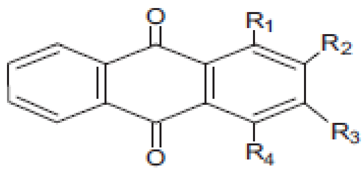
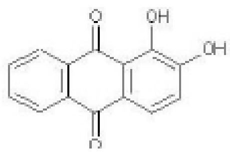
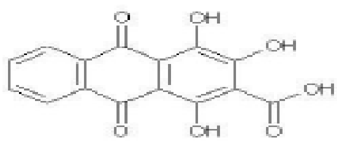
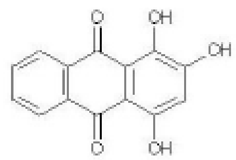
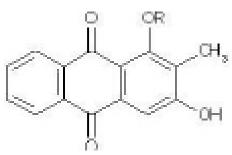
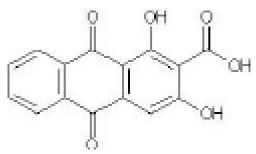
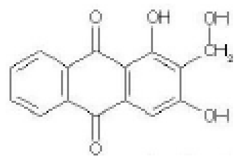
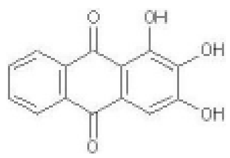
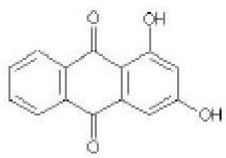
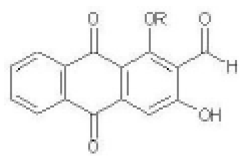
	 Madder	
 alizarin	 Pseudopurpurin	 purpurin
 Rubiadin,etc	 munjistin	 Lucidin
 anthragallol	 munjistin	 nordamnacanthal

Table 4: Chemical structures of madder (anthraquinone components).

Materials and Methods

Materials

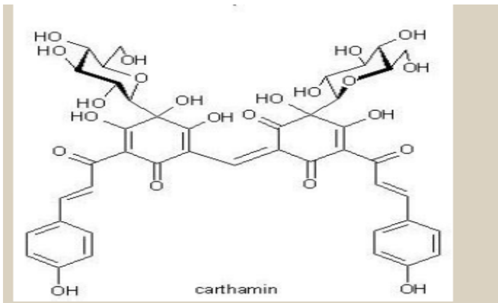
Natural dyes such as red onion peel extract were used, a vegetable by-product waste from the onion food industry, in addition to the imported madder and locally cultivated chamomile crop.

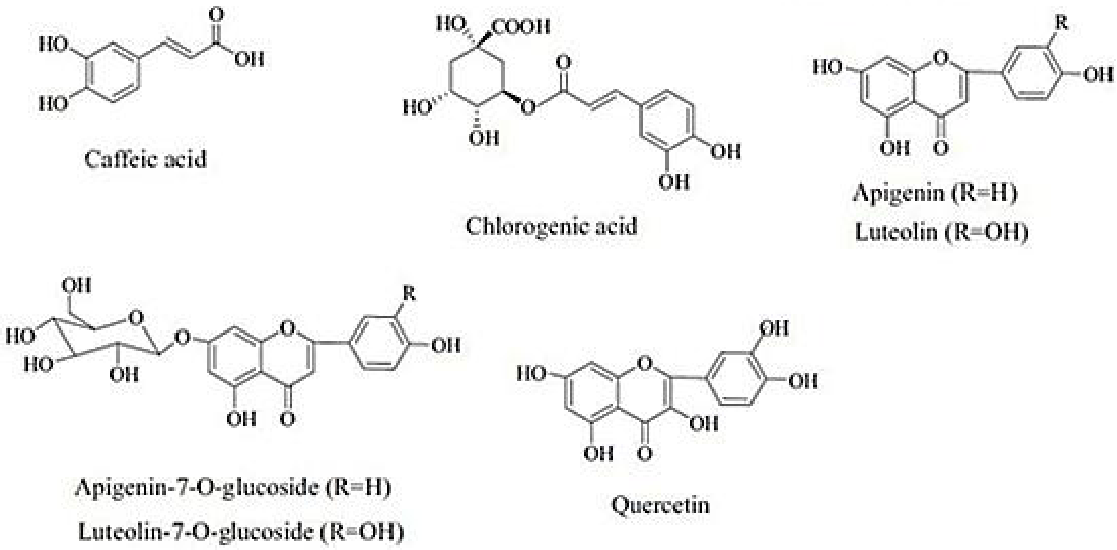
Chemical reagents: Chemical reagents used for adjusting the pH are glacial acetic acid and anhydrous sodium carbonates. The mordants used are potash alum ($Al_2 K_2(SO_4)_4 .24H_2O$), ferrous sulphate ($Fe SO_4 7H_2O$) and Tannic acid for cotton fabric. Non-ionic detergent (Triton X-100) and sodium sulphate are used in the washing process.

Fabrics: Different natural fabrics are used such as cotton (weight 133.78 g/m^2, thickness 0.37 mm), wool (308.8 g/m^2, 0.55 mm), silk (58.08 g/m^2, 0.18 mm) and nylon fabric (89.14 g/m^2, 0.31 mm). All the fabrics were produced by The Misr Spinning and Weaving Company, El-Mahalla El-Kubra with the exception of silk.

a- Chamomile plant

b- Chemical structure of Chamomile





C: Some phenolic components of Chamomile

Table 5: Chamomile and some of its phenolic components.

Methods

Extraction Method: Red onion peel (40 g) was extracted in 1 L of boiled water for 1 h, and then the extract was cooled down to room temperature and filtered to get rid of insoluble materials. The percentage of extracted colorants was calculated and the absorbance of the colorant extract was measured to determine the λ_{max} of the colorant [29]. Also madder and chamomile were extracted in hot water at 80°C using different concentrations (25-40 g/l). Extraction percentage (%) of different colorants was as follow; red onion peel 15, madder 29, chamomile 37.

Scouring of fabrics:

- Silk fabric was added to a bath containing 2 g/l nonionic detergent (Triton X-100) and water at liquor ratio 1:50. Then the temperature of the entire bath was raised to 60°C and was maintained for 1 hr. Finally, Silk was rinsed with warm water and air dried.
- Wool and nylon fabrics were added to a bath containing 2 g/l nonionic detergent and 5 g/l sodium sulfate at liquor ratio 1:50. Then the temperature of the entire bath was raised to 45°C and the temperature remained constant for 30 min. Finally, wool and nylon were rinsed with warm water and air dried.
- Cotton fabric was added to a bath containing 2 g/L $Na_2 CO_3$ and 5 g/l nonionic detergent at liquor ratio 1:50. Then the temperature of the entire bath was raised to boiling and was maintained for 1 h, then rinsed and air dried.

