The Changes of Appearance Properties of Bamboo Knitted Fabric After Loess Dyeing

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Abstract : In this study, the mechanical properties related to the fabric appearance of well being functional bamboo knitted fabric before and after loess dyeing were evaluated. The mechanical properties of fabrics were measured by KES-F system, that is, shape retention, draping, wrinkle recovery, compression property, and surface properties, and total hand value of three types of knitted fabric, 100% bamboo, 100% cotton, and bamboo / cotton blend (60 / 40) were evaluated before and after loess dyeing. As a result, it was found that appearance density, shape retention, and drape coefficient of cotton knitted fabric were greater than those of bamboo knitted fabric. After loess dyeing, shape retention and drape coefficient, wrinkle recovery of bamboo knitted fabric improved and WC/C and MMD/SMD decreased. According to THV, the hand of bamboo/cotton blend knit is the best among three samples by compensation the weak properties of the two fiber. Therefore, loess dyeing seemed to be a good method for improving shape retention and hand value of 100% bamboo and bamboo blended fabric.

Key Words : bamboo, loess dyeing, knitted fabric, appearance property, total hand value

I. Introduction

Bamboo fabrics, which were made by echo-friendly fiber, have the following advantages: lightweight, good weathering ability, good design and manufacture flexibility and medium strength. Dyeing using loess, a major kind of mineral natural dye is good for human body, protects environment and is able to produce beautiful natural colors (Lee, 2003; Noh, 1999). In the previous article (Lee, 2007), the changes of mechanical properties of bamboo knitted fabric after loess dyeing were evaluated and compared with those of cotton knitted fabric and cotton / bamboo blended knitted fabric. It was found that, bamboo knitted fabrics were more flexible than cotton knitted fabrics. The crystalinity, unevenness, hairiness, coefficient of friction of bamboo yarn is lower than those of cotton. After loess dyeing, tensile strain was decreased and tensile and compression linearity, bending and shear rigidity, and coefficient of friction and surface roughness of knitted fabrics further increased. Cotton knitted fabrics showed higher value of KOSHI than bamboo knitted fabrics. Cotton knitted fabrics showed lower value of NUMERI, FUKURAMI than bamboo knitted fabrics. Therefore, it is supposed to be valuable to evaluate appearance properties of bamboo knitted fabric based on the previous mechanical properties measured by KES-F system.

Shape retention of fabric represents the changes of shape of sample after finishing, sewing, or wearing, and can be evaluated by combination value of basic mechanical properties measured by KES-F system. Kawabata (Kawabata, 1980) explained the bending recovery and drape properties with the combination of basic mechanical properties measured by KES-F

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system. Moreover, Niwa (Niwa, 1976) studied on the relationship between combination of basic mechanical properties measured by KES-F system and appearance properties evaluated from the drape property, shape retention, liveliness, and skin sensibility.

Bending rigidity (B: $g.cm^2 / cm$) of fabric is the most important property which influences on the drape and shape retention properties of cloth. It depends on fiber resilience and structure of yarn and fabric (Skelton, 1971; Owen, 1968). Bending hysteresis (2HB : mg/cm^2) of the fabric which related with the fiber viscoelastic behavior and friction between fibers and yarns, affect on the shape retention and wrinkle properties of fabric (Skelton, 1971; Niwa, 1994). As the bending rigidity decreases, draping increases but shape retention property decreases. And bending hysteresis of the fabric increases, and fabric wrinkles easily (The Quality management of Sewing Process, 2001). Furthermore, the ratio (2HB/B) of bending hysteresis to bending rigidity has high correlation with liveliness of fabric (Dawes, 1971).

Shear property is also major factor influencing on the appearance of fabric. As shear rigidity increases, draping of fabric decreases, then wearing comfort decreases. But if the shear rigidity is too low, it would cause troubles during cutting and sewing process. Shearing hysteresis (2HG) of the fabric increased, fabric was twisted and shape was corrupted.

Fabric weight is one of the important factors affecting on the appearance of fabric since the appearance was always evaluated under the gravity. Therefore, the ratio (B/W) of bending rigidity (B) to weight (W) is related to the appearance of fabric when it is draped. Low value of B/W represents low shape retention. Furthermore, the ratio (2HB/W) of bending hysteresis (2HB) to weight (W) increases, shape retention decreases and time to recover increases (Kawabata, 1973).

