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Analysis of Physical/Mechanical Properties and Color of Bast Fiber Fabrics Dyed using *Rubia akane Nakai*

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Abstract

The fashion industry saw the emergence of environment-friendly and natural fabric materials recently. The naturalism trend has established sectors in the textile and fashion industry also. Ramie and hemp have long been favored fabric materials in Korea especially for summer.

The hand-related mechanical/physical properties of the fabric specimens were analyzed using a fabric objective measurement system, KES(Kawabata Evaluation System). Subjective evaluation was also implemented based on a series of selected adjectives. Studies on natural dyeing methods are important since the establishment of scientific approach is needed in terms of environment and human safety along with the reproduction of traditional natural dyeing methods. In this study, linen, ramie, hemp, and cotton/polyester/linen union fabric specimens were used for the natural dyeing using *Rubia akane Nakai* with the mordant of gallnut. ΔE values of dyed fabric specimens, mordanted and dyed once using *Rubia akane Nakai*, increased significantly compared to those of repeatedly dyed fabric specimens without mordanting.

Key Words : *Rubia akane Nakai*, gallnut, bast fiber, hand value, surface

I. Introduction

The current naturalism trends have been growing in the fashion and textile industry sectors. Great emphasis on the environment -friendliness, health, and sustainability has also been placed in the industry-wide management policies. Thus the naturalism trends, along with Lohas(Lifestyle of health and sustainability), cast light on the ramie, linen, and hemp originating from plants. Most of the fabrics from these natural cellulosic fibers exhibit some irregularities, yarn unevenness or dyeing irregularities, due to the processes for yarn production or weaving.

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However, this unique irregularity is rather a good product characteristics, if the fabrics are employed in a naturalism fashion product appropriately, contrary to the general fact that good evenness is interpreted as good product quality in a mass-production oriented industry sector.[1)]

The Kawabata Evaluation System (KES) has been developed to make objective measurements of hand-related properties of textile fabrics. The KES measures mechanical and physical properties that explain subtle deformation of fabrics during hand manipulation. The data obtained using the KES may be interpreted using translational equations and related to the tactile responses to the texture, softness, smoothness, and other hand properties of fabric materials. Human panel evaluations may further be utilized for engineering the target hand qualities for fabrics.

The human panel evaluation procedure aims to obtain the subjective response of subjects while they touch, squeeze, or rub specimens of the textile fabrics.

Bast fiber is a fiber obtained from the bark of plant stem, which is known as first fiber humans developed and used since clothing living had begun. Bast fiber currently used for clothing fabric includes the kinds of linen, ramie, and hemp. In our country and other East Asian countries, bast fabric has been used for several thousand years. Bast fabric is superior in moisture absorption, moisture discharging, and quick drying with cool feel. Therefore it is popular for summer textile use. And as it is stiff and does not stick to body surface with coarse tactile sensation, it gives cool feel to the touch, which seems to be well suited to Korean's needs.

As 21st century consumers' sensibility changes to be highly sensitive, desire to express differentiated sensibility for selection of clothing increases and importance of tactile sensation of texture including hand value is emerging greatly. In addition, recent naturalism draws popularity in fashion trend changes in pursuit of convenience, functionality, practicability, which leads to rising interest on the expression of color for clothing materials made of natural fabric, which is eco-friendly, superior in body-consciousness, and dyed using natural dyestuff.

Accordingly, this study is intended to give help to harmonious application between fabrics made of bast fibers by identifying color difference between linen, ramie, hemp, cotton/polyester/ linen union fabric through gallnut mordanting on *Rubia akane Nakai*, red natural dye usually used in our country, and by comparing not only physical functions of mechanical performance and surface characteristic through objective measurement of factors determining hand value, but also aesthetic aspects based on subjective evaluation procedure.

II. Experimentals

1. Fabric Specimens

As fabric specimens for this study, commercially available spun ramie fabric, ramie fabric, hemp fabric, linen fabric, and cotton/ polyester/linen union fabric were purchased. The weave of the fabric specimens were all plain weave.

Characteristics of each sample is described <Table 1>.

