Study of Enhancing Dye Affinity of Fabric using Microwave

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Abstract

Of all the ways that energy is consumed within textile industry, few are as high energy-expending as dyeing process. The energy consumption in dyeing process amounts to 77% of total fuel consumption, 54% of total electricity use. A technical development in terms of efficient saving energy and time as well is required in the process of dyeing textiles. Recently, dyeing experts are investigating new technologies can conserve energy grafting into microwaves, radio waves, infrared lights, etc. Dyeing industry in Korea, however, the research related to energy conservation has been rarely conducted. Accordingly, this study aims to examine the possibility where especially microwaves could be applied to reduce the energy use and enhance dyeing process skill. This study performs the experiment in which microwave is employed as heating condition in dyeing and figures out as color yield being promoted, bathochromic effect would be achieved. Applying microwaves in dyeing process is expected to lower the carbon emission, energy and time wasted, ultimately exalt economic efficiency.

Key words : microwave, dyeing, bathochromic effect.

Ⅰ. Introduction

In developed countries, more energy efficient dyeing technique using microwave as heat source is having been developed (Lim, 2004). In Japan, facilities and processing techniques that use microwave to Continuous Reduced polyester fabric is being utilized (Jo, 2002). Therefore, it is required that Korea should apply more eco-friendly dyeing technique using electromagnetic waves like microwave, radiowave, inflared light rather than conventional way of using gas and fossil fuel as heat source. The purpose of this study is to compare microwave with hot plate in terms of dye affinity and heat consumption to determine more energy efficient heat source in dyeing process.

If microwave is used as heating source in dyeing process, it would shorten the processing time and reduce carbon dioxide and hydrochlorofluoride emissions caused by gas and fossil fuel use so that dyeing process could be less energy consuming and more environment-friendly than conventional method. In addition, it is expected that vibration from microwave would enhance color absorption and deep color absorption on the specimens.

Ⅱ. Material and Method

1. Material

1) Specimen Fabric

100% cotton and 100% silk was used in this experiment as specimens and displays properties

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〈Table 1〉 Properties of Fabrics

Fabric	Weave Structure	Density Warp×Weft (inch^2)	Weight (g/m^2)	Thickness (mm)
Cotton 100%	Plain	74×68	125.0	0.29
Silk 100%	Plain	136×104	50.0	0.01

described in 〈Table 1〉.

2) Dye

Direct dyestuff Omega Cotton Art Dye 127 and acid dyestuff Omega Silk Art Dye 227, which are Red Color dyes manufactured by Omega, was used for the experiment as 〈Table 2〉.

3) Heating Equipment

For the comparison of energy efficiency, microwave and pre-heated hot plate, which has different rated power consumption are used.

Heating source displays properties as In 〈Table 3〉.

2. Methods

1) Dyeing Method

Fabric specimens used in the experiment are 100% cotton 30cm×30cm swatch and 100% silk 30cm×30cm swatch. Concentration of the dye is 8% o.w.f and constant throughout the experiment. Bath ratio 1:30 is determined based on the weight of the specimen. Heating sources were microwave and hot plate with a different level of energy consumption Dye affinity was compared depending on the heat source and the length of time i.e. 3min, 6min and 9min.

〈Table 2〉 Used Dye Stuffs

Color	Name
Red	Omega Cotton Art Dye 127
	Omega Silk Art Dye 227

〈Table 3〉 Properties of Microwave and Hot Plate

Microwave	Heating Source	Hot Plate
AC 220v	Voltage	AC 220v
60Hz	Rated Frequency	60Hz
1,050W	Power Consumption	1,300W
LG electronics	Manufacturer	Winikoff
MS-342MV	Model Name	KAH-2007

(1) Dyeing

In order to achieve deep color on the cotton fabric, dyeing fluid was made with distilled water, direct dyestuff 8% o.w.f and sodium sulfate (Na_2SO_4) 30% o.w.f and was heated to 40 degrees centigrade at the condition of bath ratio 1:30.

To achieve deep color on the silk fabric, dyeing solution was made with distilled water, acid dyestuff 8% o.w.f and acetic acid 3% o.w.f, and was heated to 40 degrees centigrade at the condition of bath ratio 1:30 based on specimen weight.

Specimens were soaked in distilled water for 5 minutes, (moisture regain) was adjusted to 250% and then dyed gradually in 40 degrees centigrade for 3 min, 6 min and 9 min, respectively.