Draping of fabric is related not only to the fiber content, yarn properties and structure, fabric construction, but also to the viscoelastic property. The various modes of draping involve the bending, shearing, tensile, and in-plane compression (Morooka, 1978). The major factors related to the drape coefficient are bending rigidity (B) and weight (W), so bending length ($\sqrt[3]{B/W}$) and unbending length ($\sqrt{2HB/W}$) values are important to evaluate fabric shape retention properties. In the previous study (Seto, 1986), in order to evaluate formability of silhouette, drape coefficient obtained from circular specimen has been used. The relationship between draping and mechanical properties of fabrics is analyzed to correlate the drape coefficient with fabric mechanical property. As a result, it is shown that the value given by $\sqrt[3]{B / W}$ is most related with drape coefficient. When the stability of drape shape is examined, it was found that the hysteresis in shearing and bending deformation of fabric is greater, and the stability in the drape coefficient becomes decreased.

Wrinkle recovery property is also important for the care of fabric well being. Wrinkle recovery is affected by viscoelastic behavior of fiber, yarn and fabric structure, friction between fibers and yarns, and environmental factors. Instant wrinkle recovery depends on the fiber viscoelastic behavior, and equilibrium wrinkle recovery is related to the plastic properties of fiber, yarn, and fabric (Morooka, 1976; Brenner, 1964; Olofsson, 1968). Therefore, shape stability, liveliness, and drape properties of fabrics are all affected by wrinkle recovery as well as bending and shear properties (Morooka, 1977).

The purpose of this study is to evaluate the appearance properties of bamboo knitted fabric before and after loess dyeing. Mechanical properties of fabrics were measured by KES-F system, and shape retention, draping, wrinkle recovery, compression property, and surface properties, and total hand value of three types of knitted fabric, 100% bamboo, 100% cotton, and bamboo/cotton blend (60/40) were evaluated before and after loess dyeing.

II. Experimentals

1. Materials

The characteristics of used yarns were shown in

<Table 1>. Three kinds of single jersey, 100% bamboo, 100% cotton, and bamboo/cotton blend (60/40), were knitted by knitting machine (model no. : KSMJ-72V). The specification of knitted fabrics was shown in <Table 2>.

2. Loess Dyeing

Loess dyeing method was followed by the traditional method. Loess was obtained from Chonla-buckdo province in Korea. The stained materials in the loess solution were removed by filtering using fine strainer. The 600 g/*l* dyeing liquid, 1 : 100 liquid manure, were boiled to 30 ~ 45°C. The scouring samples were hand died for 25 min. After knitted fabrics were dried naturally, they were dried and washed several times with tap water. Three kinds of fabrics were dyed 8 times according to the upper method.

3. Analysis Method

Before and after loess dyeing, the tensile, bending, shearing, surface and compressional properties of knitted fabrics were measured using the KES-FB systems, and. the mechanical properties of knitted fabrics were shown in <Table 3>. The ratio (W/T) of weight per unit area (W) to thickness (T), the ratio (B /W) of bending rigidity (B) to weight per unit area (W), the ratio (2HB/W) of bending hysteresis (2HB) to weight per unit area (W), bending length ($\sqrt[3]{B/W}$), unbending length ($\sqrt{2HB/W}$), the ratio (WC/W) of the work of compression (WC) to weight per unit area (W) and the ratio (MMD/SMD) of the mean deviation of coefficient of friction (MMD) to geometric roughness (SMD) were calculated. Also, THV (Total Hand Value) were calculated by KN-201MDY equation (Kawabata, 1980).

III. Results and Discussion

1. Changes in W/T

Appearance density is evaluated by the ratio (W/T) of weight per unit area (W) to thickness (T). The lower the W/T value, the bigger the volume and air content. W / T values of bamboo, bamboo / cotton, and cotton fabrics before and after loess dyeing were compared and shown in <Figure 1>. As a result, W/T value of 100% bamboo knitted fabric is the highest and bamboo / cotton blend and 100% cotton in decreasing order. This result is coincident with the previous result which proved that unevenness and hairlines of cotton are greater than those of bamboo (Lee, 2007). In addition, appearance density of bamboo is greater than cotton due to presence of lumen on cotton structure. After loess dyeing, W / T values of knitted fabrics increased due to adhesion of loess to the surface of fiber and pore filling.