Pre-mordanting method: In the pre-mordanting method, fabrics were treated before dyeing process. Wool, silk, and nylon fabrics were added to a bath containing alum or $FeSO_4$ (1.5 g/l) at liquor ratio 1:50. Then the temperature of the entire bath was raised to 45°C and continues stirring at this temperature for 30 min. The mordanted fabrics were rinsed with warm water to remove the excess mordants.

Cotton fabrics were treated with 8% tannic or gallic acid (owf) at liquor ratio 1:30 then the temperature of the entire bath was raised to 90°C and hold for 30 min. Then cotton fabrics were removed from this bath and put in another bath containing alum or ferrous sulphate (1.5 g/l) at liquor ratio 1:50. Then the temperature of the entire bath was raised to 90°C and maintained for 30 min, rinsed and air dried (Table 1).

Dyeing method: Dyeing of cotton fabrics was carried out using exhaustion method utilizing infrared dyeing machine (Roaches Co., England) with natural colorant extract (25/40 g/l). Cotton fabric was pre-mordanted with 8% tannic acid (owf) and then treated with alum (1.5 g/l) at 100°C for 60 min. After extraction of natural colorant, it was added to the dyeing bath at pH 4 for all fabrics except cotton at pH 8, using liquor ratio 1:40 at a specified temperature (80°C for all fabrics and 100°C for cotton fabrics). The temperature of the entire bath was raised to 45°C and the maintained constant for 30 min. The dyeing procedure was started at 40°C, and then the temperature of the dyeing bath was raised to 100°C and was maintained for 1 h. Then, the fabric was thoroughly rinsed with warm water and soaped using 2 g/l nonionic detergent (Triton X-100) at 50°C for 30 min then rinsed with water and air dried.

Colorfastness to washing: The colorfastness to washing test was implemented according to ISO 105-CO2. It was carried out in a Launderometer (ATLS-Germany); the test specimen was compressed with the two adjacent fabrics (cotton and wool) in contact with the main sample. The test composite specimen was added to the bath containing 5 g/l nonionic detergent using liquor ratio 1:50 and the temperature of the bath was raised to 50°C and remained constant for 45 min. Then, the test composite specimen was removed from the bath, rinsed with water, squeezed, opened and air dried. The grayscale was used to assess the color change of the colored sample and the staining on the two adjacent undyed fabrics after washing [30].

Colorfastness to light: Colorfastness to light test was performed in a Ci3000+Xenon-Ometer® manufactured by Atlas Materials Testing Solutions. Two borosilicate filters were used to simulate outdoor conditions. Fabrics were exposed to UV for 35 hours according to ISO 105-B02 [31].

Colorfastness to rubbing: Colorfastness to rubbing test was performed according to test method ISO 105-X12, using a crockmeter for conducting the dry and wet fastness test. The gray scale was used to assess the staining of colored sample on dry and wet fabrics [32].

Color measurement

Color strength (K/S): The color strength K/S of dyed fabric was measured using a Datacolor Spectra Flash SF600X (Datacolor) and was assessed using Kubelka-Munk equation [33,34]:

$$K/S = \frac{(1-R)}{2R} - \frac{(1-RO)}{2RO}$$

Where:

R=Decimal fraction of the reflectance of the dyed fabric.

R0=Decimal fraction of the reflectance of the undyed fabric.

K=Absorption coefficient.

S=Scattering coefficient.

Color data CIE LAB space: The total difference CIE (L*, a*, b*) was measured using the Hunter-Lab spectrophotometer (model: Hunter Lab DP-9000).

CIE (L*, a*, b*) between two colours each given in terms of L*, a*, b* is calculated from:

L* value: indicates lightness, (+) if sample is lighter than standard, (-) if darker.

a* and b* values: indicate the relative positions in CIE Lab space of the sample and the standard, from which some indication of the nature of the difference can be seen.

Measurement of UPF factor: The ability of the dyed fabric to block UV light is given by the ultraviolet protection factor (UPF) value. The measurement of UPF was performed in UV/Visible Spectrophotometer 3101, using an integrating sphere loaded with the fabric sample from 290 nm at an interval of 10 nm. The measurements of the UV-penetration characteristics of the compressed fabrics were carried out in the range of 290-400 nm using the UV penetration and protection measurements system. Before measurement, the fabric was conditioned at normal temperature and pressure (NTP) for 24 h. During the measurement, four scans were performed by rotating the sample 90° each time and the spectral data were recorded as the average of these four scans.

The equation used by the software to calculate the UPF value for a flat [35], tensionless dry fabric:

$$UPF = \frac{\sum_{290}^{400} E_{ë}\, S_{ë}\, \Delta_{ë}}{\sum_{290}^{400} E_{ë} S_{ë}\, T_{ë}\, \Delta_{ë}}$$

Equation for calculating UPF value (1)

Where: (UPF)-ultraviolet protection factor value through fabrics, E_λ-relative erythemal spectral effectiveness ($W/m^2 \cdot nm^{-1}$), S_λ-solar spectral irradiance (Melbourne), Δλ-measured wavelength interval (nm), and T_λ-spectral transmittance of the sample (%). The percentage blocking of UVA range (315-40 nm) and UVB range (315-290 nm) was calculated from the transmittance data.

Generally, in all the cases in which UPF reached at least the good protection level and UVA transmittance was also below 5%, which the European standard for Sun Protective Clothing [36] and also the Chinese National standard GB/T18830-2002 [5] consider the threshold above which photosensitive skin disorders, like chronic actinic dermatitis and solar urticaria, can be aggravated (Table 6) [37].

Results and Discussions

Effect of mordants on K/S and colour data of pre-mordanted dyed cotton, wool, silk and nylon fabrics with red onion peel, madder, chamomile, and mixture of red onion peel/chamomile extracts [25,29]

Effect of mordants on K/S and colour data of pre-mordanted dyed cotton, wool, silk and nylon fabrics with red onion peel extract: Table 7 shows that all mordanted dyed fabrics displayed higher color strength values as compared to non-mordanted ones with this order; $FeSO_4$>alum>control fabrics. This may be linked to the mordanting process that increases interaction between colorant and fabrics through coordination complex formation, which, after all, boosts the colorant uptake.

