Dyeing and Deodorizing Properties of Cotton, Silk, Wool Fabrics Dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* Extracts

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ABSTRACT: This study used four kinds of natural colorant solutions extracted from Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* using water at 90°C for 90 min with a liquor ratio (solid natural colorant material/solvent water, weight ratio) of 1/10. The dyeing, color fastness, deodorizing properties of cotton, silk, wool fabrics dyed with natural colorant extracts were compared. These properties were found to be significantly dependent on the extract concentration, colorant structure, fabric type. Color fastness (light, water, perspiration fastness) ranged between second and fifth grades and deodorizing performance of fabrics dyed with various natural colorant extracts between 34 and 99%. It is worth noting that the use of natural colorants notably enhanced the deodorizing performance. Wool fabrics showed the highest performance increase at 98–99%, followed by silk and cotton. © 2009 Wiley Periodicals, Inc. J Appl Polym Sci 115: 2246–2253, 2010

Key words: dyeing; Amur corktree; *Dryopteris crassirhizoma*; *Chrysanthemum boreale*; *Artemisia*; deodorization performance

INTRODUCTION

Recently a revival interest in the use of natural dyes in textile coloration has been growing. This is a result of the stringent environmental standards imposed by many countries in a response to the toxic and allergic reactions associated with synthetic dyes. There is interest in the dyeing of textile fibers using natural colorants, on account of their high compatibility with environment, softer color shade, naturalness, lower toxicity, antibacterial/antiallergic/deodorizing/anticancer properties, harmonizing natural shades or just the novelty.[1–5]

It is well-known that problems in dyeing with natural dyes are the low exhaustion of natural colorants and the poor fastness of dyed fabrics. Attempts to overcome these problems have been mainly focused on the use of metallic salts as mordants, which are traditionally used to improve fastness properties or exhaustion and to develop different shades with the same dye.[6–12] However, most synthetic mordants are toxic heavy metal ions, which are also pollutive components. So, the mordant is not used in this study. Dyeing of natural fibers using *Teminalia arjuna, Punica granatum, Rheum emodi, Rubia cordifolia*, madder as natural dyes without mordants was investigated by Vankar et al.[13–15] But there are only a few researches on dyeing property using various natural colorants without mordants. Therefore, it is very important to obtain high exhaustion and good fastness using various natural colorants without mordant.

With growth of living standards, people have become extremely concerned about health and hygiene. People are extremely sensitive to smells, making deodorizing an entrenched social need. Deodorizing aims to protect health and living environment by regulating the discharge of foul smelling substances generated by factories and other commercial activities.[16] However, deodorization performance using natural colorants has not been widely studied yet. We have previously studied the dyeing, fastness and deodorizing properties of cotton, silk, wool fabrics using some natural colorants (Sappan wood, Black tea, Peony, Clove, Gardenia, Coffee sludge, *Cassia tora L.*, Pomegranate).[17–19] We could get fabrics of diverse natural color tone with prominent deodorizing property using clove and pomegranate. To find better-performance new natural

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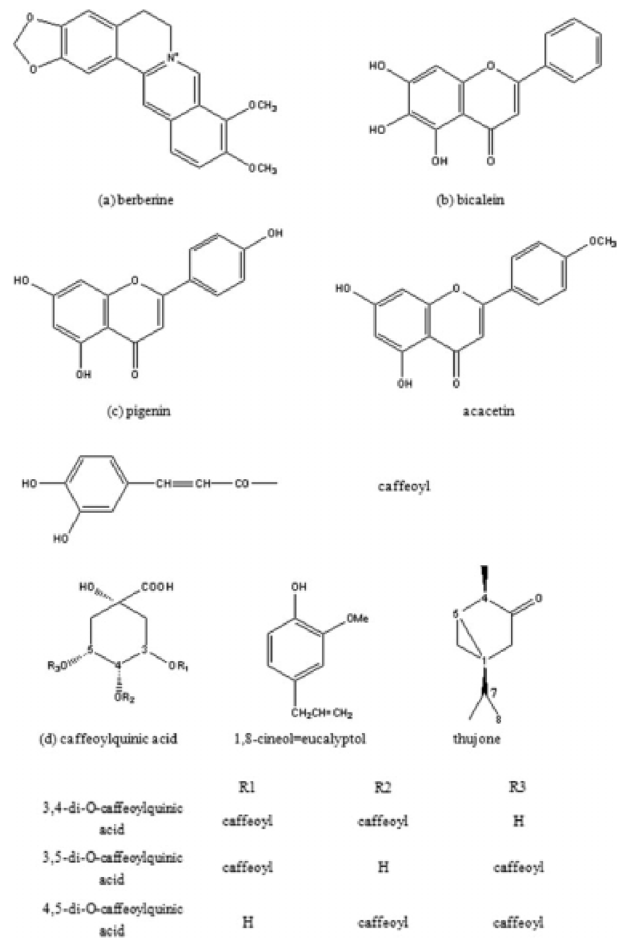