2. Mordant and reagent

Dry domestic *Rubia akane Nakai*(Rubia Cordifolia) and dry gallnut were purchased from oriental drug stores were used.

<Table 1> Characteristics of fabric specimens

Fabric	Fiber (%)		Fabric Count (thread/5cm)		Weight (g/㎡)	Thickness(㎜)
	Warp	Weft	Warp	Weft		
14lea linen	linen (100)	linen (100)	64.4	47.0	122.8	0.73
40lea linen	linen (100)	linen (100)	115.4	89.4	164.6	0.63
cotton/polyester/ linen	cotton/polyester(35/65)	linen/polyester (40/60)	270.4	139.6	140.9	0.61
spun ramie	ramie (100)	ramie (100)	129.4	114.0	132.4	0.65
ramie	ramie (100)	ramie (100)	101.4	90.4	129.7	0.56
hemp	hemp (100)	hemp (100)	69.6	60.4	144.0	0.89

Alum($KAl(SO_4)_2 \cdot 12H_2O$) was used as reagent for mordant. For adjustment of pH while extracting *Rubia akane Nakai*, acetic acid(CH_3COOH) was used.

3. Test method

1) Comparison of evenness

Evenness of fabric specimens dyed with gallnut was analyzed objectively after obtaining images of fabric specimens. Calculation of CV(%) is based on standard deviation and average value of the pixel intensity values of the gray scale image of the specimen.

$$CV(\%) = \frac{Std.Dev.}{Average} \times 100$$

2) Objective evaluation (KES testing)

Faberic specimen size of 20×20㎝ was prepared for the. Tensile, bending, compression, shear, surface properties were measured using KES(Kawabata Evaluation System)-FB system.

3) Extraction of *Rubia akane Nakai* dye liquor

To extract color from *Rubia akane Nakai* dye liquor, 100g of *Rubia akane Nakai* was poured into a water bath of 4ℓ of water. The bath was left for one day in room temperature. Then, red color was extracted from the slices of the *Rubia akane Nakai,* which was put into another beaker containing water at 80℃. Acetic acid solution was used to reach pH4.

4) Extraction of gallnut extract

For extraction of gallnut to be used as mordant, 100g of gallnut was put into 1ℓ water. The liquor was extracted 3 times for 20 minutes from 80℃ water.

5) Mordanting

Gallnut mordanting was conducted for 20 minutes at 40℃ with liquor ratio 1:10, and then alum mordanting was conducted for 20 minutes at 60℃ with 1%(o.w.f.), liquor ratio 1:50.

6) *Rubia akane Nakai* dyeing

To survey efficiency of dyeing according to gallnut and alum mordant at the time of dyeing each sample, each specimen was dyed in a beaker containing dye liquor. Extract of *Rubia*

akane Nakai was maintained at the ratio of 1:100 for 20 minutes at 70℃ with each of gallnut-mordanted, alum-mordanted sample and sample not mordanted. Mordanted sample was dyed 5 times. The color changes of the dyed specimen, resulted by repeated dyeing, were measured.

7) Measurement of surface color

For measurement of color change according to repeated dyeing procedure, Chroma-meter (CR-200, Minolta, Japan) was used to determine L^*, a^*, and b^* values.

Color difference(ΔE) between the reference specimen and the dyed specimen is calculated, based on the L^*, a^*, and b^*, as follows:

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

8) Measurement of dye uptake

For dye uptake amount calculation after dyeing, reflection percent was measured using Color-Eye 3100 Spectrophotometer (Gretag Macbeth, U.S.A.). K/S value according to Kubelka-Munk formula was calculated as below from surface reflection at maximum absorbing spectrum of dyed fabric.

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

9) Subjective evaluation

One hundred women, in their 20s~30s, participated in the survey. Questionnaire survey for total of 11 questions about their responses to the 6 types of fabric specimens was conducted.

Five score rating scheme was used. Adjectives used in questions are shown in <Table 2>. The result was analyzed using statistical analysis software packages, SPSS v12.0, and SAS

In order to simplify the subjective description of the fabric specimens, it is possible to reduce down the number of descriptors using a factor analysis.