Table 7 indicates that the darkest color hue is achieved with $FeSO_4$ compared to mordanted fabric with alum and control fabric, which is clear from the decrease of L^* values of dyed mordanted fabrics with $FeSO_4$. From all colorimetric data, the difference of color is due to the type of mordant used. In case of cotton, tannic acid was combined with alum/$FeSO_4$ for metal complexes formation, which produced a dark fabric shade.

Table 7 reveals the colorimetric data of the dyed fabrics, The largest

UPF range	Protection category	$UVBE_{eryt}$ transmittance (%)
<15	Insufficient protection	> 6.7
15-24	Good protection	6.7-4.2
25-39	Very good protection	4.1-2.6
40-50, 50+	Excellent protection	≤ 2.5

Table 6: UPF categories with relative transmittance and protection level.

Fabric	Mordant	Colour strength (K/S) ($\lambda_{max:}$ 380)	L*	a*	b*	UPF range	UPF assessment	Transmittance (%)	
								UV-A 315-400 nm	UV-B 290-315 nm
Cotton	Dyed control + Tannic acid	3.21	66.41	7.41	17.14	30	(30+) Very good	3.8	3.18
	Tannic acid + Alum	3.81	63.43	7.26	24.69	34	(30+) Very good	3.47	2.8
	Tannic acid + $FeSO_4$	4.72	48.77	3.77	11.96	56	(50+) Excellent	2.09	1.75
Wool	Dyed control	28.62	35.60	22.41	25.62	2776	(50+) Excellent	0.04	0.04
	Alum	30.75	32.56	14.81	30.08				
	Ferrous sulphate	32.95	20.24	5.39	7.86	8338	(50+) Excellent	0.01	0.01
Nylon	Dyed control	25.35	48.90	12.55	43.19				
	Alum	25.80	49.82	11.30	37.98				
	Ferrous sulphate	26.34	44.19	11.49	27.77				
Silk	Dyed control	14.33	47.10	15.95	23.92	156	(50+) Excellent	0.75	0.59
	Alum	15.07	47.20	13.92	28.56				
	Ferrous sulphate	15.51	32.42	5.88	12.08	385	(50+) Excellent	0.29	0.25

Table 7: Effect of mordants on K/S and color data of cotton, wool, silk and nylon fabrics colored with colorants extracted from red onion extract (40 g/l).

Fabric	Mordant	Colour strength (K/S)	L*	a*	b*	UPF	UPF assessment	Transmittance (%)	
								UV-A 315-400 nm	UV-B 290-315 nm
a- madder (λ_{max}: 370)									
Wool	Dyed control	9.32	45.67	28.34	25.72	780	(50+) Excellent	0.25	0.11
	Alum	11.99	40.35	35.35	27.48	1422	(50+) Excellent	0.12	0.06
	$FeSO_4$	22.32	23.01	9.44	8.01	4395	(50+) Excellent	0.03	0.02
Silk	Dyed control	2.08	64.91	23.69	17.27	34	(30+) Very good	5.64	2.23
	Alum	3.93	54.34	34.21	24.18	77	(50+) Excellent	2.95	1
	$FeSO_4$	6.55	42.65	7.69	7.20	-		-	-
Nylon	Dyed control	9.18	50.38	42.57	26.55	13	(10+) Insufficient	9.56	7.23
	Alum	7.17	47.89	44.97	26.57	14	(10+) Insufficient	7.84	6.67
	$FeSO_4$	24.35	43.93	31.98	24.95	-		-	-
b- chamomile (λ_{max}: 365)									
Wool	Dyed control	15.74	65.39	3.44	26.96	294	(50+) Excellent	0.77	0.27
	Alum	17.45	59.68	6.3	39.44	-			
	$FeSO_4$	22.28	38.4	4.55	19.75	590	(50+) Excellent	0.26	0.15
Silk	Dyed control	3.16	79.51	0.47	19.52	-			
	Alum	3.75	75.9	2.77	80.16	-			
	$FeSO_4$	8.65	54.08	4.69	23.27	-			
Nylon	Dyed control	9.88	80.80	-1.45	15.47	-			
	Alum	10.21	72.92	-1.41	90.12	-			
	$FeSO_4$	12.32	65.14	8.38	27.78	-			

Table 8: Effect of mordants (1.5 g/l) on color strength and color data of wool, silk and nylon fabrics colored with colorants extracted from madder (25 g/L) and chamomile (40 g/L).

decrease of a* and b* values has occurred with $FeSO_4$ more than alum and control samples, that means a little shifted towards green co-ordinate in red yellow zone of CIE Lab color space.

Effect of mordants on K/S and colour data of pre-mordanted dyed cotton, wool, silk and nylon fabrics with madder extract: Table 8a illustrates the effect of mordants on dyed wool, silk and nylon fabrics using madder extract on K/S and color data.

There is a significant enhacment of K/S of pre-mordanted colored fabrics using alum and $FeSO_4$ as a result of metal complex formation among dye, fabric, and mordant.

From Table 8a, it is clear that pre-mordanted colored fabric with $FeSO_4$ gives the highest K/S among pre-mordanted colored fabrics with alum and control fabrics. This is attributed to the change of ferrous to ferric form through oxygen of the air. Ferrous and ferric forms are on the surface of the fabric and their spectra overlapped, resulting in change of K/S and consequently dark hue was obtained [24]. The color of fabrics is dependent on the mordant used.

Table 8a shows that adding mordants leads to a decrease of L* values, that means darker shade is obtained. Pre-mordanted colored fabric with $FeSO_4$ gives the darkest shade among pre-mordanted colored fabrics with alum and control colored fabrics.

From Table 8a, it is clear that a* and b* values of pre-mordanted colored fabrics with alum increase compared to the control fabrics, that means a little shifted towards red co-ordinate in red yellow zone of CIE Lab color space. Conversely, a* and b* values of pre-mordanted colored fabrics with $FeSo_4$ decrease in comparison to control colored fabric, that means a little shifted towards green co-ordinate in red yellow zone of CIE Lab color space. The colored nylon fabric is not affected by the alum treatment in comparison to the control colored fabric.

Effect of mordants on K/S and colour data of pre-mordanted dyed cotton, wool, silk and nylon fabrics with Chamomile extract: Table 8b shows the results of mordanted dyed wool, silk and nylon fabrics with chamomile extract in comparison to non-mordanted dyed one. The effect of mordants on K/S and colorimetric data is demonstrated.