Scheme 1 The structures of main components of natural colorants: (a) Amur Corktree, (b) *Dryopteris crassirhizoma*, (c) *Chrysanthemum boreale*, (d) *Artemisia*.

colorants, different natural colorants extracts of Amur Corktree (main component: berberine, origin: Korea/east Asia/northern Japan), *Dryopteris crassirhizoma*(main component: bicalein, origin: Korea/Japan/northern China), *Chrysanthemum Boreal* (main component: apigenin/acacetin, origin: Korea/Japan/China), *Artemisia* (main component: eucalyptol/thujone/caffeoylqunic acid, origin: Korea/Japan/China), which grow naturally in Korea, were used in this study.[20] The structures of these main components are shown in Scheme 1. The influence of these colorants extracts without mordant on dyeing, fastness (light, water, perspiration fastness) and deodorizing properties of fabrics (cotton, silk, wool) was investigated.

EXPERIMENTAL

Materials

Cotton, silk, wool fabrics (Standard Adjacent Fabrics for Staining of Fastness Test: KS K 0905) were used. The characteristics of these fabrics are shown in Table I.

Mordants [Aluminum sulfate hydrate ($Al_2(SO_4)_3 \cdot 13–14\ H_2O$, M_w: 585, Junsei Chemical Co), Manganese (II) sulfate hydrate ($MnSO_4 \cdot 5H_2O$, M_w: 241, Junsei Chemical Co), Copper(II) sulfate hydrate ($CuSO_4 \cdot 5H_2O$, M_w: 249.68, Junsei Chemical Co), Iron(II) sulfate hydrate ($FeSO_4 \cdot 7H_2O$, M_w:278.03, Junsei Chemical Co), and Cobalt (II) sulfate hydrate ($CoSO_4 \cdot 7H_2O$, M_w: 281.10, Shinyo Pure Chemicals Co)] were used without further purification.

The bark of Amur Corktree, the root of *Dryopteris crassirhizoma*, the flower of *Chrysanthemum Boreal*, the leaf of *Artemisia*, which grow naturally in Korea were used as natural colorants sources.

Extraction, mordanting, dyeing

Extracton

Four kinds of dyeing solutions were extracted from Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum Borea, Artemisia* using water at 90°C for 90 min. at a fixed liquor ratio (solid natural colorant/water ratio) of 1 : 10.

Mordanting

To compare the deodorizing properties of mordanted fabrics and dyed fabrics with natural colorant extracts, fabrics were premordanted at 40°C for 60 min using 3% o.w.f. mordant solutions (except aluminum sulfate hydrate 10% o.w.f) with bath ratio 1 : 50.

TABLE I
Characteristics of Control Fabrics

Fabric	Thickness[a] (mm)	Counts (Tex)		Density (threads/cm)		Weight (g/m^2)	*K/S*	*L**	*a**	*b**	WI	YI	BI
		Warp	Weft	Warp	Weft								
Cotton	0.27	14	16.5	31	35	115	0.08	88.97	−0.25	1.10	68.51	1.97	73.08
Silk	0.10	2.3/2	2.3	38	55	26	0.11	86.87	−0.21	1.03	64.34	1.93	68.88
Wool	0.33	15.6/2	15.6/2	18	21	125	0.27	86.38	−1.23	5.00	43.65	8.69	64.76

Weave: plain.
WI: whiteness index, 10 deg/D65/Ganz.
YI: Yellowness index, 2 deg/C/ASTM D1925.
BI: brightnessindex, 2deg/C/TAPP1452/ISO2470.
[a] Thickness were measured under 1 kpa pressure.

Dyeing

All dyeing was carried out using a 1 : 100 bath ratio at 80°C for 60 min by exhaustion method.

Characterization

FTIR spectrometer (Impact 400D, Nicolet, Madison, WI) was used to confirm the structure of natural colorants extracts. For each IR spectrometer samples 32 scans at 4 cm^{-1} resolution in the wave number of 400–4000 cm^{-1} was collected in the transmittance mode. The IR spectra of samples in transmittance mode were obtained by grinding the dried natural colorants extracts and by using a KBr pellet method. The UV-visible spectra were measured by using a UV-visible spectrophotometer (Scinco S-3100, Seoul, Korea). The percentage dye-bath exhaustion was calculated as follows: E (%) = $(A_0 - A_d)/A_0 \times 100$, where A_0 and A_d are the concentration (or absorbance) of as-extracted colorants solution and dye-bath solution after dyeing. The pH of natural colorants extracts were measured using pH meter (EcoScan pH 6, Evtech, Twain). The reflectance values and the corresponding CIE L^*, a^*, b^*, HV/C and color strength (K/S) values for the dyed samples were measured using a CCM (Gretag Macbath Color-Eye 7000A) interfaced to a digital PC under illuminant D_{65}, with a 10° standard observer. K/S was calculated from the reflectance values using the Kubelka-Munk equation as follows: $K/S = (1-R)^2/2R - (1-R_0)^2/2R_0,$ where R is the reflectance of the colored fabric, R_0 is the reflectance of the uncoloured fabric, and K/S is the ratio of the absorption coefficient (K) to scattering coefficient (S): the higher the value, the greater the color strength. The light fastness, the water fastness, the perspiration fastness were determined according to KS K 0700, KISO 105-E01_2005, KISO 105-E04_2005, respectively. Gas detecting tube method was used to measure ammonia gas concentration. The change of concentration of ammonia gas in the tube with fabrics over the elapse of time was measured at 25°C. The concentration of ammonia gas in blank (reference) tube was about 500 ppm. The deodorizing performance was calculated as follows: Deodorization performance (%) = $(C_b - C_s)/C_b \times 100$, where, C_b is the gas concentration (ppm) of test tube without fabric (blank state), and C_s is the concentration of tube with fabrics. The sample size and weight for deodorizing performance test: cotton (length × width × thickness: 10 cm × 10 cm × 0.27 mm, 1.2 g), silk (10 cm × 10 cm × 0.10 mm, 0.3 g), and wool (10 cm × 10 cm × 0.33 mm, 1.3 g).