<Table 2> List of adjectives for subjective evaluation

Questionnaire	Adjectives (1-5)
1	rough - smooth
2	coarse - soft
3	slack - dense
4	thick - thin
5	heavy - light
6	warm - cool
7	dry - wet
8	stiff - pliable
9	wrinkle-prone - not-wrinkle-prone
10	vivid - mild
11	natural - artificial

III. Results and Discussion

1. Comparison of evenness of Fabric Specimens

Trendy fabrics of 'Naturalism' are becoming one of the enticing theme fabrics in the current fashion trends. However, one of the intriguing issues related to the term 'natural' has been the evenness of the fabrics. For this purpose, images of fabrics were analyzed using an image analysis software.

The evenness of fibers or yarns is represented as CV% or U% of the mass of yarn lengthwise. In order to analyze the evenness of fabric appearance, images of specimens were acquired

using a CCD camera under specific illumination condition. The color images were converted to gray-scale images for the calculation.

The appearance of slack fabric specimen is prone to be affected by the background colors. Therefore, as a first examination method, it was needed to remove the black background using the plug-in function of 'Otsu Thresholding' under the function of 'Histogram' of the ImageJ program. In this case, the standard deviation and CV% were calculated.<Table 3> The CV% value of 14lea linen fabric was 12.3, the most irregular one, then that of hemp 12.0, and linen 11.5, while that of cotton/polyester/linen union fabric was 4.5, the least irregular one.

Second examination method was based on an as-is measurement. Considering visual examination, the black background was not removed from the images of the fabric specimens. The CV% of the 14lea linen fabric was 32.6, the most irregular one. Second most irregular one was hemp fabric with CV% of 27.7, followed by ramie fabic with 23.1. The least irregular one was cotton/polyester/linen union fabric with CV% of 8.2. In short, 14lea linen fabric is the most irregular fabric, while the cotton/polyester/linen union fabric the most regular fabric.

The level of absolute CV% was changed by the background effect, the general tendency of the CV% order was almost the same as the analysis result with removed background effect by adopting thresholding function of the histogram.

2. Result of objective evaluation of fabrics

1) Mechanical properties

Result of objective evaluation of mechanical properties measured using KES-FB is described in <Table 4>.

(1) KES tensile properties

Ramie-spun yarn fabric has larger WT and higher EM than ramie fabric. Since ramie fiber, in a filamentous form, is one of the least extensible natural plant fiber, the WT and EM values of the ramie fabric are both lower than those of the spun ramie fabric specimen. This seems to be related to the spinning process, involving combing and twisting of staple fiber strands, which imparts the staple yarns with higher bulkiness and extensibility.

<Table 3> CV% calculation result of Fabric Image
(1st method: background removed, 2nd method: background retained)

	CV%, 1st method	CV%, 2nd method
14lea linen	12.3	32.6
40lea linen	7.2	15.8
cotton/polyester/linen	4.5	8.2
spun ramie	9.9	21.5
ramie	11.5	23.1
hemp	12.0	27.7

<Table 4> The mean value of mechanical properties of test fabrics

ITEM		14lea linen	40lea linen	cotton/ polyester/ linen	spun ramie	ramie	hemp
TENS.	EM	1.78	1.63	1.28	1.16	0.61	0.82
	LT	0.704	0.851	0.691	0.651	0.787	0.753
	WT	0.34	0.35	0.23	0.19	0.12	0.16
	RT	81.57	79.78	57.78	87.59	84.62	95.51
BEND.	B	0.259	0.277	0.061	0.351	1.344	2.247
	2HB	0.1194	0.1158	0.0549	0.1177	0.7145	1.6193
SHEAR	G	0.23	0.34	1.10	0.26	0.23	0.22
	2HG	0.05	0.05	2.20	0.04	0.11	0.09
SURFACE	MIU	0.144	0.143	0.160	0.133	0.123	0.134
	MMD	0.0172	0.0178	0.0210	0.0173	0.0339	0.241
	SMD	4.88	2.33	2.67	2.22	5.57	9.94
COMP.	LC	0.362	0.497	0.536	0.482	0.491	0.554
	WC	0.060	0.074	0.061	0.081	0.05	0.057
	RC	73.33	70.43	65.73	72.00	84.24	87.50

(2) KES bending properties

In case filamentous ramie fibers were cut down to short fibers and then spun by utilizing spinning machine, due to the increased pliability, spun ramie fabric found to become remarkably pliable than ramie fabric, with its B value of 0.351 compared to 1.344 of ramie fabric.