For wool fabric, K/S increases with $FeSO_4$ to 22.28 and for alum to 17.45 in comparison to control (15.74). For silk fabric, K/S increases with $FeSO_4$ to 8.65 and for alum to 3.75 in comparison to control (3.16). For nylon fabrics, K/S increases with $FeSO_4$ to 12.32 and to 10.21 using alum in comparison to control (9.88). Pre-mordanted colored fabrics with $FeSO_4$ gives the highest K/S, then Pre mordanted colored fabrics with alum and everyone one of them is higher than the colored control fabrics.

In general, the dyeing affinity of fabrics is dependent on the content of functional polar groups in fabrics. It is well known that the number of functional group in wool is larger than that of silk, and polarity of protein fibres is higher than that of cellulose fibre. The K/S value was in the order of wool>nylon>silk>cotton fabric for all natural colorants. It was found that this order of dyeing affinity matched the order of polarity/functional group content of fabrics very well.

For L* values (lightness), the fabrics shade becomes darker by using mordants and fabrics mordanted with $FeSO_4$ is darker than fabrics mordanted with alum and everyone of them is darker than the colored control fabrics.

Also, the increase of a* and b* values of mordanted colored fabric with alum, means a little shift towards red co-ordinate in red yellow zone of CIE Lab color space. in the opposite, the decrease of a* and b* values of mordanted colored fabric with $FeSO_4$, means a little shift towards green co-ordinate in red yellow zone of CIE Lab color space, except mordanted colored nylon fabric with $FeSO_4$, which shifted towards red co-ordinate.

Effect of mordants on K/S and colour data of pre-mordanted dyed cotton, wool, silk and nylon fabrics with mixture of red onion peel/chamomile extract: Table 9 shows the effect of mordants on color strength and color data of wool, silk and nylon fabrics colored with natural colorants extracted from a mixture of red onion peel/ chamomile (50% wt).

Mordants have a slight effect on K/S of wool and silk fabrics. For nylon, the mordants don't improve the K/S compared to the colored control fabric. It is clear from Table 8 that the color of fabrics depends on the type of mordant used.

For L* values (lightness), the shade of pre-mordanted wool and silk fabrics with $FeSO_4$ turns into darker shade than with alum. For nylon, a little change is observed by using $FeSO_4$ and alum.

For a* and b* values, a little shift towards red co-ordinate in red yellow zone of CIE Lab color space in case of pre-mordanted colored fabric with alum in comparison to colored control fabrics in case of wool and silk fabrics. While using $FeSO_4$ as a mordant leads to a little shift towards green co-ordinate in red yellow zone of CIE Lab color space in comparison to the colored control fabrics in case of wool and silk fabrics. However, using $FeSO_4$ and alum as mordants with colored nylon fabrics have a slight effect on the color compared to the control one (there is no remarkable shift of color as for wool and silk fabrics).

Colorfastness properties

Table 10 reveals that pretreatment with tannic acid/$FeSO_4$ and $FeSO_4$, improves colorfastness to washing of cotton. Mordants don't affect colorfastness to rubbing.

Also, Table 10 illustrates all colorfastness properties of colored control and pre-mordanted colored fabrics with red onion peel. From these results, it is obvious that colorfastness to washing and rubbing are fair to very good. While, colorfastness to light is very good to excellent.

Fabric	Mordant	Colour strength K/S (λ_{max}: 385)	L*	a*	b*	UPF	UPF assessment	Transmittance (%)	
								UV-A 315-400 nm	UV-B 290-315 nm
Wool	Dyed control	26.23	43.19	20.03	26.55	2848	(50+) Excellent	0.04	0.03
	Alum	29.0	41.69	14.22	34.85	-		-	-
	$FeSO_4$	28.65	25.06	15.98	12.40	4294	(50+) Excellent	0.02	0.02
Silk	Dyed control	9.71	56.65	16.95	21.53	-		-	-
	Alum	9.35	55.13	10.24	34.48	-		-	-
	$FeSO_4$	13.59	39.03	4.17	16.62	196	(50+) Excellent	0.58	0.49
Nylon	Dyed control	25.12	51.22	10.82	31.08	-		-	-
	Alum	20.65	54.39	17.66	35.12	-		-	-
	$FeSO_4$	24.39	45.78	8.72	28.00	-		-	-

Table 9: Effect of mordants (1.5 g/l) on color strength and color data of wool, silk and nylon fabrics colored with colorants extracted from a mixture of red onion peel/ chamomile (40 g/L, 50% wt).

Citation: Gawish SM, Helmy HM, Ramadan AN, Farouk R, Mashaly HM (2016) UV Protection Properties of Cotton, Wool, Silk and Nylon Fabrics Dyed with Red Onion Peel, Madder and Chamomile Extracts. J Textile Sci Eng 6: 266. doi: 10.4172/2165-8064.1000266

Fabric	Mordant	Rubbing fastness		Washing fastness			Light fastness
		Dry	Wet	St*	St**	Alt.	
Cotton	Dyed control	3-4	4	3-4	4	4	5-6
	Tannic acid /alum	3	4	3-4	4	4	5-6
	Tannic acid/$FeSO_4$	3	4	3-4	4-5	4-5	5-6
	Alum	4-5	3	3	3	3-4	6
	$FeSO_4$	3	4	3-4	4-5	4-5	5-6
Wool	Dyed control	3-4	3-4	2-3	2-3	3-4	5-6
	Alum	2	1-2	3	3	4	6
	$FeSO_4$	1-2	2	3	3	3-4	6
Silk	Dyed control	3	3-4	3-4	3	4	6
	Alum	2-3	3	3-4	2-3	4	6
	$FeSO_4$	2	3	3-4	3	4	6
Nylon	Dyed control	4-5	3-4	2-3	2-3	3-4	6
	Alum	4-5	3	3	3	3-4	6
	$FeSO_4$	3	2-3	2-3	3	3-4	6

St.* staining on cotton
St. ** staining on wool
Alt. Alteration

Table 10: Colorfastness of cotton, wool, silk and nylon fabrics colored with colorants extracted from red onion peel.

Table 11a clarified the colorfastness properties of colored control and pre-mordanted colored fabrics with madder. Comparing colorfastness properties, it is clear that colorfastness to washing is fair to very good. Also, colorfastness to rubbing is fair to good. While, colorfastness to light is very good to excellent. It is clear that pre-treatment of fabrics using mordants enhances colorfastness to washing, except for $FeSO_4$/wool and $FeSO_4$/nylon. Colorfastness to Light and rubbing doesn't improve by mordants.