RESULTS AND DISCUSSION

Confirmation of components of various natural colorants

Figure 1 shows the IR spectra of Amur Corktree (a), *Dryopteris crassirhizoma* (b), *Chrysanthemum Boreal* (c), *Artemisia* (d) extracts. Amur Corktree (a) have the characteristic peaks corresponding to the OH stretch at 3354 cm^{-1}, sym CH stretch in O—CH_3 at 2932 cm^{-1}, ring stretch(benzene ring in aromatic compound) at 1605 and 1416 cm^{-1}, NH_2 deformation at 1416 cm^{-1}, C—O stretch at 1101 and 1062 cm^{-1}were observed indicating the presence of berberine and palmatine(alkaloid) component in the Amur Corktree extract.[21]

Dryopteris crassirhizoma extract(b) shows the characteristic peaks corresponding to the OH stretch at 3352 cm^{-1}, CH antisymmetric and symmetric stretch at 2931 cm^{-1}, ring stretch at 1607 cm^{-1}, in-plane OH bending at 1417 cm^{-1}, C—O stretch at 1052 cm^{-1} were observed indicating the presence of flavonoid mixture(baicalein and bacalin) components.[21]

Chrysanthemum boreale extract (c) shows characteristic peaks corresponding to OH stretching at 3362 cm^{-1}, CH antisymmetric and symmetric stretching at 2933 cm^{-1}, ring stretch at 1606 cm^{-1}, in-plane OH bending at 1416 cm^{-1}, C—O stretch at 1062 cm^{-1}, OH out-of-plane deformation at 629 cm^{-1} were observed. These characteristic peaks indicated the presence of α-thujone, dl-camphor, flavonoid (apigenin and acacetin) in *Chrysanthemum boreale* extract.[21]

Artemisia extract (d) have the characteristic peaks corresponding to the OH stretch at 3352 cm^{-1}, CH stretch in aromatic —CH_3 compound at 2933 cm^{-1}, C=C stretch (aromatic ring system) at 1605 and 1516 cm^{-1}, C—N stretch at 1396 cm^{-1}, C—O stretch at 1259 cm^{-1}, and C=O stretch at 1072 cm^{-1} were observed. This indicated the presence of eucalyptol, thujone, 3,4-,3,5-,4,5-di-*O*-caffeoylqunic acid in *Artemisia* extract. Natural colorant extracts are composed of main component and many unknown components which we have not yet analyzed. Detailed analysis of each component requires future research.

The visible light absorbance, concentration, pH, dye-bath exhaustion (%) of extracted natural colorants

From the results of our previous study, the optimum liquor ratio was found to be 1 : 10.[19] Therefore, all natural colorants were extracted at 1 : 10 liquor ratio in this study. The UV-visible spectra of visible region (400–800 nm) for four as-extracted natural colorants are shown in Figure 2. The concentrations, pH and the degree of dye-bath exhaustion of as-extracted natural colorants are shown Table II. The visible absorbance of four colorants solution