Specimen was put in the heat resistant container and was heated in the microwave. When using hot plate, specimen was stirred with glass rod. After dyeing for 3 min, 6 min and 9 min respectively, the specimen was recovered with the glass rod. Then, the specimens were washed and dried to wet pick-up rate of 250%. Specimen was air-dried for 24 hours at room temperature.

2) Chromaticity Measurement

Chromaticity of dyed fabric was defined as CIE L*a*b* Color Index in accordance with KS A 0066 standard and as Munsell Color Index in accordance with KS A 0062 standard. L*, a*, B* was measured with UV-VIS-NIR Spectrophotometer Varian, Cary 5000 at CIE-D65 and light source 10 degrees visual field. The measurements were used to derive H. V/C of Munsell Color Index.

3) Color Fastness

Test methodology for color fastness is deter-

mined by Korean Industrial Standard (Kang, 2001).

In this study, degree of soiling of white fabric attached to the specimen was separately determined with two parameters, which are washing fastness and soil.

Ⅲ. Results and Discussion

1. Dye Affinity

1) Change of Properties in Specimen

After dyeing cotton fabric for 3 min, 6 min and 9 min respectively, thickness, density and weight of the fabric was measured to see how the properties of cotton was changed. 〈Table 4〉 shows the change of properties in cotton according to length of dyeing time.

〈Table 5〉 shows the change of properties in silk according to the length of dyeing time.

2) Color

(1) Cotton

〈Table 6〉 summarizes CIE L*a*b* values and Munsell values of the cotton.

In cotton, L* showed deep color in fabric dyed using microwave as heat source. L* value decreased as dyeing time increased. In terms of

〈Table 4〉 Change of Properties of Cotton according to the Length of Dyeing Time

Cotton	Thickness (mm)		Density (Threads/5cm)				Weight (g/30cm^2)	
Heat / Time	Microwave	Hot Plate	Microwave	Hot Plate	Microwave	Hot Plate	Microwave	Hot Plate
3 min	0.42	0.40	82	80	78	78	10.50	10.52
6 min	0.41	0.41	80	80	77	77	10.52	10.56
9 min	0.40	0.41	80	80	77	76	10.54	10.54

〈Table 5〉 Change of Properties of Silk according to the Length of Dyeing Time

Silk	Thickness (mm)		Density (Threads/5cm)				Weight (g/30cm^2)	
Heat / Time	Microwave	Hot Plate	Microwave	Hot Plate	Microwave	Hot Plate	Microwave	Hot Plate
3 min	0.155	0.150	192	188	113	110	4.62	4.48
6 min	0.155	0.155	194	188	115	110	4.68	4.71
9 min	0.155	0.155	194	190	115	114	4.70	4.71

〈Table 6〉 CIE L*a*b* Values/Munsell Values of Cotton

	Time	Heat	CIE L*a*b*			Munsell	
			L*	a*	b*	H	V/C
Cotton	3 min	Microwave	37.53	48.66	13.42	2.29R	3.7/10.8
		Hot Plate	38.02	48.54	12.93	2.10R	3.7/10.8
	6 min	Microwave	35.09	46.10	12.74	2.40R	3.4/10.1
		Hot Plate	35.31	46.32	12.81	2.41R	3.4/10.1
	9 min	Microwave	33.71	44.93	12.72	2.57R	3.3/ 9.7
		Hot Plate	34.79	45.72	12.69	2.42R	3.4/10.0

a* and b* values, a* and b* value of dyed specimen using microwave were lower than when hot plate was used and was interpreted as lower chroma (L*) and deep color. The fabric dyed using microwave as heat source was measured as deep color according to L*, a* and b* as parameter. Characters of material and color index were lower between 6 min to 9 min than 3 min to 6 min. It is considered that high heat might lead to transition in water molecules and dye molecules which hindered the penetration of the color into the fabric.

(2) Silk

〈Table 7〉 summarizes CIE L*a*b* values and Munsell values of the silk.

In silk, deep color was measured in the silk fabric dyed using microwave as heat source. L* value showed deep color effect, as dyeing time increased, suggesting increase in amount of dye bonding in the non-crystallized area of the fabric. As with the cotton, stirring the specimen with the glass rod may have enhanced dye affinity when using hot plate as heat source.

In silk, the fabric dyed using microwave as the heat source was measured to have deep color in 3 min, 6 min and 9 min. L* value difference in silk by using different heat source was larger than cotton. Hue (R) was measured higher in silk than in cotton. This phenomenon may be explained by the fibroin in the silk that contains activating group such as amino group, carboxyl group and hydroxyl group that can form bond and dye site with dyestuff.