Table 11b illustrates colorfastness properties of colored control and pre-mordanted colored fabrics with chamomile. By comparing colorfastness properties, it is appear that, colorfastness to washing and to light is very good to excellent. Also, it is clear that pre-treatment with mordants improves colorfastness to light and to washing of all fabrics, but colorfastness to rubbing doesn't improve by using mordants.

Table 12 illustrates colorfastness properties of colored control and pre-mordanted colored fabrics with red onion/chamomile mixture (40 g/l, 50% wt). These results show that colorfastness to washing is good to very good and colorfastness to rubbing is fair to good. While, colorfastness to light is very good to excellent. Pre-treatment with mordants enhances colorfastness to light and washing, but colorfastness to rubbing is not affected by mordants.

UPF properties of colored fabrics

In this study the measurement of UPF based on UV protective properties for colorants namely; red onion peel, chamomile, madder and red onion peel/chamomile mixture (50% weight) of colored fabrics is investigated [5,35,37-40]. Coloration is performed without mordants (control) or using tannic acid (2.6 g/l for cotton) or with a low concentration of $FeSO_4$ or alum (1.5 g/L).

Figures 2-5 of UV transmittance Percentage of different colorants and Figure 6 of UPF and UV-A of all colored wool with different colorants show that wool fabrics colored with 4 colorants used, acquire excellent UPF values (50+) and the order of the UPF values are as follows, red onion peel>mixture of red onion peel/chamomile>madder>chamomile. Also, the addition of $FeSO_4$ as a mordant increases the values of UPF and show excellent UPF values (50+) with this order, red onion peel+$FeSO_4$>madder+$FeSO_4$>mixture of red onion peel/chamomile+$FeSO_4$>chamomile+$FeSO_4$. Also, the values of T (UV-A) in both cases (mordanted and non-mordanted fabrics) are lower than 1%. Results of Tables 7-9 reveal that increasing K/S of colored wool fabrics with/without mordants accompanied by increasing UPF of these fabrics.

Accordingly, it can be concluded that wool fabrics are ranked as "excellent UV protection" after dyeing with or without a mordant because wool fabric has some properties such as; low porosity and high weight and thickness. Hence, wool fabric gives a high UPF by allowing the penetration of less UV. All wool fabrics colored with 4 colorants extracts without/with mordant (alum-$FeSO_4$) have much higher UPF values and lower T(UVA) and T(UVB).

Figures 2-5 of UV transmittance Percentage of different colorants and Figure 7 of UPF and UV-A of mordanted colored silk fabrics with different colorants using $FeSO_4$ and alum, acquire excellent UPF values

Fabric	Mordant	Rubbing fastness		Washing fastness			Light fastness
		Dry	Wet	Alt	St*	St**	
a- Madder							
Wool	Dyed control	3	2-3	3-4	3	2	6
	Alum	2	2	3-4	3-4	3-4	6
	$FeSO_4$	2	1-2	3-4	2-3	2	5-6
Silk	Dyed control	3-4	4-5	2-3	3-4	3	5
	Alum	2-3	3	3-4	4	3-4	5
	$FeSO_4$	2	3-4	3-4	4	4	5
Nylon	Dyed control	4-5	4	2-3	4	3	4-5
	Alum	2	2	3	4	3-4	4
	$FeSO_4$	2	2	3-4	3	3-4	4-5
b- Chamomile							
Wool	Dyed control	4-5	3-4	4	4-5	4	4-5
	Alum	3	2	5	5	5	6
	$FeSO_4$	2	2	5	4-5	5	6
Silk	Dyed control	4-5	5	4-5	4-5	4-5	5-6
	Alum	4	4-5	5	5	5	5-6
	$FeSO_4$	2-3	2	5	5	5	6
Nylon	Dyed control	5	4-5	4-5	4-5	4-5	5-6
	Alum	3-4	3	5	5	5	5
	$FeSO_4$	2	2	4-5	4-5	5	5

St.* staining on cotton St. ** staining on wool Alt. Alteration

Table 11: Colorfastness of wool, silk and nylon fabrics colored with colorants extracted from madder and chamomile.

Fabric	Mordant	Rubbing fastness		Washing fastness			Light fastness
		Dry	Wet	Alt	St*	St**	
Wool	Dyed control	3-4	3	4-5	3	3	6
	Alum	3	2-3	5	3-4	3	5-6
	$FeSO_4$	2	2	5	4	3-4	6
Silk	Dyed control	3-4	4	4	4	3-4	5
	Alum	3	3	5	5	3-4	5
	$FeSO_4$	2-3	3	5	5	4-5	6
nylon	Dyed control	4-5	4	4	3-4	3	4-5
	Alum	3-4	2-3	4-5	3-4	3-4	5
	$FeSO_4$	3	2-3	4	3-4	3-4	5-6

St.* staining on cotton
St. ** staining on wool
Alt. Alteration

Table 12: Colorfastness of wool, silk and nylon fabrics colored with colorants extracted from mixture of red onion/ chamomile (40g/l, 50% wt).

Citation: Gawish SM, Helmy HM, Ramadan AN, Farouk R, Mashaly HM (2016) UV Protection Properties of Cotton, Wool, Silk and Nylon Fabrics Dyed with Red Onion Peel, Madder and Chamomile Extracts. J Textile Sci Eng 6: 266. doi: 10.4172/2165-8064.1000266

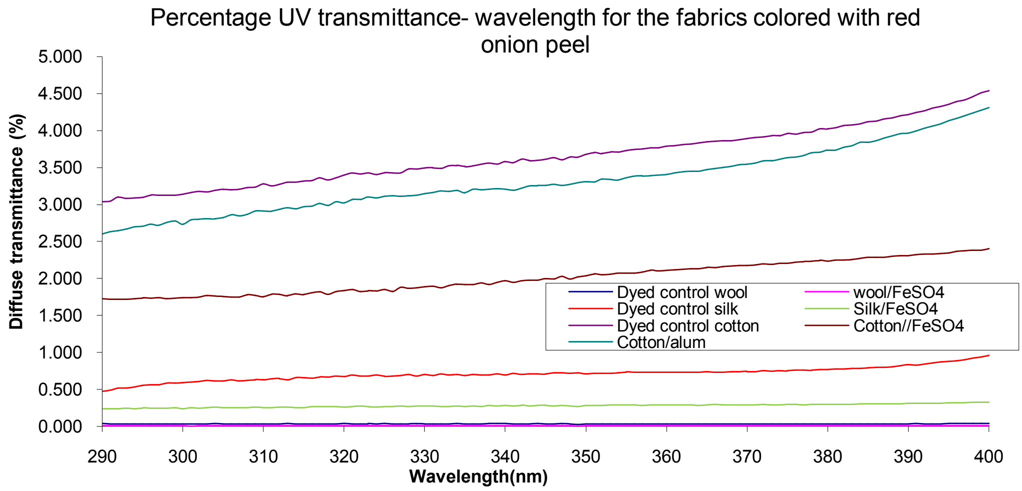


Figure 2: Percentage UV transmittance- wavelength for the fabrics colored with red onion peel.