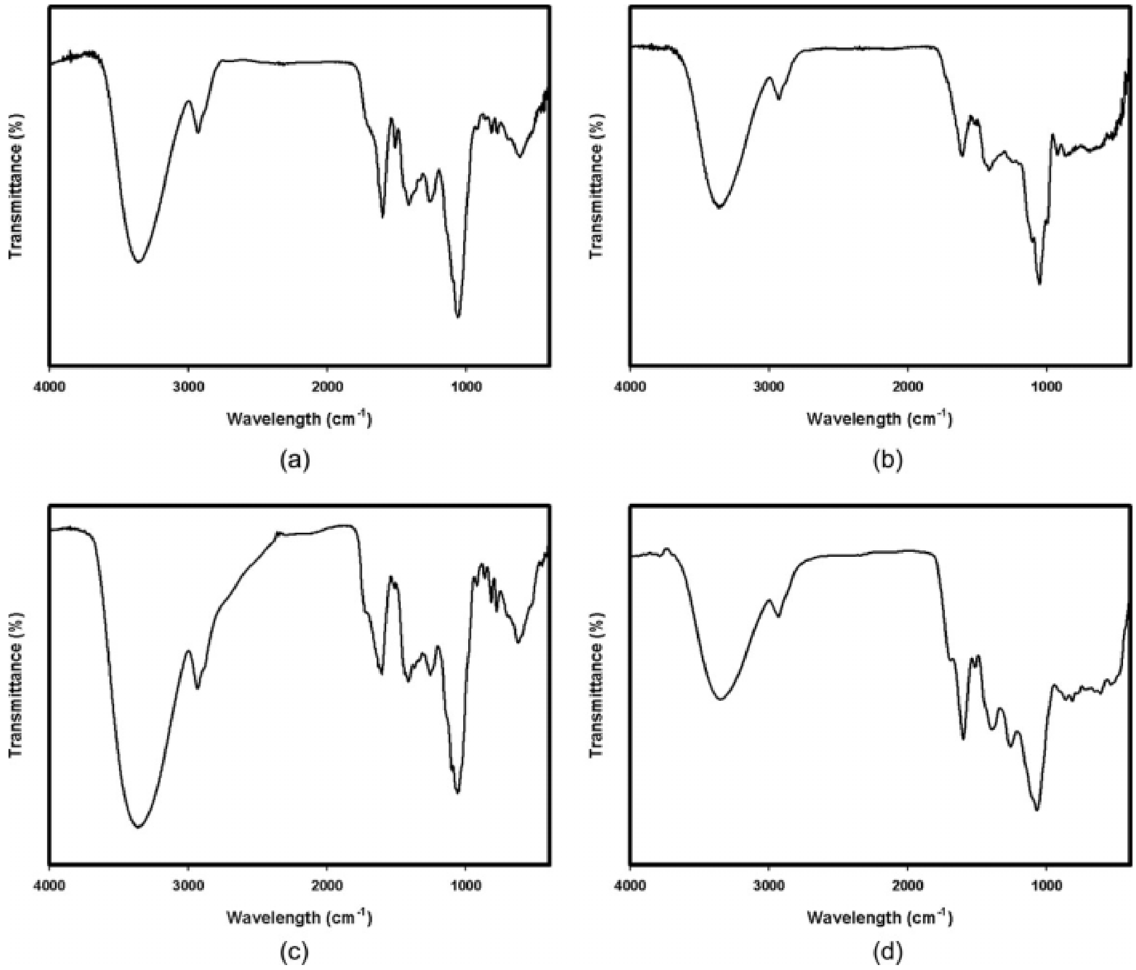

Figure 1 Infrared spectra of extracted natural colorants: (a) Amur Corktree, (b) *Dryopteris crassirhizoma*, (c) *Chrysanthemum boreale*, (d) *Artemisia*.

decreased with increasing wave length. This indicated that the colors of colorants are yellowish. The absorbance increased in the order of Amur Corktree < *Dryopteris crassirhizoma* < *Artemisia* < *Chrysanthemum boreale*. The absorbance increased in proportion to the concentration of colorants solutions. The concentrations of Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale* and *Artemisia* extracts were found to be 1.35, 1.48, 3.19, 1.9 g/100 mL, respectively. The pH of Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale* and *Artemisia* extracts were found to be 4.8, 4.5, 3.8, 5.2, respectively. This indicated that these natural colorant aqueous extracts were acidic solutions. The degree (%) of dye-bath exhaustion was found to be in the range of 24–38%. It was found that dye-bath

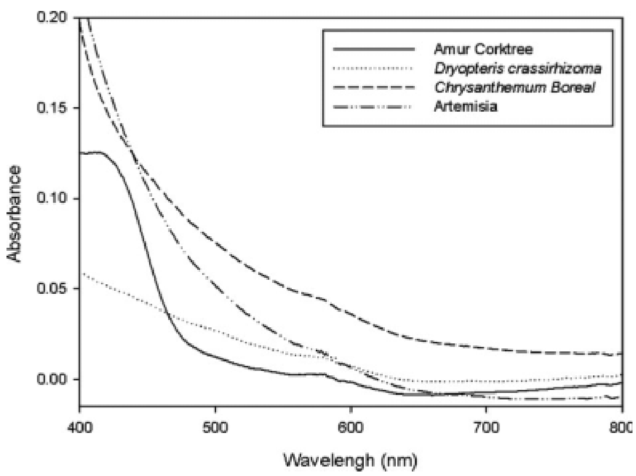

Figure 2 UV-visible spectra of extracted natural colorants solutions.