<Table 1> Specifications of fabrics

	Fiber composition	Structure of fabrics	Yarn count	Thickness (mm)	Weight (mg/cm^2)	Cover factor
A	Cotton 100	Single Jersey	2/40	1.04	12.17	2.5
B	Bamboo 60 / cotton 40	Single Jersey	2/40	0.89	13.5	2.5
C	Bamboo100	Single Jersey	2/40	0.88	14.6	2.5

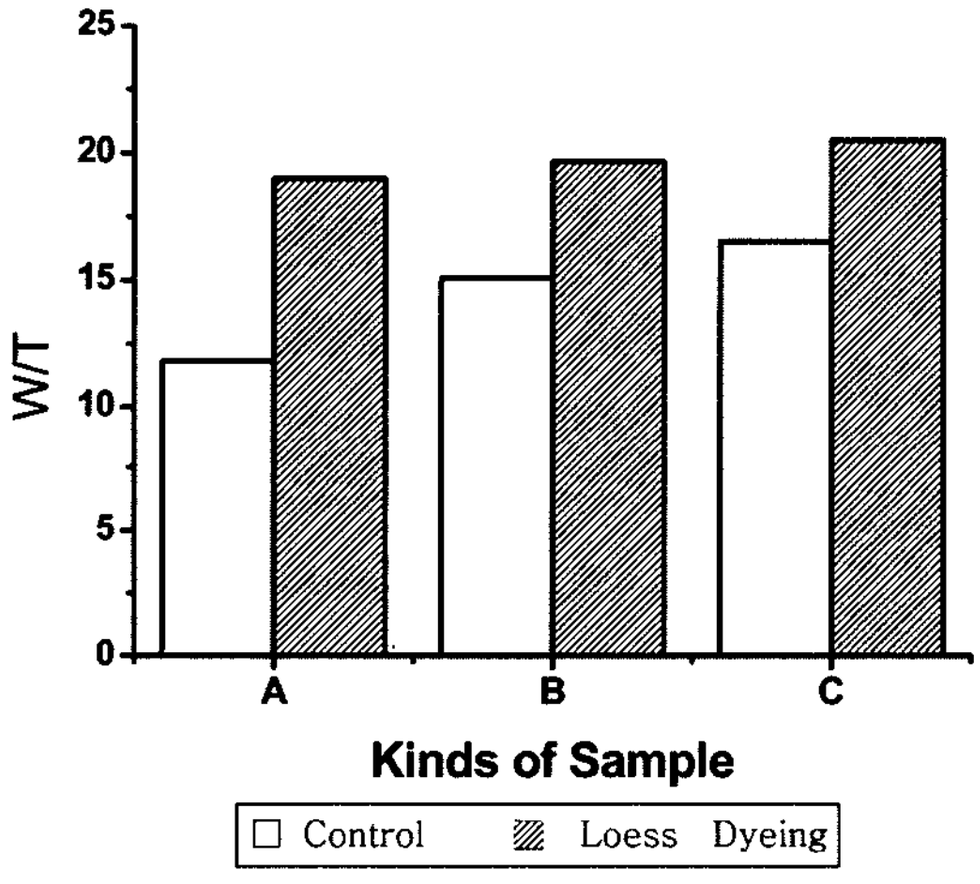
<Table 2> Characteristics of yarns

	Linear density	U%	CV	H	COF
Cotton 100	40 Nec	11.710	14.780	11.170	0.110
Bamboo 100	40 Nec	11.170	14.110	5.700	0.080

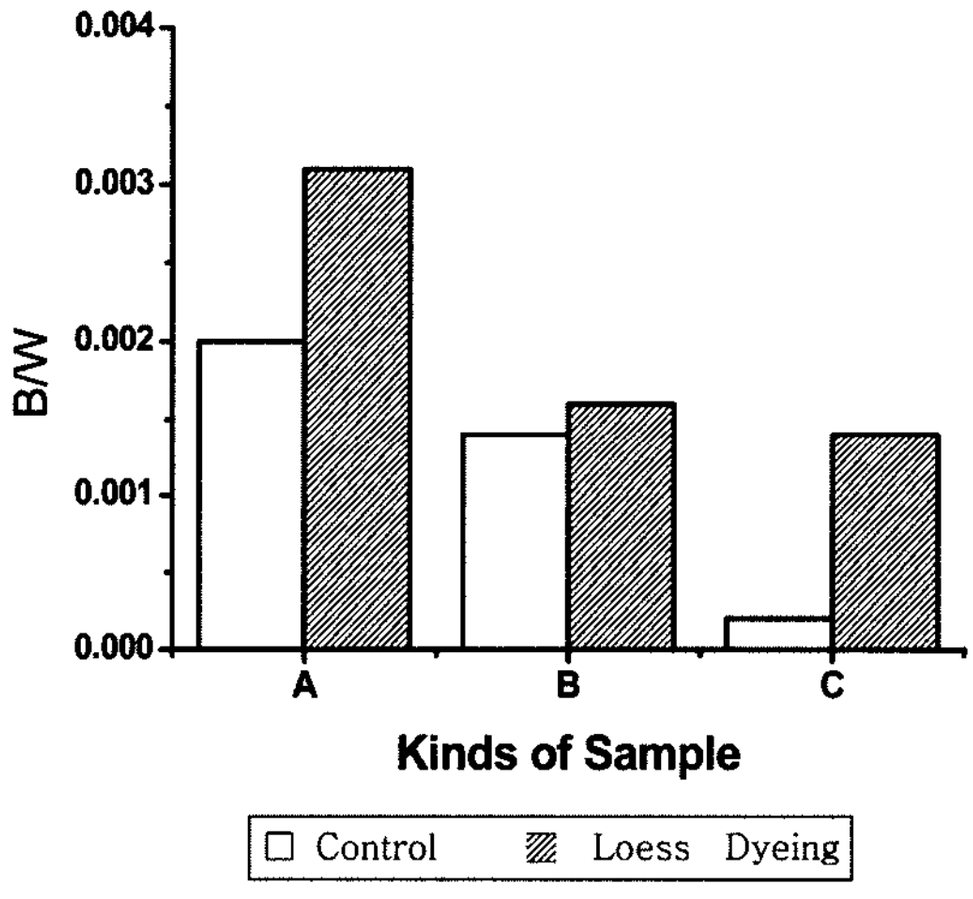
U% = Unevenness (%), CV : Coefficient of Variance, H : Hairiness, COF : Coefficient of Friction