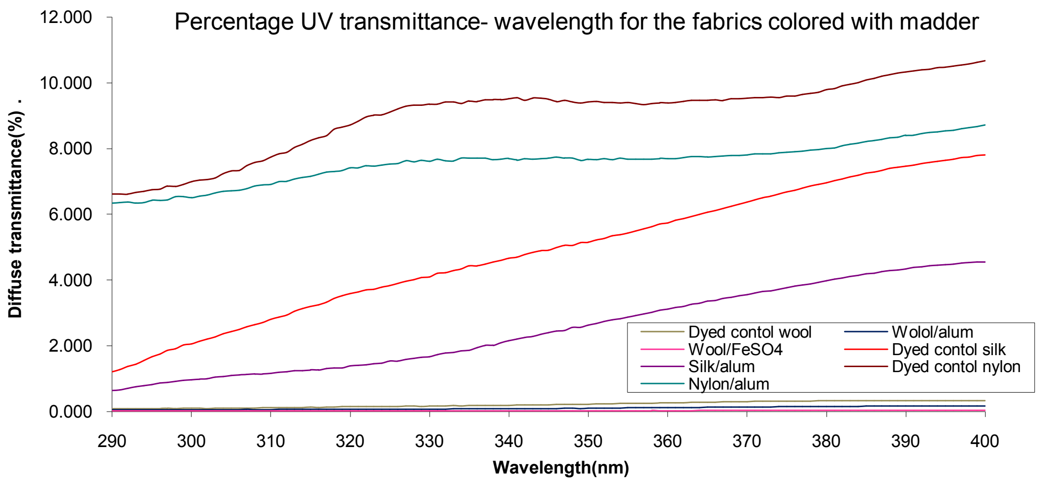


Figure 3: Percentage UV transmittance- wavelength for the fabrics colored with madder.

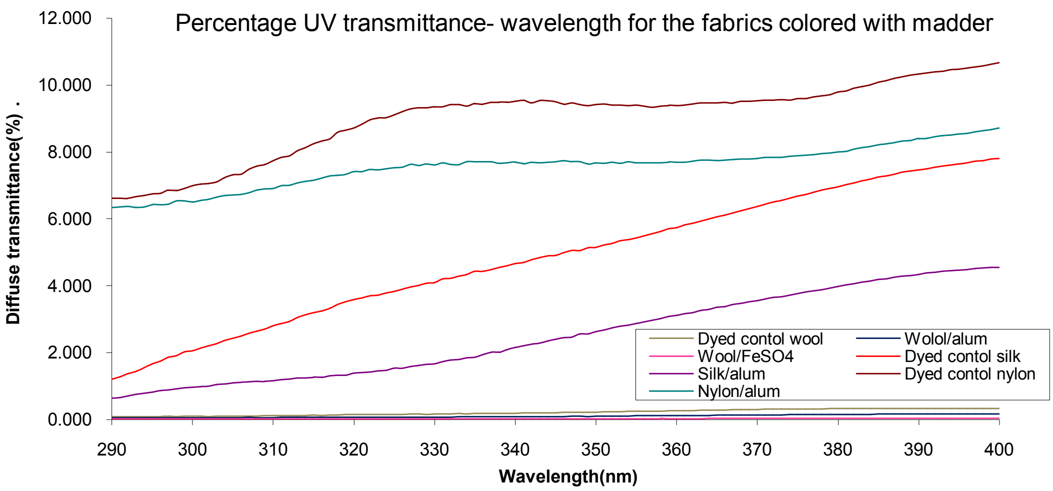


Figure 4: Percentage UV transmittance- wavelength for the fabrics colored with chamomile.