Accordingly, when ramie-spun yarn is prepared and woven after making ramie fabric from spun yarn comprising short fiber through wet spinning as a method to adjust or control the intrinsic rigidness of ramie fabric, it is possible to provide a sensible textile fabric material whose flexibility is much improved.

Due to properties of its yarn, hemp fabric showed high bending rigidity than other samples. And it has bending rigidity value higher than ramie by about 60%.

(3) KES compression properties

Compression properties in relation to volume have influence on especially plumpness, softness, comfortableness, thermal insulation, which is explained by LC, WC and RC. As LC and Rc of hemp fabric are larger than others, it is found to be not easily compressed and has volume.

(4) KES shear properties

Cotton/polyester/linen union fabric, which has been found to be soft as a result of bending properties test, showed highest shear strength(G value) as its frictional force increases and restriction of movement between yarns due to higher density of its yarn than other samples. In case of hemp fabric, though comprising yarn's own bending properties and fabric's bending properties are high, its fabric density is relatively low and the friction between comprising yarns is low. Accordingly, as the resisting force between

comprising yarns during shear deformation is relatively low, the shear rigidity of the hemp fabric show the lowest.

(5) KES surface properties

In case of SMD, hemp fabric showed highest value. The surface is coarse. Compared to ramie fabric of which SMD is next to hemp fabric, spun ramie fabric showed lower value than ramie fabric. It is therefore found that though they are made out of almost same ramie species, they exhibit difference in smoothness, which seems to be similar to the tendency shown in the analysis result of CV% obtained from the 3-dimensional images.

2) Hand value

Three primary hand values obtained from mechanical properties measured by KES-FB system is described in <Table 5>. Higher primary hand value means that the corresponding hand feel becomes significant.

In KOSHI value, ramie fabric and hemp fabric were significantly rigid and cotton/polyester/linen union fabric was the softest. In NUMERI value, 14lea linen fabric and cotton/polyester/linen union fabric were felt very smooth, while ramie fabric showed the coarsest tactile sensation. In FUKURAMI value, 14lea fabric and spun ramie fabric showed higher values proving to be voluminous, but smooth.

In total hand value(T.H.V.) obtained from combination of primary hand value(H.V.), sample with the best T.H.V. is cotton/polyester/linen union fabric and the worst sample was found to be hemp fabric. This result is from evaluation method of Kawabata and Niwa, based on the researches for Japanese adjectives and participants. This trend seems to be somewhat different from the preference tendency toward the bast fiber fabrics used in Korea. It seems that further separate subjective researches on hand value evaluation of the bast fiber fabrics are desirable.

3. Result of subjective evaluation of fabrics

As survey respondents, one hundred subjects (women in their 20s~30s) were selected in several classes. Statistical analysis was implemented from the results of questionnaire survey for total 11 questions about their sensible preference for 6 kinds of fabric specimens.

For the two questionnaires, rough-smooth and coarse-soft, subjects responded with almost same ratings to the fabric specimens. Hemp fabrics was rated as being the scratchiest and coarsest one, while cotton/polyester/linen spun yarn union fabric as being the smoothest and softest one.

For slack-dense scale, hemp fabric was rated as being the slackest one, while cotton/polyester

<Table 5> The hand value of mechanical properties of test fabrics

ITEM		14lea linen	40lea linen	cotton/ polyester/ linen	spun ramie	ramie	hemp
H.V	KOSHI	7.47	8.01	7.14	8.17	9.17	9.37
	NUMERI	6.78	6.18	5.74	6.57	5.05	5.45
	FUKURAMIE	8.07	7.47	7.13	7.97	6.44	6.94
T.H.V		2.11	1.86	2.46	1.50	0.74	0.34

/linen spun yarn union fabric the densest one.
For thick-thin scale, hemp fabric was rated as being the thickest one, while cotton/polyester/linen spun yarn union fabric the thinnest one.