<Table 3> Mechanical properties of knitted fabrics.

Mechanical properties		A		B		C	
		Control	Dyeing	Control	Dyeing	Control	Dyeing
Tensile	LT	0.679	0.747	0.641	0.671	0.456	0.856
	WT	26.20	19.40	25.45	24.80	24.65	20.05
	RT	26.46	22.50	30.51	25.65	40.42	26.02
	EM	15.55	10.38	15.95	14.95	17.55	15.20
Shearing	G	1.26	2.03	1.18	1.36	0.91	1.59
	2HG	7.07	9.73	5.75	7.61	4.47	6.42
Bending	B	0.0249	0.0583	0.0211	0.0289	0.0030	0.0253
	2HB	0.0322	0.0567	0.0256	0.0337	0.0032	0.0147
Compression	LC	0.34	0.28	0.37	0.28	0.33	0.31
	WC	0.45	0.32	0.33	0.28	0.34	0.29
	RC	30.62	30.31	37.84	33.33	40.24	41.24
Surface	MIU	0.090	0.181	0.094	0.209	0.095	0.217
	MMD	0.0069	0.0070	0.0044	0.0045	0.0078	0.0055
	SMD	0.77	1.14	0.88	0.93	0.96	1.11



<Figure 1> Changes of the ratio of weight per unit area to thickness of knitted fabrics.