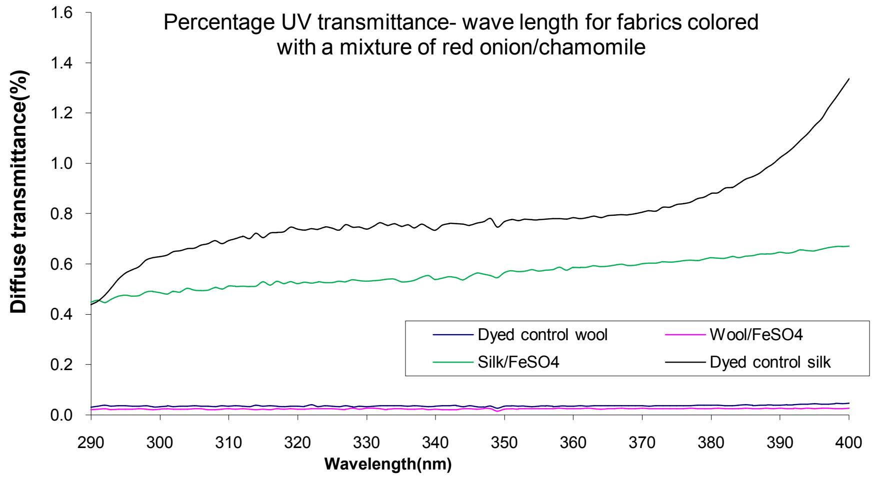
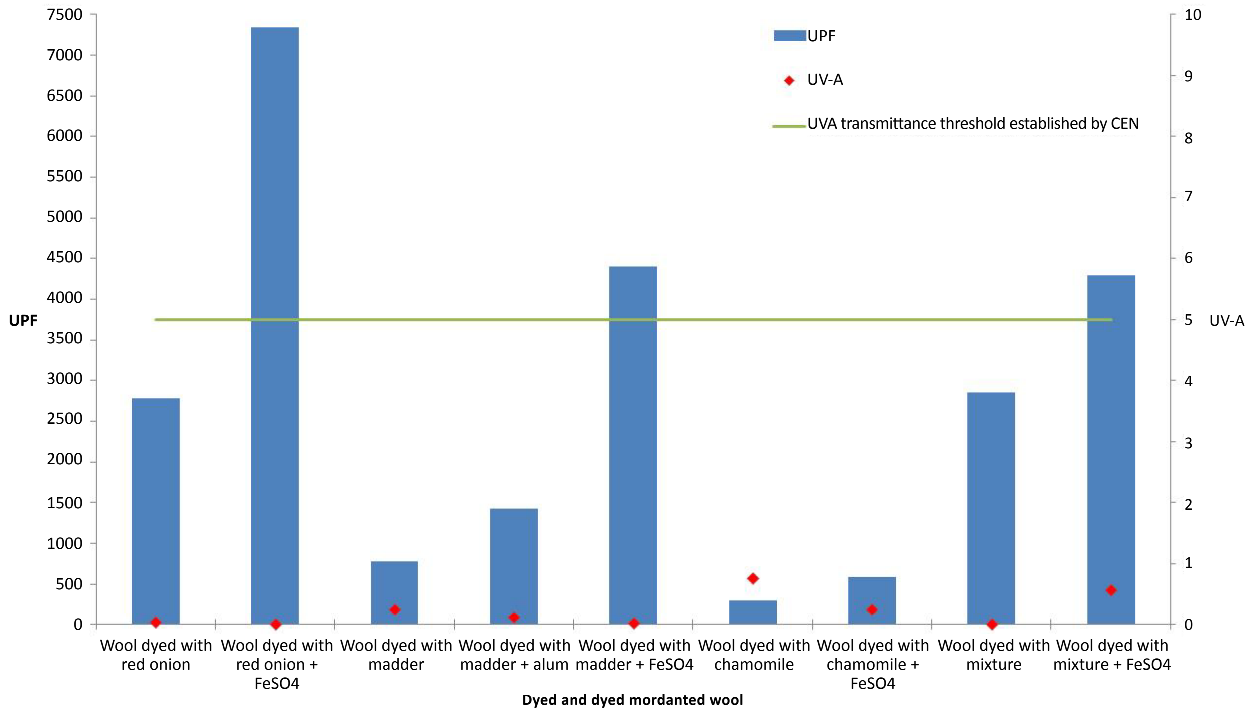


Figure 5: Percentage UV transmittance-wave length for fabrics colored with a mixture of red onion/chamomile (40 gm/L, 50% wt).



Horizontal line represents the UVA transmittance threshold established by the European standard for Sun Protective Clothing [29].

Figure 6: UPF and UV-A of non-mordanted and mordanted dyed wool with red onion, madder and mixture of red onion/chamomile extracts using alum and $FeSO_4$.

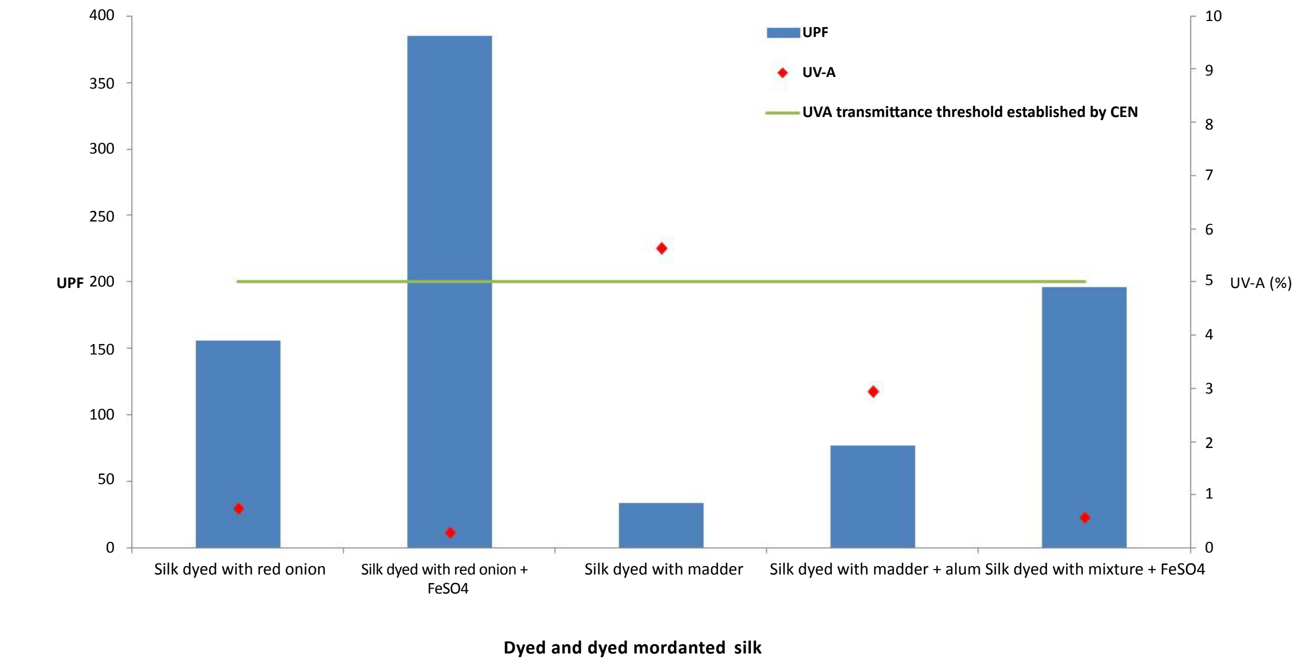
(50+) according to this order; red onion peel+$FeSO_4$>mixture of red onion peel/chamomile+$FeSO_4$>madder+alum and the values of T (UV-A) is lower than 5%.

From Figure 7, it is clear that different mordants have different impacts on the spectral transmittance of silk fabrics colored with 4 used colorants. Comparing with the colored silk fabric without mordant, the values of the spectral transmittance are reduced, but the UPF values are augmented by using mordants such as $FeSO_4$ and alum and show excellent UPF values.

In this experiment, the UPF of the fabrics colored with these natural dyes was higher than 50 according to Figure 7, and the value of the T (UV-A) was lower than 5%, except with madder (without mordant).