TABLE II
Concentrations, pH, Dye-Bath Exhaustion of as-Extracted Natural Colorants

Natural colorant	Concentration (g/100 mL)	pH	Bath exhaustion (%) Cotton/silk/wool
Amur Corktree	1.35	4.8	26/33/34
Dryopteris crassirhizoma	1.48	4.5	35/33/34
Chrysanthemum boreale	3.19	3.8	25/38/38
Artemisia	1.90	5.2	24/32/28

TABLE III
Colorimetric Data of Fabrics Dyed with Amur CorkTree, *Dryopteris crassirhizoma*, *Chrysanthemum boreale*, *Artemisia*

Fabric	Natural colorant	*K/S*	*L**	*a**	*b**	*H*	*V/C*
Cotton	Control	0.08	88.97	−0.25	1.10		
	Amur corktree	1.63	86.16	−3.64	27.30	7.0Y	8.5/3.7
	Dryopteris crassirhizoma	0.57	85.61	3.52	11.81	9.1YR	8.4/2.0
	Chrysanthemum boreale	3.43	89.04	−1.21	10.45	4.2Y	8.9/1.2
Silk	Control	0.11	86.87	−0.21	1.03		
	Amur corktree	8.19	79.12	−3.48	52.79	6.6Y	7.9/7.2
	Dryopteris crassirhizoma	3.73	75.98	8.62	18.26	7.4YR	7.6/3.4
	Chrysanthemum boreale	7.63	81.90	0.89	16.41	2.3Y	8.1/2.4
Wool	Control	0.27	86.38	−1.23	5.00		
	Amur Corktree	10.48	73.78	0.88	51.97	4.6Y	7.3/7.0
	Dryopteris crassirhizoma	7.61	69.34	13.51	25.32	5.6YR	6.9/4.7
	Chrysanthemum boreale	16.11	67.64	3.83	27.36	1.1Y	6.7/3.9

exhaustion was not significantly dependent on the concentration of colorant solution, *K/S* and the kind of fabrics. This might be attributable to many complex factors. The reason is not clear at the present moment. More detailed studies should be done.

Dyeing properties

In this study, the dyeing time and temperature were fixed at 60 min and 80°C, respectively. It was because the preliminary experiment found that the optimum dyeing time and temperature at a fixed liquor ratio (1 : 10)[19] were 60 min and 80°C respectively, to give the highest *K/S* value for all fabrics.

Table III shows the color strength *K/S* value and colorimetric parameter (*L**, *a**, *b**, *H and V/C*) of fabrics (cotton, silk, wool) dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* extracts. Generally, the dyeing affinity of textile materials is dependent on the content and type/polarity of functional groups of fibers. It is well known that the number of functional group in wool is larger than that of silk, and polarity of protein fibers is higher than that of cellulose fiber.[22] The color strength *K/S* value was in the order of cotton < silk < wool for all natural colorants. This order of color strength is matched to the content and polarity of functional group of fibers. From these results, wool was found to be the lowest *L** and *V* values for all natural colorants used in this study, followed by silk and cotton. The highest *K/S* value of wool should be attributed to the lowest *L** and *V* values of wool.

The *K/S* value of dyed cotton fabrics increased in the order of *Dryopteris crassirhizoma* < Amur Corktree < *Artemisia* < *Chrysanthemum boreale*. The *K/S* value gave the order of *Dryopteris crassirhizoma* < *Artemisia* < *Chrysanthemum boreale* < Amur Corktree for dyed silk fabrics. However, the *K/S* value of dyed wool fabrics increased in the order of *Dryopteris crassirhizoma* < Amur Corktree < *Chrysanthemum boreale* < *Artemisia*. Generally, the dyeing affinity also depended on many complex factors such as the concentration and structural features of colorants/fibers. It was found that the *K/S* value depended on the concentration of colorant solution. However, the *K/S* value of dyed fabrics was not perfectly matched to the concentration of natural colorant extract described above (Amur Corktree < *Dryopteris crassirhizoma* < *Artemisia* < *Chrysanthemum boreale*). From these results, the color strength *K/S* of fabrics (cotton, silk, wool) dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* extracts was found to be dependent on the concentration of colorants and the kind of fiber.

In this study, various color characters of dyed fabrics were characterized using coordinate *a** (redness) and *b** (yellowness) as shown in Figure 3. The *a**/*b** values of control cotton, silk, wool fabrics were found to be −0.25/1.10, −0.21/1.03, −1.23/5.00, respectively, indicating that the color hues of control fabrics were almost white. The *a** and *b** values of dyed fabrics with all natural colorants showed the higher values compared to control fabrics. Wool showed the highest *a** and *b** values for all colorants (Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia*), followed by silk and cotton, indicating that the increase of redness and yellowness was in the order of wool > silk > cotton (see Table III and Fig. 3).