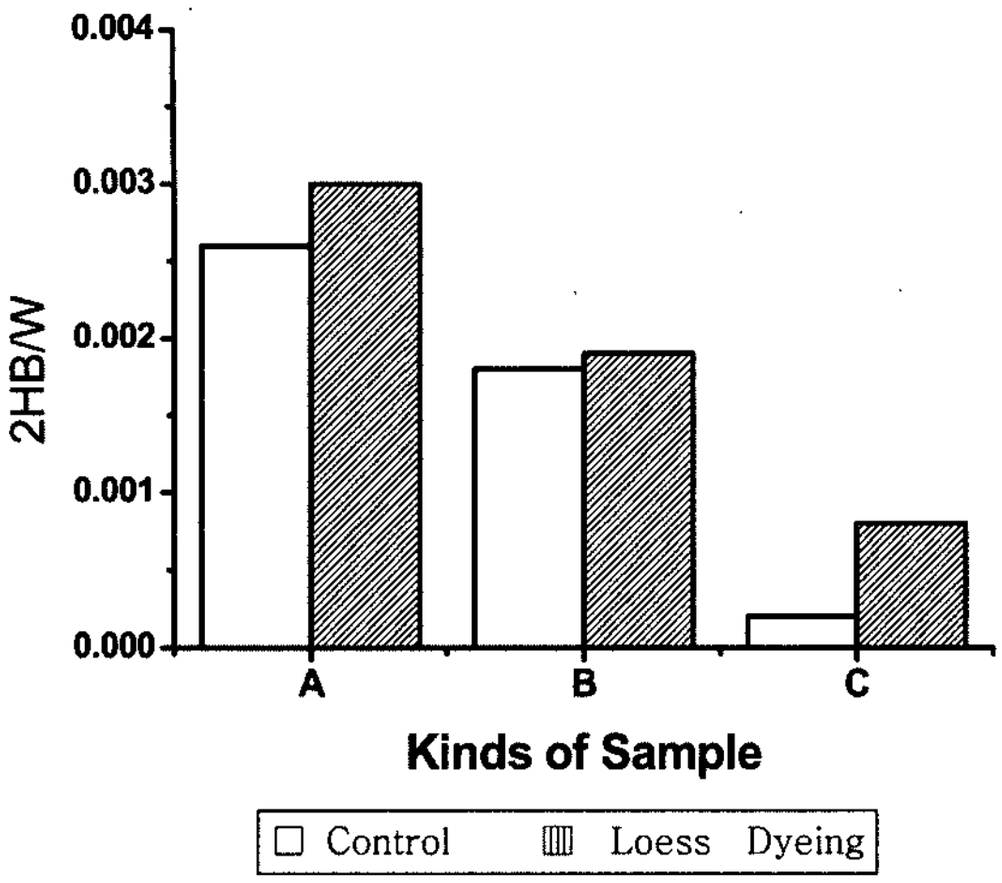


<Figure 2> Changes of the ratio of bending rigidity to weight per unit area of knitted fabrics.

2. Comparison of Shape Retention of knitted fabrics

1) Changes in B/W

The ratio (B/W) of bending rigidity (B) to weight per unit area (W) is related to the shape of fabric on draping. Low B/W value represents the fact that fabric can be more easily draped. B/W values of bamboo, bamboo / cotton, and cotton fabrics before and after loess dyeing were compared and shown in <Figure 2>. As a result, B / W value of 100% cotton knitted fabric is the highest and bamboo/cotton blend and 100% bamboo in decreasing order. Cotton is stiff and has higher shape retention property due to higher crystallinity of cotton than bamboo. Bamboo knitted fabric is more flexible than cotton due to less developed crystallinity of wet spinning bamboo fiber. Therefore, cotton knit is more suitable for formal suit wear than bamboo knit. Shape retention of bamboo / cotton blend is more close to that of cotton knit. After loess dyeing, B and B / W values of knitted fabrics increased due to increase in friction resistance by adhesion of loess to the surface of fiber.



<Figure 3> Changes of the ratio of bending hysteresis to weight per unit area of knitted fabrics.

After loess dyeing, shape retention B / W value of bamboo / cotton blend is closer to that of bamboo knit. Therefore, shape retention properties of bamboo knit was improved after loess dyeing.

2) Changes in Shape Stability, 2HB/W

The ratio (2HB/W) of bending hysteresis (2HB) to weight per unit area (W) is related to the stability of fabric shape on draping. As 2HB/W value increases, the stability of fabric shape and the liveliness of fabric on moving decreases. 2HB / W values of bamboo, bamboo / cotton, and cotton knitted fabrics before and after loess dyeing were compared and shown in <Figure 3>. As a result, B / W value of 100% cotton knitted fabric is the highest and bamboo / cotton blend and 100% bamboo in decreasing order. 2HB / W value of bamboo / cotton blend is closer to that of cotton knit. After loess dyeing, 2HB / W value of all three knitted fabrics increased.

3. Comparison of drape properties of knitted fabrics

1) Changes in Bending Length ($\sqrt[3]{}$B/W)

Bending Length ($\sqrt[3]{}$B / W) represents the degree of draping according to the fabric weight. As the Bending Length ($\sqrt[3]{}$B / W) value increases, fabric becomes more difficult to bend and drape coefficient of fabric increases. Bending Length ($\sqrt[3]{}$B / W) values of bamboo, bamboo / cotton, and cotton knitted fabrics before and after loess dyeing were compared and shown in <Tables 4>. As a result, bending length ($\sqrt[3]{}$B / W) value of 100% cotton knitted fabric is the highest and bamboo / cotton blend and 100% bamboo in decreasing order. It represents the fact that it is more difficult to bend cotton knitted fabric than bamboo. Therefore bamboo knitted fabric is more suitable for the knit wear needed for high draping in style. Drape properties of bamboo / cotton blend is closer to that of bamboo knit. After loess dyeing, bending length value of of bamboo knitted fabric further increased

2) Changes in unbending Length ($\sqrt{}$2HB / W)

Unbending length ($\sqrt{}$2HB/W) is the ratio of bending hysteresis to weight per unit area. It is related to the shape stability on draping and liveliness of the fabric. As its value increases, shape stability of fabric decreases and so does liveliness of fabric. <Tables 4> shows the changes in unbending length ($\sqrt{}$2HB/W) of bamboo, bamboo / cotton, and cotton knitted fabrics before and after loess dyeing. As a result, unbending length ($\sqrt{}$2HB/W) value of 100% cotton knitted fabric is the highest and bamboo / cotton blend and 100% bamboo in decreasing order. After loess dyeing, unbending length ($\sqrt{}$2HB/W) value of all knitted fabrics increased.