2. Assessment of Color Fastness

1) Washing Fastness

Washing fastness is determined on the scale of 1 to 5. 〈Table 8〉 shows washing fastness of test result shows low washing fastness and degree of soiling regardless of heat source and dyeing time. The reason why the attached white cotton fabric showed low soiling level of 1 to 2 is because of plant-based direct dyestuff which has high dye affinity on cotton. In addition, it is thought that dye on the cotton fabric stained attached white fabric during the experiment.

〈Table 9〉 shows washing fastness of silk. When microwave was used as heat source, test result showed washing fastness at level 3-4 regardless of length of dyeing time. In case of hot plate, washing fastness increased as length of dyeing time increased. For example, 3 minutes of dyeing time achieved grade 1 washing fastness while

〈Table 8〉 Washing Fastness of Cotton

Time	Heat	Washing Fastness (Grade)	Soiling (Grade)	
			Cotton	Wool
3 min	Microwave	2-3	1-2	4-5
	Hot Plate	2-3	1-2	4-5
6 min	Microwave	2-3	1-2	4-5
	Hot Plate	2-3	1-2	4-5
9 min	Microwave	2-3	1-2	4-5
	Hot Plate	2-3	1-2	4-5

〈Table 7〉 CIE L*a*b* Values/Munsell Values of Silk

	Time	Heat	CIE L*a*b*			Munsell	
			L*	a*	b*	H	V/C
Silk	3 min	Microwave	42.83	61.40	26.86	4.22R	4.2/14.4
		Hot Plate	46.53	60.60	21.67	3.11R	4.5/14.2
	6 min	Microwave	39.82	59.57	32.71	5.67R	3.9/14.1
		Hot Plate	43.19	60.11	25.96	4.14R	4.2/14.1
	9 min	Microwave	37.16	58.83	33.77	6.23R	3.6/13.8
		Hot Plate	40.40	60.02	30.35	5.08R	3.9/14.1

〈Table 9〉 Washing Fastness of Cotton

Time	Heat	Washing Fastness (Grade)	Soiling (Grade)	
			Cotton	Silk
3 min	Microwave	3-4	4-5	4-5
	Hot Plate	1	4-5	4-5
6 min	Microwave	3-4	4-5	4-5
	Hot Plate	2-3	4-5	4-5
9 min	Microwave	3-4	4-5	4-5
	Hot Plate	4	4-5	4-5

6 minutes got at level 2-3 and 9 minutes at grade 4, respectively. Soiling test result shows high washing fastness and stain at grade 4-5 for both cotton and silk regardless of heat source and length of dyeing time.

Washing fastness of silk is at level 3-4 when dyed for 3 min in the microwave. To achieve the same level of washing fastness using hot plate, length of dyeing time needed to be more than 6 min. Test result shows dyeing process using microwave would shorten the dyeing time and is therefore less energy consuming silk has higher level of soiling than cotton and is at grade 4-5 of soiling.

2) Light Fastness

〈Table 10〉 shows light fastness. In cotton, light fastness was consistent regardless of heat source and length of dyeing time. In case of silk, test result shows light fastness at grade 2-3 in the fabrics dyed for 3 min and 6 min using hot plate. Light fastness of cotton is at grade 3 when dyed for 9 min using hot plate. And the same level of light fastness was witnessed in the cotton when dyed for 3 min, 6 min and 9 min in the microwave. In case of silk, 9 minutes of dyeing using hot plate was equivalent to 3 minutes of dyeing in the microwave.

〈Table 10〉 Light Fastness of Cotton and Silk

Time	Heat	Cotton	Silk
3 min	Microwave	3	3
	Hot Plate	3	2-3
6 min	Microwave	3	3
	Hot Plate	3	2-3
9 min	Microwave	3	3
	Hot Plate	3	3

Ⅳ. Conclusion

This study shows that better deep color effect and color was obtained with microwave than with hot plate. Difference in light fastness, washing fastness and chromaticity all stem from the difference in heating source, fabric structure, degree of crystalline and properties of the cotton and silk. Dyeing method which cater to the characteristics of microwave needs to be developed based on the further research about optimal dyeing condition (dye, dye concentration, dyeing time, dyeing process) considering unique properties of different fabrics. More extensive and further research on dyeing technique using microwave is strongly required so that dyeing process could be more energy efficient and eco-friendly by reducing carbon emission.

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