The *a**/*b** values of cotton, silk, wool fabrics dyed with Amur Corktree were found to be −3.64/27.30, −3.48/52.79, 0.88/51.97, and their color hues 7.0Y, 6.6Y, 4.6Y respectively. The *a**/*b** values of cotton, silk, wool fabrics dyed with *Dryopteris crassirhizoma* were found to be 3.52/11.81, 8.62/18.26, 13.51/25.32, and their color hues 9.1YR, 7.4YR, 5.6YR respectively. The *a**/*b** values of cotton, silk, wool fabrics dyed with *Chrysanthemum boreale* were found to be −1.21/10.45, 0.89/16.41, 3.83/27.36, and their color hues 4.2Y, 2.3Y, 1.1Y respectively. The *a**/*b** values of cotton, silk, wool fabrics dyed with *Artemisia* were found to be 0.31/15.68, 0.12/21.39, 4.49/32.76, and

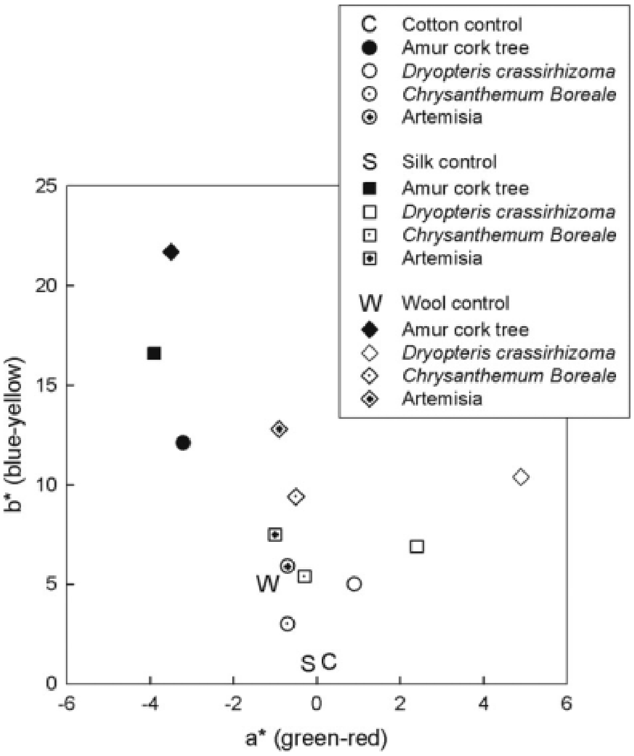

Figure 3 Various colors of dyed fabrics on coordinate a^* (greenness-redness) and b^* (blueness-yellowness).

their color hues 3.2Y, 3.5Y, 1.4Y respectively. From these results, it was found that various yellowish colors of dyed fabrics (cotton, silk, wool fabrics) were dependent on the kinds of natural colorants and fabrics. Figure 4 shows that various apparent colors of fabrics (cotton, silk, wool fabrics) dyed with four kinds of natural colorants. From the colorimetric result, it was found that the diverse elegant yellowish colors of fabrics dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* colorants extracts were obtained.

Color fastness

Color fastness (light, water, perspiration fastness) of fabrics dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* extracts are shown in Table IV. All fastness of cotton fabric dyed with Amur Corktree were poor. This might be due to the week interaction between cotton and main component berberine (cationic dye component) in Amur Corktree. However, especially cotton—*Dryopteris crassirhizoma*/*Chrysanthemum boreale*/Artemisa, silk—*Chrysanthemum boreale* showed high value (grade 4–5) of light fastness. Considering natural dyes generally have low fastness (about second grade), the fastness of dyed fabrics obtained in this study are considerably good. All fastness of fabrics (cotton < silk < wool) dyed with all natural colorants except Amur Corktree were high values in the range of 3–5.

Deodorizing performance

Deodorizing performance of fabrics contributes to enhancing health and hygiene of mankind, and making life more pleasant. In this study, we investigated the deodorizing performance of fabrics dyed with natural colorants such as Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* extracts. We compared these deodorizing performance of dyed fabrics with fabrics mordanted using various mordants such as $MnSO_4$, $CuSO_4$, $Al_2(SO_4)_3$, $FeSO_4$, $CoSO_4$.

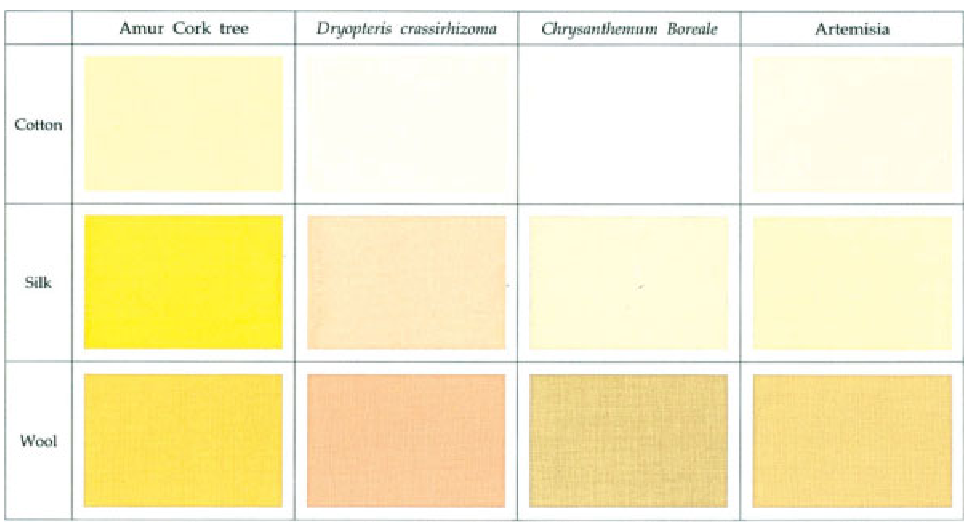

Figure 4 Various colors of fabrics (cotton, silk, wool fabrics) dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia*. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