4. Changes in wrinkle recovery, 2HB/B, and 2HG/G

2HB / B and 2HG / G calculated from KES mechanical properties are related to the wrinkle recovery property of fabric. These values represent the elastic behavior and shear deformation of fabric during wrinkle deformation. The higher the values, the more wrinkle. As shown in <Tables 4 and 5>, there are changes in 2HB / B and 2HG / G of bamboo, bamboo / cotton, and cotton knitted fabrics after loess dyeing. As a result, 2HB / B and 2HG / G value of 100% cotton knitted fabric is the highest and bamboo / cotton blend and 100% bamboo in decreasing order. Even though bending rigidity of cotton knitted

<Table 4> Changes of bending properties of knitted fabrics

Bending properties	A		B		C	
	Control	Dyeing	Control	Dyeing	Control	Dyeing
B	0.0249	0.0583	0.0211	0.0289	0.0030	0.0253
2HB	0.0322	0.0567	0.0256	0.0337	0.0032	0.0147
2HB/B	1.2929	0.9725	1.2101	1.1639	1.0306	0.5809
$\sqrt[3]{B/W}$	0.2122	0.2360	0.1951	0.1998	0.1231	0.1928
$\sqrt{2HB/W}$	0.0512	0.0549	0.0419	0.0431	0.0154	0.0283

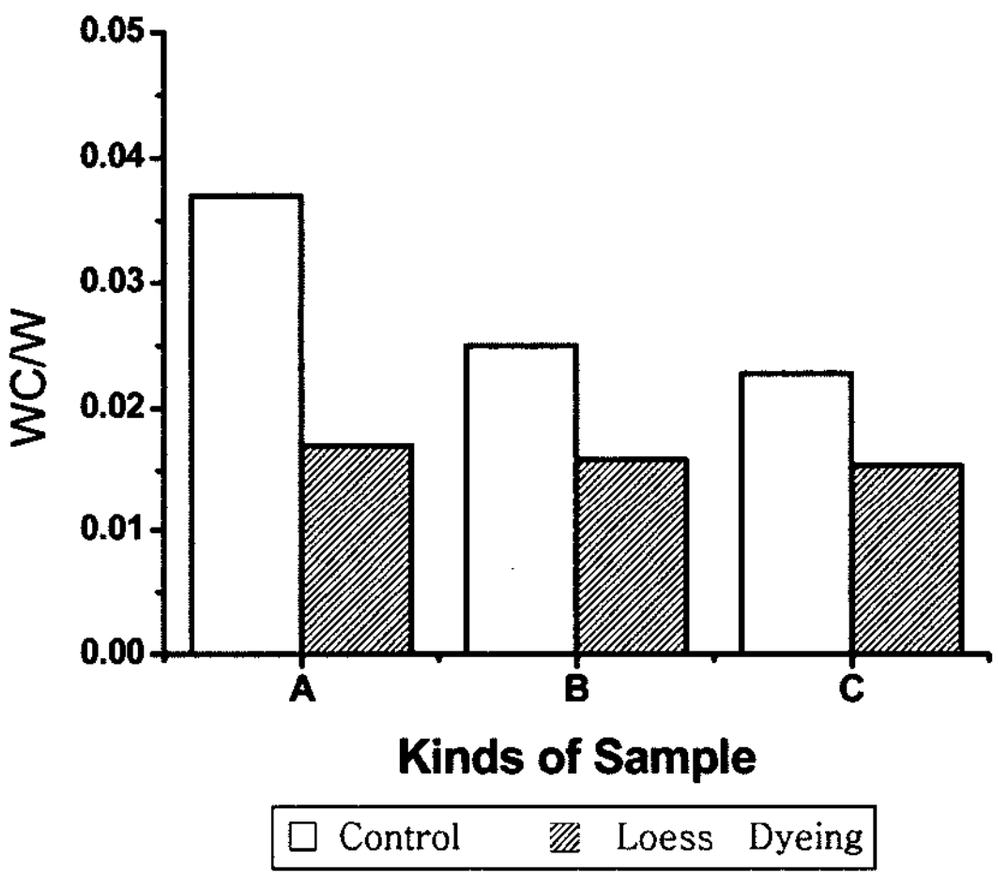
<Table 5> Changes of shearing properties of knitted fabrics

Shearing properties	A		B		C	
	Control	Dyeing	Control	Dyeing	Control	Dyeing
G	1.26	2.03	1.18	1.36	0.91	1.59
2HG	7.07	9.73	5.75	7.61	4.47	6.42
2HG/G	5.6151	4.7671	5.3080	5.5992	4.1358	4.0156

fabric is greater than that of bamboo knit, friction coefficient of cotton yarn is greater than that of bamboo yarn. Thus, the plasticity of cotton is greater than that of bamboo since unevenness and hairlines of cotton are greater than bamboo. 2HB / B value of bamboo / cotton blend is closer to that of cotton knit. 2HB / B value of all knitted fabrics decreased after loess dyeing, due to increase in elasticity, thus wrinkle recovery of fabric improved. As compared with changes in 2HB / B, 2HG / G values weren't changed significantly.

