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Natural Dyeing of Cotton and Silk with Red Pigment Extract from Safflower

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Abstract

Natural dyeing is an eco-friendly and non-toxic. And it has the various functional properties. Obangsaek refers to the five colors such as blue, red, white, black, and yellow as a unique color of Korean nation. Obanggansaek is additional five colors which mixed together the five colors of the Obangsaek. The final aim of this study is to develop cultural crafted products using functional fabric dyed in Obangsaek and Obanggansaek using natural materials. For the purpose, in this study, surface color measurement, the fastness, UV-protection, deodorization, and antimicrobial activity of the cotton and silk dyed with red pigment extract from safflower was done. The results were as follows. All of the dyed cotton and silk showed the brightness of the middle. The dyed cotton tinged red with blue. The dyed silk appeared yellowish red. Chroma of the dyed cotton and silk was very low as 2.2. All of the dyed cotton and silk appeared a grade 4 to 5 in dry cleaning fastness. Cotton was better than silk in rub fastness. Also in acidity perspiration fastness, cotton was better than silk. Acidity perspiration fastness was better than alkalinity perspiration fastness in all of the cotton and silk dyed. Cotton was better than silk in functionality such as UV-protection, deodorization, and antimicrobial activity.

Keywords: *Safflower, Red pigment, Natural dyeing, Fastness, UV protection, Deodorization, Antimicrobial activity*

1. Introduction

With the public awareness of eco-safety and health concerns, environmentally friendly and non-toxic bioresource products are regaining popularity in different fields of our lives. Natural dyes obtained from plants, insects/animals and minerals, are renewable and sustainable bioresource products with minimum environmental impact and known since antiquity for their use, not only as food ingredients [1] and cosmetics [2] but also in textile colouration [3]. At the beginning of the twentieth century and with the development of synthetic dyes that led to more complete level of quality and more reproducible techniques of application, the use of natural colorants slumped sharply. However, the application of a number of synthetic dyes has detrimental effects on environment and associated allergic, toxic, carcinogenic, harmful responses. For these reasons, many countries have imposed stringent environmental standards [4]. Natural dyes/colorants derived from flora and fauna are believed to be an eco-friendly, safe and viable substitute to synthetic colorants because of their non-toxic, non-carcinogenic and biodegradable nature [5-6]. Moreover, natural dyes do not cause pollution and waste water problems. As per present trend of meeting peoples demand keeping in view ecological concerns of synthetic colorants, natural dyes are used for textile functional treatments with antimicrobial, UV-protection, de-odorizing, anti-allergic, anti-feedants, fluorescence and some other functional finishing properties [7-13]. Therefore, constantly increasing demand and new source of natural dyes are to be explored suitably and systematically for sustainable coloration of synthetic and natural textile material. Color image is a measure

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of a society's culture and citizenship. *Obangsaek* is a unique color of Korean nation. It refers to the five basic colors (blue, red, white, black, and yellow) which is pure without mixing by yin yang. Also additional five colors which mixed together the five colors of the *Obangsaek* is called *Obanggansaek* [14]. Obangsaek is Korea's own color culture. This study is to develop cultural crafted products using functional fabric dyed in *Obangsaek* and *Obanggansaek* using natural materials. As a part, in this study, it was reviewed and studied on the fastness, UV-protection, deodorization, and antimicrobial activity of cotton and silk dyed with red pigment extract from safflower.

2. Theoretical Background

2.1. Safflower

Safflower, the corolla from *Carthamus tinctorius* L. (Asteraceae) is used as a natural pigment, food additive, and cosmetic. Also, it is widely used as traditional medicine for cardiovascular diseases [15-16]. Safflower (*Carthamus tinctorius* L.), which is an annual plant of chrysanthemum, contains yellow and red pigments (carthamin) in its petal. The safflower pigments have been traditionally used in cloth dyeing and natural cosmetic material as early as 4500 BC. Currently, the yellow pigment (water-soluble) are utilized as a natural yellow food colorant in rice, bread, candy, jelly, and beverage, whereas the red pigment (water-insoluble) has been mainly used as a cloth dyeing [17-18]. According to Saito (1990), the major principle of the cloth dyeing using the red pigment is based on the specific and strong adsorbability of primary alcoholic hydroxyl group on glucose in carthamin to cellulose. Carthamin is the major red pigment in safflower and it has antioxidant activity [19-20]. The basic structure of those pigments is a C-glucosyl quinochalcone [21-22]. However, carthamin is very unstable in an aqueous solution. It is usually extracted with an alkaline solution, but the red colour fades progressively to reddish orange, orange-yellow, yellow and light yellow [23-20]. Carthamin has been reported to be more stable under alkaline than under acid and neutral conditions [24]. But it degrades rapidly when heated, having a half life, under alkaline conditions, of 12.5 h at 25°C and 0.75 h at 60°C [25].