TABLE IV
Color Fastness of (a) Cotton, (b) Silk, (c) Wool Fabrics Dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia*

Fabric	Natural colorant				Amur Corktree	*Dryopteris crassirhizoma*	*Chrysanthemum boreale*	*Artemisia*
(a) Cotton	Light				1	5	4	4
	Water		Fade		2	3	4	3
			Stain	Silk	2	4	4	4
				Cotton	1	4	3	3
	Perspiration	Acidic	Fade		1	3	3	2
			Stain	Silk	1	4	4	2
				Cotton	2	4	4	3
		Alkaline	Fade		1	3	3	3
			Stain	Silk	1	4	3	4
				Cotton	1	3	3	3
(b) Silk	Light				1	2	5	3
	Water		Fade		4	4–5	4	4–5
			Stain	Silk	1–2	4–5	4	4–5
				Cotton	1–2	4	4–5	4–5
	Perspiration	Acidic	Fade		3	4	3	4
			Stain	Silk	2	4	4	4–5
				Cotton	2	3–4	4	4
		Alkaline	Fade		3	3	3	4–5
			Stain	Silk	3	4	3	4
				Cotton	2	3	3	3
(c) Wool	Light				1	2	2	2
	Water		Fade		4–5	4–5	4–5	4–5
			Stain	Silk	4	4–5	4–5	4–5
				Cotton	4	4	4–5	4–5
	Perspiration	Acidic	Fade		4	4	4	4
			Stain	Silk	4	4–5	4	4–5
				Cotton	3	4–5	3–4	4–5
		Alkaline	Fade		4	4–5	3	4–5
			Stain	Silk	3	4	3	4–5
				Cotton	2	4	3	4

Figure 5 shows the deodorizing performance difference between treated fabrics and control fabrics to compare the deodorizing properties of mordanted fabrics and dyed fabrics with natural colorant extracts. The deodorizing performance of control fabrics (cotton, silk, and wool) were 28%, 61%, 86%, respectively. The deodorizing performance of mordanted fabrics, dyed fabrics were in the range of 62–99%, 34–99%, respectively. Generally, it was well known that mordanting improved the deodorization

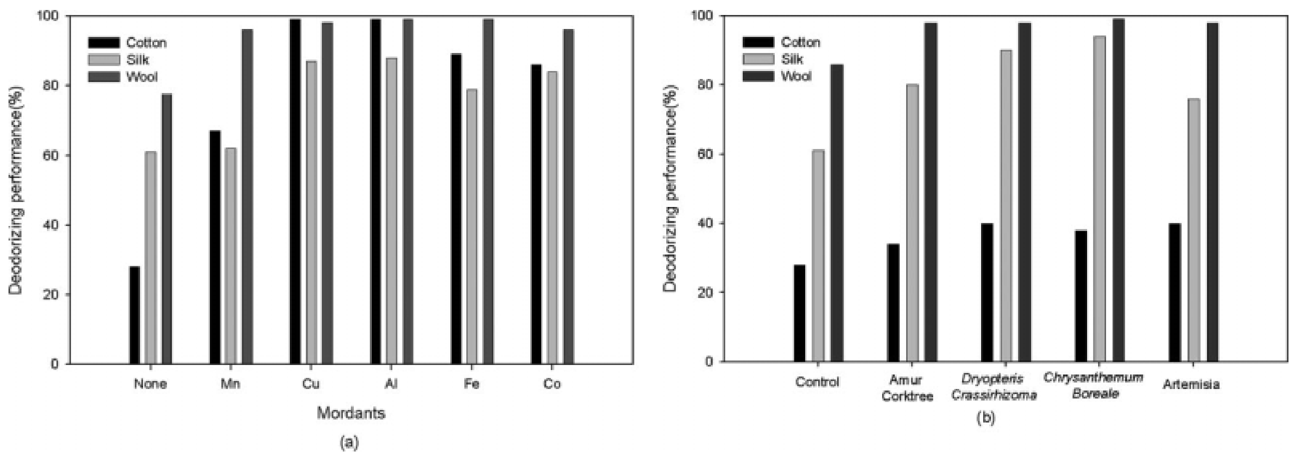

Figure 5 Comparison of deodorizing performance of fabrics mordanted with various metallic sulfate salts(a) and dyed with Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* (b).