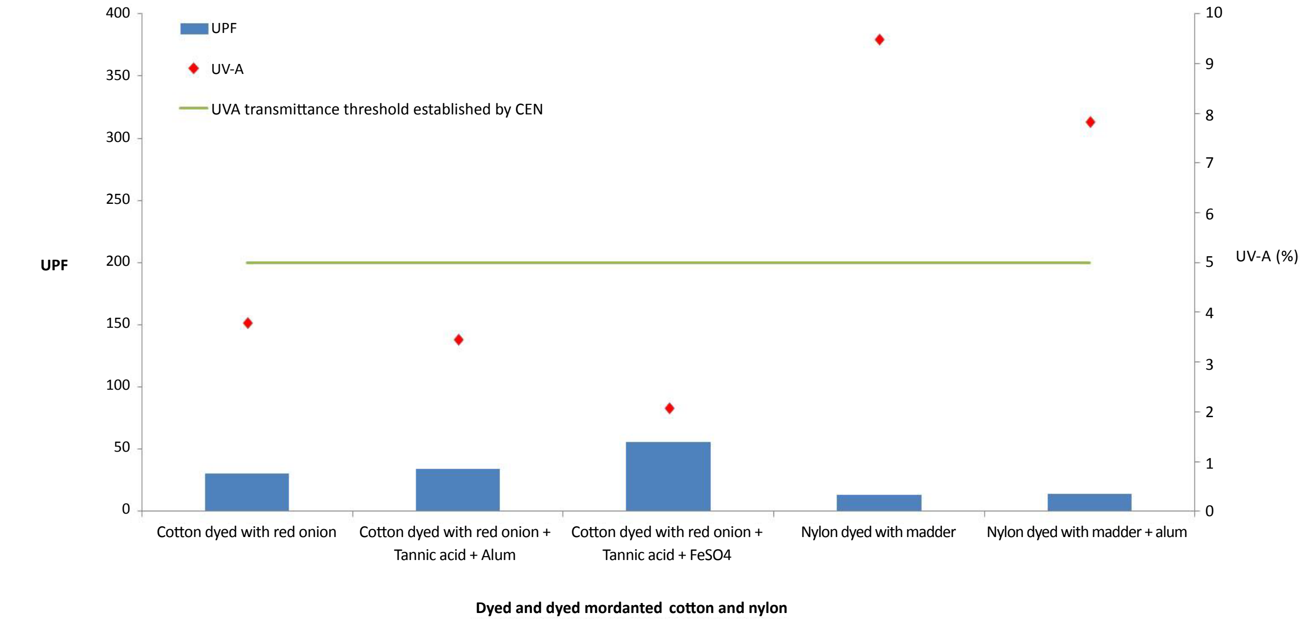
Actually, when the UPF value of the colored silk fabric was higher than 50 and the value of the T (UV-A) was lower than 5%, the colored silk fabric was supposed to be a solar ultraviolet protector [40]. This means that the fabrics colored with natural dyes can greatly prevent the penetration of UVR. Consequently, these colored silk fabrics could effectively shield skin from sunlight UV radiation.

From Figures 2-5 of UV transmittance Percentage of different colorants and Figure 8 of UPF and UV-A of mordanted colored cotton



Horizontal line represents the UVA transmittance threshold established by the European standard for Sun Protective Clothing [29].

Figure 7: UPF and UV-A of non-mordanted and mordanted dyed silk with red onion, madder and mixture of red onion/chamomile extracts using alum and $FeSO_4$.



(Horizontal line represents the UVA transmittance threshold established by the European standard for Sun Protective Clothing [29].

Figure 8: UPF and UV-A of non-mordanted and mordanted dyed cotton and nylon with red onion, madder and mixture of red onion/chamomile extracts using alum and $FeSO_4$.

and nylon fabrics with different colorants using alum and $FeSO_4$, it is obvious that non-mordanted/mordanted colored cotton fabric acquire very good UPF values (50+) according to this order; red onion peel+tannic acid+$FeSO_4$>red onion peel+tannic acid+alum>red onion peel+tannic acid (without mordant) and the values of T (UV-A) is lower than 5%.

The tannin molecules contain functional groups which absorb UV radiation, in this way, the colored cotton fabric treated with tannin-demonstrates higher UV protection than fabric without tannic acid [40], as appeared by the higher UPF value and a lower T (UV-A) rate. Cotton fabrics indicated an additional enhancement of UV protection which could be accounted for high uptake of tannin because of formation of the complex with metallic salt (mordant). Tannin molecules which turned into the ligands in the metal tannate complex hold their capability to absorb UV and, alongside the metal ions from the mordant, the overall UV protection effectiveness of the cotton fabrics is assigned to them.

Conversely, it is clear from Table 8, Figures 2-5 and 8 that the colored nylon fabric with madder has insufficient UPF value (13) as well as with alum (14) and the values of T (UV-A) is higher than 5%, which mean that this fabric hasn't any protection against UV radiation (Table 8a and Figure 8).

This study is important to increase natural dyes cultivation in our country for domestic market in addition to produce UV protective apparel clothing and carpets (wool and silk), curtains, and blankets with beautiful colors.

Conclusions

The coloration of fabrics with colorants of red onion peel, madder, chamomile and red onion/chamomile mixture (50% wt) extracts without or with mordants have revealed excellent protective level UPF (50+) for fabrics with exception of nylon, or that mordanted with alum. Colored madder gives insufficient protection with nylon fabric. Control cotton colored with red onion peel and that mordanted with alum have very good protection .While cotton mordanted with $FeSO_4$ has an excellent one. Pretreatment of fabrics with mordants enhances colorfastness to washing and light. Mordanting of fabrics doesn't enhance wet and dry rubbing fastness. All colored fabrics acquire very good to excellent colorfastness to light, but colorfastness to washing is fair to very good. UPF calculations have shown excellent values for all colored control fabrics or mordanted fabrics according to this arrangement; wool fabrics>silk fabrics>cotton fabrics>nylon fabrics, which confirmed UV protection of fabrics colored with the 4 mentioned colorants. When the UPF value of the colored fabrics was higher than 50 and the value of the T (UV-A) was lower than 5%, then the colored fabrics with colorants such as red onion, madder, chamomile, red onion peel/chamomile mixture were supposed to be a solar ultraviolet protector. This further explained that the fabrics dyed with natural dyes strongly blocked UV radiation. Thus, these colored fabrics could efficiently protect skin from solar UV radiation. The above colorants are friendly environment and their colored fabrics are suggested to use in preventing skin cancer of humanity in the world.

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