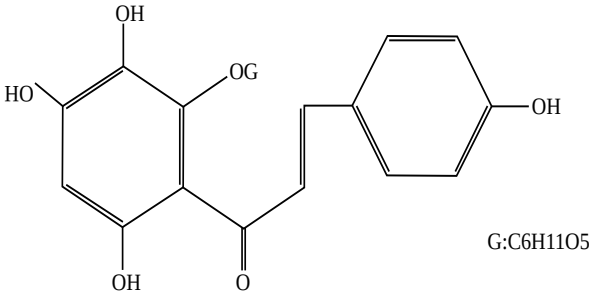

Figure 1. Chemical Structure of Carthamin Contained in Safflower and Image of Safflower [26]

3. Experimental Materials and Methods

3.1. Experimental Materials

Fabrics: Fabrics used in this study were purchased from Testfabrics Inc. (West Pittston, PA)., and the characteristics are as shown on the Table 1.

Table 1. The Characteristics of Cotton and Silk

Fabric	Weave	Fabric Counts (Threads/in.)		Weight (g/m^2)
Cotton	Plain	29.5	26.8	100
Silk	Plain	56	39	26

Safflower: Safflower was purchased from a local market in Korea.

3.2. Experimental Methods

The extraction treatment of safflower: The ground safflower petals were washed with water to remove yellow pigments, which are water-soluble from safflower for twenty-four hours. The washed safflower petals were added to ten volumes(V/W) of 0.1 N potassium carbonate solution(K2CO3) to extract safflower red pigments, which are solubilized in alkali condition, and stirred for twenty-four hours. The extract solution was adjusted with 0.1 M acetic acid solution until pH 5.5-5.7 to red color of expression.

Dyeing: Before the application of dyeing, cottons ands silk were soaked in water. Cottons and silks were dyed in liquor ratio of 1:30 at room temperature for 20 minutes with constant stirring. Then the samples were washed with cold water (Three repetitions), squeezed and dried at room temperature.

Color Measurement: The color of cotton and silk dyed was recorded the Munsell color system of H V/C and the CIE L*, a*, and b* at 2 degrees from view by light sources C using UV-VIS spectrophotometer with integrating sphere. H describes hue; V measures value; C measures chroma in the Munsell color system. L* corresponding to the brightness (100 = white, 0 = black), a* to the red-green coordinate (+ve = red, -ve = green) and b* to the yellow-blue coordinate (+ve = yellow, -ve = blue)[26].

Color Fastness Tests: The light fastness of cotton and silk dyed was carried by KS K ISO B02:2005. The dry cleaning fastness was measured by KS K ISO 105 D01:2010, specification. The dry and wet rub fastness was tested by KS K ISO 0650:2011. The perspiration fastness was examined by KS K ISO 105E04:2010.

UV protection factor: UV-protection factor was tested using UV-Vis spectrophotometer (Varian Cary 5000) by the KS K 0850:2014. Transmission measurements were made in 290-400㎚ range with a 1㎚ step.

Deodorization activity: Deodorization activity was measured by deodorization rate (%) into time zones (30min., 60min., 90min., and 120min.) in test environment of 24 degrees temperature and 28% humidity according to gas detecting tube method.

Antimicrobial Activity: The antimicrobial ability of cotton and silk dyed was tested using S*taphylococcus aureus*(AATCC 6538) and *Klebsiella pneumonia*(AATCC 4352) cultures, according to an established protocol to test the antibacterial of textiles (KS K 0693). Antimicrobial activity was showed by reduction bacteria (%).