performance, since the mordant metallic salts could absorb smelling molecules through the formation of coordination bonds between transition metal ions and unshared electron pairs of smelling molecules.[16] Along with main components of natural colorants and fabric itself, many unknown components of natural colorants also greatly contributed to the high deodorizing performance. More detailed studies should be done. It is evident that the deodorizing performance was enhanced when dyeing had been carried out. The deodorizing performance increased in the order of cotton < silk < wool, proportional to the *K/S* value and in accordance with inherent property of each fabric. In case of cotton, the deodorizing performance of fabric mordanted with metallic salts was higher than that of fabrics dyed with natural colorants, indicating the unviability of used natural colorants on cotton. The silk fabrics dyed with *Dryopteris crassirhizoma* and *Chrysanthemum boreale* showed better deodorizing performance than mordanted ones, while silk fabrics dyed with Amur Corktree and *Artemisia* performed poorer. It is notable that wool fabric dyed natural colorants showed better than mordanted one. This result shows that protein fiber (e.g., silk and wool) has better deodorizing performance than cellulose fiber (e.g., cotton), probably attributable to their distinctive functional groups. The highest value of *Chrysanthemum boreale* might be due to the main component flavonol of *Chrysanthemum boreale* which could react with ammonia based foul odors through the sensory (neutralizing) reaction mechanism. These results clearly demonstrate that utilizing extracted natural colorants as dyeing materials significantly facilitate to obtain prominent deodorizing fabrics.

CONCLUSIONS

Four kinds of natural colorants were extracted from Amur Corktree, *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* using water as extracting solvent, with the optimum extraction temperature, time and liquor ratio found to be at 90°C, 90 min and liquor ratio (solid natural colorant material/water, weight ratio) of 1/10, respectively. This study explored the effect of natural colorant solution on dyeing, fastness and deodorizing properties of fabrics (cotton, silk, wool fabrics). The *K/S* value came in the order of cotton < silk < wool for all colorant solutions. The concentration of natural colorant extract increased in the order of Amur Corktree < *Dryopteris crassirhizoma* < *Artemisia* < *Chrysanthemum boreale*. The *K/S* value of dyed cotton fabrics increased in the order of *Dryopteris crassirhizoma* < Amur Corktree < *Artemisia* < *Chrysanthemum boreale*. The *K/S* value gave the order of *Dryopteris crassirhizoma* < *Artemisia* < *Chrysanthemum boreale* < Amur Corktree for dyed silk fabrics. However, the *K/S* value of dyed wool fabrics increased in the order of *Dryopteris crassirhizoma* < Amur Corktree < *Chrysanthemum boreale* < *Artemisia*. Color fastness (water and perspiration fastness) of fabrics dyed with *Dryopteris crassirhizoma, Chrysanthemum boreale, Artemisia* ranged from second to fifth grades. Wool showed the highest water and perspiration fastness followed by silk and cotton. The deodorizing performance of fabrics dyed with various natural colorants extracts was in the range of 34–99% and increased in the order of cotton < silk < wool. Especially, the deodorizing performance of wool fabrics dyed with various natural colorants ranked highest among the three at 98–99%. From this study, we could get fabrics of diverse elegant color tone with prominent deodorizing property using various natural colorants.

References

1. Hill, D. J. Rev Prog Color 1997, 27, 18.
2. Deo, H. T.; Desai, B. K. J Soc Dyers Color 1999, 115, 224.
3. Bechtold, T.; Turcanu, A.; Ganglberger, E.; Geissler, S. J Clean Prod 2003, 11, 499.
4. Kenneth, M. K. Text Res J 1973, 43, 404.
5. Shin, Y. S.; Cho, E. K. J Korean Soc Clothing Textiles 2001, 25, 577.
6. Montazer, M.; Parvinzadeh, M. Fibers Polym 2007, 8, 181.
7. Popoola, A. V. J Appl Polym Sci 2000, 77, 746.
8. Cho, K. R. J Korean Soc Dyers Finishers 1999, 11, 257.
9. Cristea, D.; Vilarem, G. Dyes Pigments 2006, 70, 238.
10. Tsatsaroni, E. G.; Eleftheriadis, I. C. J Soc Dyes Colourists 1994, 110, 203.
11. Lee, Y. H.; Hwang, E. K.; Kim, H. D. J Korean Soc Dyers Finishers 2000, 12, 53.
12. Lee, Y. H.; Kim, H. D. Fibers Polym 2004, 5, 303.
13. Vankar, P. S.; Shanker, R.; Verma, A. J Cleaner Production 2007, 15, 1441.
14. Vankar, P. S.; Shanker, R.; Mahanta, D.; Tiwari, S. C. Dyes Pigments 2008, 76, 207.
15. Parvinzadeh, M. Enzyme Microb Technol 2007, 40, 1719.
16. Washino, Y. Functional Fibers; Toray Research Center Inc.: Japan, 1993; p 216.
17. Lee, Y. H. J Appl Polym Sci 2007, 103, 251.
18. Hwang, E. K.; Lee, Y. H.; Kim, H. D. J Korean Soc Dyers Finishers 2007, 19, 12.
19. Hwang, E. K.; Lee, Y. H.; Kim, H. D. Fibers Polym 2008, 9, 334.
20. http://www.alric.org/fplant.
21. Pouchert, C. J. The Aldrich Library of FTIR Spectra; Aldrich Chemical Company, Inc.: USA, 1989; Vol. 2, 1070B, 95A.
22. Vickerstaff, T. The Physical Chemistry of Dyeing; Oliver and Boyd: London, 1954; p 346.