For heavy-light scale, hemp fabric was rated as being the heaviest one, while cotton/polyester/linen spun yarn union fabric the lightest one.
For warm-cool scale, cotton/polyester/linen spun yarn union fabric was rated as the warmest one, while hemp fabric the coolest one to the touch.

For dry-wet scale, hemp fabric was rated as being the driest one, while cotton/polyester/linen spun yarn union fabric the wettest one.
For stiff-pliable scale, hemp fabric was rated as being the stiffest one, while cotton/polyester/linen spun yarn union fabric the most pliable one.

For wrinkle-prone -not-wrinkle-prone scale, hemp fabric was rated as being the most wrinkle-prone one, while cotton/polyester/linen spun yarn union fabric the least wrinkle-prone fabric.

For vivid-mild scale, hemp fabric was rated as being the most vivid one, while cotton/polyester/linen spun yarn union fabric the mildest one.
For natural-artificial scale, the differences in ratings were not significant.

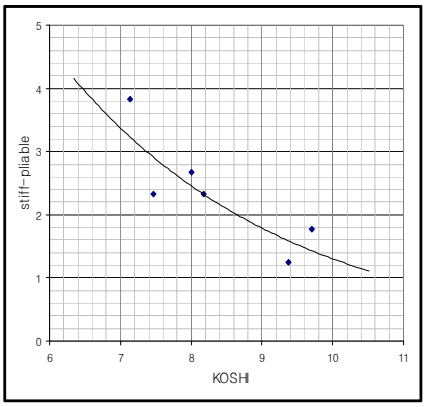
Factor analysis shows that there are three large eigenvalues, 5.31 and 1.17 for the factors, which together account for 59 percent of the standardized variance. Thus the first two factors, out of eleven, provide an adequate summary of the subjective data for most of purposes.

<Table 6> shows that Factor 1 comprises rough-smooth, coarse-soft, slack-dense, thick-thin, stiff-pliable, vivid-mild, and wrinkle-prone -not-wrinkle prone adjectives. Factor 2 comprises warm-cool, and heavy-light, and natural-artificial. Factor 1 may be titled as 'surface texture/stiffness' and Factor 2 as 'warmness' factor.

As a result of analysis of questionnaire survey for 100 persons, cotton/polyester/linen union fabric was evaluated as most pliable and hemp fabric as most stiff. This shows that high negative correlation(-0.84) exists between the result of questionnaire survey and objective analysis value by KES. <Fig. 1>

<Table 6> Factor analysis result

adjectives	Factor 1	Factor 2
rough - smooth	0.861	-0.158
coarse - soft	0.892	-0.089
slack - dense	0.807	-0.078
thick - thin	0.804	0.239
heavy - light	0.586	0.517
warm - cool	-0.366	0.636
dry - wet	0.594	-0.079
stiff - pliable	0.847	-0.004
wrinkle-prone - not-wrinkle-prone	0.654	-0.050
vivid - mild	0.705	0.082
natural - artificial	-0.063	-0.625



<Fig.1> Correlation between stiff-pliable and KOSHI

4. Effect of gallnut mordanting on *Rubia akane Nakai* dyeing and subjective color vividness

To compare mordanting effect of gallnut, color change of fabrics dyed with only *Rubia akane Nakai* not mordanted and dyed fabric processed through gallnut mordanting-alum mordanting-*Rubia akane Nakai* dyeing was investigated.

As shown in <Table 7>, ΔE value of the specimen for the case of dyeing only with *Rubia akane Nakai* not mordanted by gallnut or alum was 32.7 for 14lea linen fabric, 33.5 for 40lea linen fabric, 33.3 for cotton/polyester/linen union fabric, 30.7 for spun ramie fabric, 32.9 for ramie fabric, 26.7 for hemp fabric, which showed relatively low color difference value revealing that dye affinity for the case is not so significant. In addition, it is found that as b^* value gets very higher than a^* value, red color shifted toward yellow as a whole.