5. Changes in WC/W

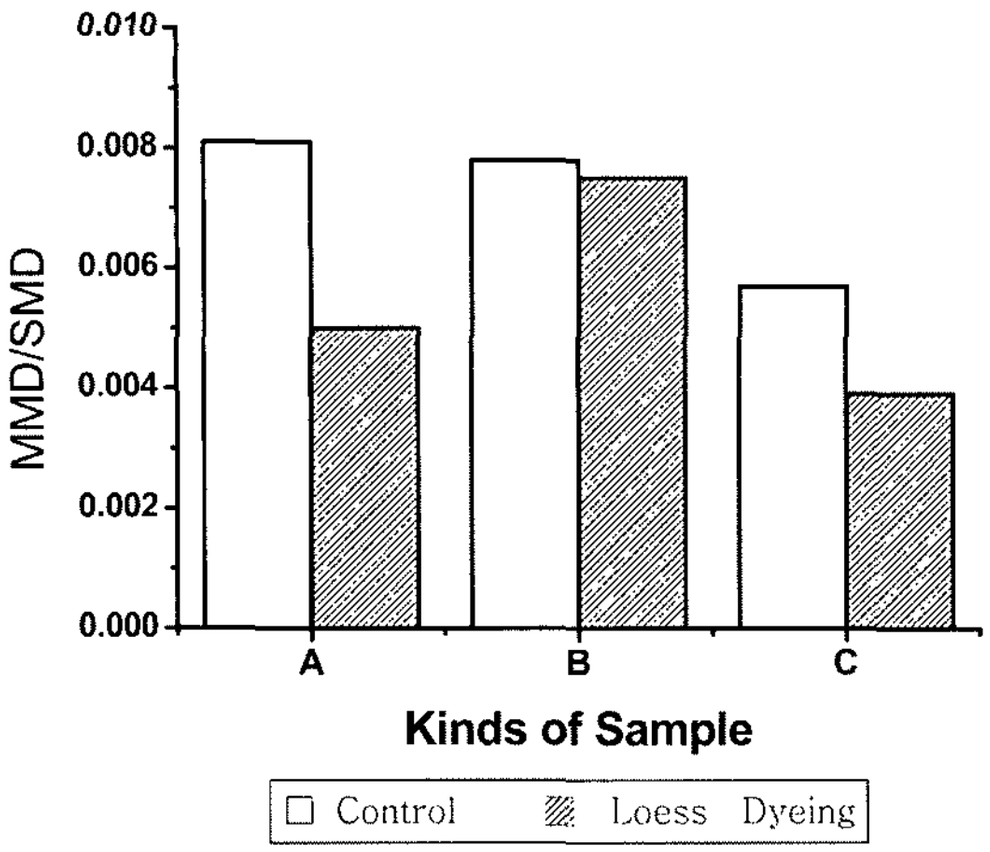
Fabric compression properties represented by WC / W value are significantly related to fabric fullness (Morooka, 1978). As this value increases, fabric can be softly compressed. The higher the work of compression (WC) value, the bigger the volume. <Figure 4> represents the changes in WC / W of bamboo, bamboo / cotton, and cotton knitted fabrics before and after loess dyeing. As a result, WC / W value of 100% cotton knitted fabric is the highest and bamboo/cotton blend and 100% bamboo in decreasing order: After loess dyeing, WC / W value of all knitted fabrics decreased representing that fabric become harder and less fullness.