4. Results

4.1. Surface Color

The surface colors of the cotton and silk dyed with safflower red extract were investigated by the Munsell color system and CIE L*, a*, b* as shown in Table 2. L* of the dyed cotton and silk was 56.20 and 58.19, respectively and H of the dyed cotton and silk was 5.4 and 5.7, respectively. These results suggested that the cotton and silk dyed with safflower red extract showed the brightness of the middle. The dyed cotton appeared highly positive a* (37.53) but slight negative b* (-0.13), which means that it tinges red with blue. The dyed silk appeared highly positive a* (43.79) but slight positive b* (1.98),

which means that it tinges yellowish red. Chroma of the dyed cotton and silk was equal as 2.2 and seemed to be desaturated.

Table 2. Surface Colors of the Cotton and Silk Dyed

	Munsell			CIE		
	H	V	C	L^*	a^*	b^*
Cotton	7.0P	5.4	2.2	56.20	37.53	-0.13
Silk	2.6P	5.7	2.2	58.19	43.79	1.98

4.2. Fastness Properties

Fastness properties of the cotton and silk dyed were appeared in Table 3. As can be seen from Table 3, all the dyed cotton and silk revealed a grade 4 to 5 in the case of the discoloration and contamination of dry cleaning fastness. In the case of dry rub of rub fastness, cotton appeared a grade 4 to 5 and silk revealed a 4 grade. Also in wet fastness, cotton showed a 4 grade and silk appeared a 3 grade. These results suggest that dry rub fastness was better than wet rub fastness in all of the cotton and silk dyed, and cotton was better than silk. Cotton appeared a grade 3 to 4 and silk revealed a 3 grade in the case of the discoloration and contamination on acidity perspiration of perspiration fastness. The discoloration and contamination on alkalinity perspiration appeared a grade 2 to 3 in all of the cotton and silk dyed. All of the dyed cotton and silk revealed lowly into 1 grade in light fastness.

Table 3. Fastness Properties of the Cotton and Silk Dyed

Dyeing Fastness			Grade	
			Cotton	Silk
Light Fastness			1	1
Dry Cleaning Fastness	Discoloration		4~5	4~5
	Solvent Contamination		4~5	4~5
Rub Fastness	Dry		4~5	4
	Wet		4	3
Perspiration Fastness	Acidity	Discoloration	3~4	3
		Contamination(Cotton)	3~4	3
		Contamination(Silk)	3~4	-
	Alkalinity	Discoloration	2~3	2~3
		Contamination(Cotton)	3	3
		Contamination(Silk)	3	-

4.3. UV Protection Rate

UV protection rate of the cotton and silk dyed was provided by SPF (Sun protection Factor). Australia/New Zealand is adopted the most widely among the current classification system. According to this standard, SPF is classified in three categories: SPF of 15 to 24 (ratings 15 and 20) offer good protection; SPF of 25 to 39 (ratings 25, 30 and 35), very good protection; and SPF of 40 and higher (ratings 40, 45, 50 and 50+), excellent protection. Fabrics with a SPF of less than 15 are not labelled. [27]. SPF of the dyed cotton was 39.2. The dyed cotton was found to represent very good protection effect through the result. Whereas SPF of the dyed silk was 11.1. This result suggests that the dyed silk was found to represent insufficient protection. Also cotton revealed protection rate of 97.0% against UV-A and 97.5% against UV-B. In contrast silk showed protection rate of 88.8% against UV-A and 92.0% against UV-B. From the above results, it was recognized that cotton has an excellent UV protection effect than silk. And it was found

that protection rate against UV-B was higher than that against UV-A in all of the dyed cotton and silk.

Table 4. UV Protection Rate of the Cotton and Silk Dyed

	Sun Protection Factor		UV Protection Rate (%)	
	SPF	Range	UV-A	UV-B
Cotton	39.2	30	97.0	97.5
Silk	11.1	10	88.8	92.0

4.4. Deodorization Activity

Measurement results on deodorization activity of the cotton and silk dyed were shown in Table 5. As shown in Table 5, cotton appeared more than 99% high deodorization regardless of the passage of time. Deodorization activity of silk was improved from 90% to 98% with passage of time from 30 minutes to 120 minutes.