On the other hand, it is found that in samples processed through gallnut and alum mordanting, even in the case of dyeing only once, ΔE value shows remarkably high color difference compared to ΔE of the case of 4-times dyeing, which proves that tannic acid component of gallnut makes dyeing better by fixing metal chlorides. In addition, clarity is improved by repeated dyeing process, and deep and clear color is available, while it is identified that as a^* value increases, b^* value decreases, getting red color more emphasized and reducing yellow color.

For the subjective vividness rating, 'vivid-mild', hemp fabric was rated as the most vivid one, while cotton/polyester/linen was rated as the least vivid one. The correlation coefficient between 'vivid-mild' and c^* values <Table 7> was -0.95.

5. Change of dye uptake according to gallnut mordanting treatment

As shown in <Fig. 2>, for dye uptake amount according to *Rubia akane Nakai* dye of each sample processed through gallnut mordanting and alum mordanting, it is found that its K/S value was increased largely. This explains that, in this case, large amount of dye uptake takes place compared to the case of *Rubia akane Nakai* dyeing, non-mordant specimens with resultant ΔE values ranging from 26.7 to 33.5. <Table 7>

Especially, in the case of hemp, K/S value of non-mordant *Rubia akane Nakai* dyeing was 2.51, and that of mordanted *Rubia akane Nakai* dyeing was 8.06, showing significant increase of dye uptake after mordanting. This is the highest K/S value among test samples. This trend of results is in accordance with the ΔE value trend obtained from L^*, a^*, and b^* measurement.

Content of cellulose in hemp fabric is much lower than other fabrics, with its ratio of non-cellulosic materials such as pentosan and lignin is higher. This difference is supposed to be one of the reasons for high dye uptake amount.

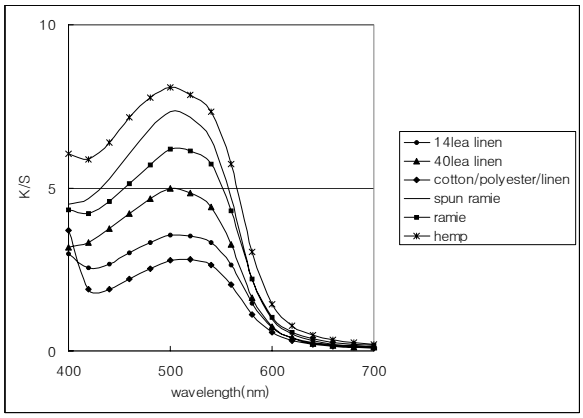
<Table 7> Color change of the fabric dyed *Rubia akane Nakai*, by various methods

mordant/dyeing \ Fabric			14lea linen	40lea linen	cotton/ polyester /linen	spun ramie	ramie	hemp
Control		L^*	90.2	93.2	90.2	90.3	88.3	79.5
		a^*	0.4	−0.2	0.3	0.0	0.1	−1.7
		b^*	2.3	4.0	1.6	3.3	3.1	17.3
Non Mordant	4th repetition of dyeing	L^*	70.9	71.6	68.6	76.1	57.7	59.1
		a^*	8.3	8.9	9.3	7.1	6.3	14.6
		b^*	27.5	29.5	25.4	29.5	13.5	22.9
		ΔE	32.7	33.5	33.3	30.7	32.9	26.7
Mordant	1st dyeing	L^*	55.6	59.0	62.3	59.4	52.8	48.2
		a^*	28.6	28.6	24.7	26.8	26.1	30.8
		b^*	22.6	24.0	20.0	23.8	21.6	26.1
		ΔE	49.0	48.9	41.4	45.7	47.7	45.9
	2nd repetition of dyeing	L^*	51.5	53.7	58.5	55.0	48.3	43.1
		a^*	32.1	32.7	27.9	30.4	33.7	35.2
		b^*	18.4	18.8	17.1	19.0	17.3	20.9
		ΔE	52.5	53.4	44.8	49.1	54.1	51.9
	3rd repetition of dyeing	L^*	49.3	51.4	56.0	50.9	45.8	40.3
		a^*	32.6	33.7	28.6	33.3	34.5	36.0
		b^*	15.9	16.8	15.0	17.0	16.8	19.7
		ΔE	53.8	55.3	46.4	53.3	56.3	54.4
	4th repetition of dyeing	L^*	48.1	49.1	54.3	50.3	44.5	37.6
		a^*	33.7	35.5	30.3	33.7	35.4	37.2
		b^*	13.8	15.3	13.9	14.4	16.5	19.2
		ΔE	54.8	57.8	48.4	53.4	57.8	57.2
		c^*	36.4	38.7	33.3	36.6	39.1	41.9
	5th repetition of dyeing	L^*	44.1	46.0	50.4	47.3	40.3	33.9
		a^*	31.8	34.0	29.7	32.9	34.7	35.4
		b^*	15.3	16.6	15.6	16.6	17.5	17.7
		ΔE	57.2	59.6	51.4	55.7	60.8	58.7