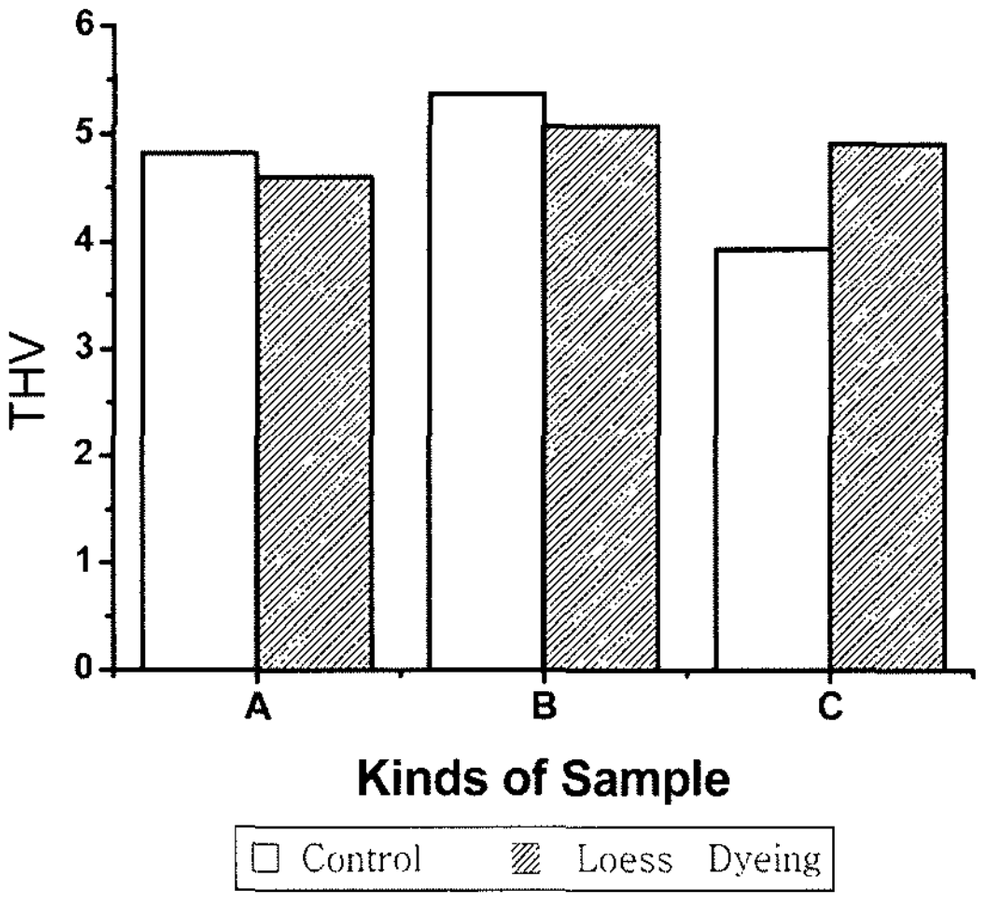
<Figure 4> Changes of the ratio of the work of compression to weight per unit area of knitted fabrics..

6. Changes in MMD / SMD

SMD is geometric roughness and MMD is the mean deviation of coefficient of friction. As MMD/SMD value decreases, surface smoothness of fabric increases and fabric hand is improved. <Figure 5> represents the changes in MMD/SMD value of bamboo, bamboo / cotton, and cotton knitted fabrics before and after loess dyeing. As a result, MMD / SMD value of 100% cotton knitted fabric is the highest and 100% bamboo and bamboo / cotton blend in decreasing order. After loess



<Figure 5> Changes of the ratio of the mean deviation of coefficient of friction to geometric roughness of knitted fabrics.



<Figure 6> Changes of Total Hand Value of knitted fabrics.

dyeing, MMD / SMD value of knit fabric decreased due to significant decrease in MMD value despite of increase in surface roughness of knit fabric.

7. THV (total hand value)

THV presented in <Figure 6> is calculated by KN-201MDY equation from mechanical property values measured by KES-F system. [Kawabata , 1980] Based on the previous study (Lee, 2007), KOSHI and FUKURAMI decreased in the order of 100% cotton > bamboo / cotton blend (60 / 40) > 100% bamboo. NUMERI and SOFUTOSA decreased in the order of 100% bamboo > bamboo/cotton blend (60 / 40) > 100% cotton. After loess dyeing, KOSHI increased and NUMERI, FUKURAMI, and SOFUTOSA decreased. Total hand value (THV) was calculated from this primary hand values in this study. According to THV, the hand of bamboo / cotton blend knit is the best among three samples by making up weak nature of two fiber properties. After loess dyeing, THV of blend fabric decreased, but THV of bamboo fabric improved.

IV. Conclusion

In this study, mechanical properties related to the fabric appearance of well being functional bamboo knitted fabric after loess dyeing were evaluated. Formability of silhouette, drape, wrinkle recovery, compression, surface properties, and total hand value of 100% bamboo, bamboo / cotton blend (60 / 40), and 100% cotton were also evaluated. As a result, appearance density, shape retention and drape coefficient of cotton knit are greater than those of bamboo contained knit. After loess dyeing, which causes adhesion of loess to the surface of fiber and pore filling, shape retention and drape coefficient, wrinkle recovery of bamboo contained knit fabric improved and WC / C and MMD / SMD decreased due to the increasing of bending and shear rigidity, and the decreasing of the work of compression value (WC) and the mean deviation of coefficient of friction (MMD) of knitted fabrics. According to THV, the hand of bamboo / cotton blend knit is the best among three samples by making up weak nature of two fiber properties.

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