Table 5. Deodorization Activity of the Cotton and Silk Dyed

		Deodorization Activity (%)
Cotton	30 min.	Over 99
	60 min.	Over 99
	90 min.	Over 99
	120 min.	Over 99
Silk	30 min.	90
	60 min.	94
	90 min.	96
	120 min.	98

4.5. Antimicrobial Activity

The reduction of bacteria on *Staphylococcus aureus* and *Klebsiella pneumonia* was appeared in Table 6, Figure 2 and Figure 3, to evaluate antimicrobial activity of the cotton and silk dyed. As shown in Table 6, cotton appeared very high bacteriostatic reduction of more than 99.9% against *Staphylococcus aureus* and *Klebsiella pneumonia*. Whereas silk showed a high bacteriostatic reduction of 93.9% against Staphylococcus aureus but a low bacteriostatic reduction of 46.8% against *Klebsiella pneumonia*. From the above results, it was found that all of the dyed cotton and silk had a high bacteriostatic reduction against *Staphylococcus aureus* and cotton also had excellent bacteriostatic reduction against *Klebsiella pneumonia*.

Table 6. Antimicrobial Properties of the Cotton and Silk Dyed

	Reduction of Bacteria (%)	
	Staphylococcus aureus	*Klebsiella pneumoniae*
Cotton	>99.9	>99.9
Silk	93.9	46.8

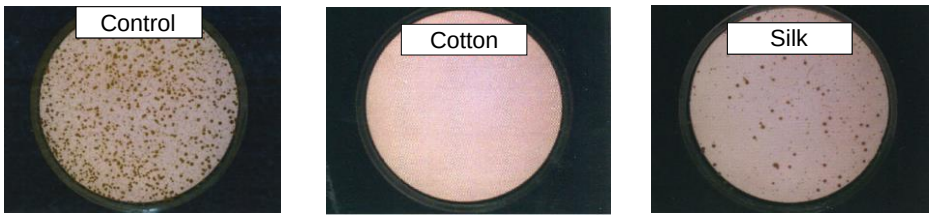

Figure 2. Antimicrobial Activity of the Cotton and Silk Dyed on Staphylococcus Aureus

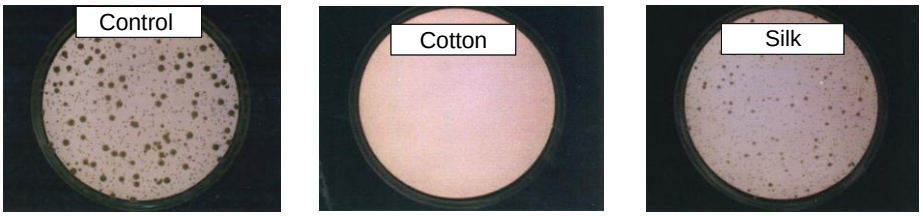

Figure 3. Antimicrobial Activity of the Cotton and Silk Dyed on Klebsiella Pneumonia

5. Conclusion

To development cultural crafted products using functional fabrics dyed in *Obangsaek* and *Obanggansaek* by natural dyeing, first in this research, the study on the fastness, UV-protection, deodorization, and antimicrobial activity of cotton and silk dyed with red pigment's extract from safflower was done. The results were as follows.

Firstly, all of the dyed cotton and silk appeared the brightness of the medium. The dyed cotton tinged red with blue. The dyed silk appeared yellowish red. Chroma of the dyed cotton and silk was very low.

Secondly, all of the dyed cotton and silk appeared excellently in grade 4 to 5 in the case of the discoloration and contamination of dry cleaning fastness. Dry rub fastness was better than wet rub fastness in all of the cotton and silk dyed, and cotton was better than silk in the case of rub fastness. Cotton was better than silk in the case of acidity perspiration of perspiration fastness. Acidity perspiration was better than alkalinity in all of the dyed cotton and silk in the case of perspiration fastness.

Thirdly, cotton had excellent UV protection effect than silk. In deodorization activity, cotton appeared more than 99% high deodorization regardless of the passage of time. Deodorization activity of silk was improved from 90% to 98% in process of time from 30 minutes to 120 minutes. In antimicrobial activity, cotton appeared a very high bacteriostatic reduction of more than 99.9% against *Staphylococcus aureus* and *Klebsiella pneumonia*. Whereas silk showed a high bacteriostatic reduction of 93.9% against *Staphylococcus aureus* but a low bacteriostatic reduction of 46.8% against *Klebsiella pneumonia*.

Acknowledgments

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