$$c^* = \sqrt{a^{*2} + b^{*2}}$$

Difference of crystallization rate and orientation distribution may also have contributed the dye uptake difference.

Cotton/polyester/linen union fabric showed the lowest dye uptake due to high crystallization and limited dye site of polyester.



<Fig. 2> The K/S value of fabrics dyed with *Rubia akane Nakai* (4 repetition of dyeing) after mordanting.

Content of cellulose in hemp fabric is much lower than other fabrics, with its ratio of non-cellulosic materials such as pentosan and lignin is higher. This difference is supposed to be one of the reasons for high dye uptake amount. Difference of crystallization rate and orientation distribution may also have contributed the dye uptake difference.

Cotton/polyester/linen union fabric showed the lowest dye uptake due to high crystallization and limited dye site of polyester.

Ⅳ. Conclusion

Fabrics made of bast fibers are known as excellent in moisture absorption, moisture discharging and cool feeling to the touch. These are popular fabric materials for summer clothing. And as these are stiffer than other fabrics and have rough surface, these were choice fabrics in hot and wet summer season in Korea for long.

In this regard, this study identified color differences among linen, ramie, hemp, cotton/ polyester/linen union fabric through natural dyeing by mordanting *Rubia akane Nakai* with gallnut, natural red dye usually used in our country and conducted evenness analysis in consideration of the possibility to link evenness in appearance of fabric to sensibility about characteristics of textile materials. And through comparing aesthetic property and preference by subjective and objective evaluation of factors determining hand value of fabrics, the following conclusion was drawn.

1. As a result of comparing evenness CV(%) value of sample fabrics, 14lea linen fabric showed the highest unevenness value, and then unevenness was in the order of hemp fabric, ramie fabric, spun ramie fabric, 40lea linen fabric, cotton/polyester/linen union fabric.

2. In KES tensile properties, spun ramie fabric was found to be more extensible and pliable than ramie fabric, and hemp fabric was found to be less compressible.

3. Based on the total hand values(T.H.V.) using Kawabata Evaluation System, it was found that the best sample was cotton/polyester/linen union fabric and that the worst sample was hemp

fabric. But this result is drawn from the evaluation method and formulae by Kawabata-Niwa made up of Japanese adjectives. It is expected to show differences with bast fabric for summer of Korea in coolness, which requires further separate subjective research on hand value evaluation. Especially it is suggested that new research in consideration of characteristics of moisture as important factor of coolness of bast fabric is necessary.

4. As a result of questionnaire survey with total 11 questions about sensible preference for 6 samples conducted by the subjects of women in 20s~30s, question 8 'stiff-pliable' showed a result relatively similar to objective evaluation. But questionnaire 'artificial-natural' showed average statistic value of about 3.5, meaning response differences among specimens were not significant.

5. When dyeing bast fabric with *Rubia akane Nakai*, ΔE values of fabric specimens processed through gallnut mordanting-alum mordanting were significantly higher than those of the fabric specimens dyed with *Rubia akane Nakai* without mordanting.

Cotton/polyester/linen union fabric showed the lowest dye uptake due to the high crystallinity and limited amount of dyeing sites of polyester molecules.

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