

## Physical Property Evaluation of Chitosan Mordanted Green Tea Dyed Cellulose<sup>†</sup>

– Focusing on the physical property changes  
upon the repetition of treatment –

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### Abstract

The UV-protection effect of green-tea dyed fabrics was reported in our previous studies. The chitosan was used as a natural mordant of cellulose fiber for green tea extract because chitosan is a natural bio-polymer. The increase in the UV protection property of summer cellulose fabrics, cotton and linen, upon the repetition of chitosan mordanting and green tea dyeing was observed. However, the physical property change would be followed by this repeated wet processing of the cellulose fabric. Therefore, the physical changes of the chitosan mordanted and green tea dyed cotton and linen fabrics were evaluated by KES-FB system. Tensile, shear, bending, compression, and surface characteristics were tested upon the repetition of mordanting and dyeing treatments. Linearity of tensile force increased in the treated cotton and linen samples. Tensile energy and resilience decreased in all treated fabrics. Shear stiffness increased in the treated cotton and linen in general. Shear hysteresis was increased in all cotton samples and some linen samples. In cotton, the bending rigidity in all treated cottons increased except C3G3. As the chitosan mordanting numbers increased, the bending rigidity tended to decrease. In linen, the bending rigidity and hysteresis increased in all treated samples. Compressional energy and resilience increased as the number of chitosan mordanting increased both in cotton and linen. This could be the result of the increase in thickness upon chitosan mordanting. Surface coefficient of friction increased in the treated cotton and linen in general. Surface roughness tended to increase in cotton.

**Key Words** : Cellulose, Chitosan mordanting, Green tea dyeing, KES-FB, Physical property

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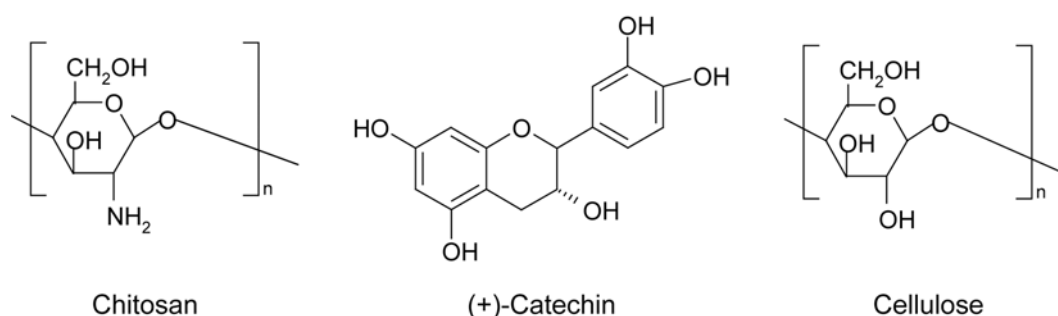
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## I. Introduction

Recently, UV radiation has been another environmental threat to human beings. As the ozone barrier of the earth became damaged, the UV radiation increased in the past few years.<sup>1)-3)</sup> The main protection against the UV radiation was the clothing. However, the UV protection efficiency was not good enough protect human in case of the thin summer textiles.<sup>3)</sup> The UV absorber such as  $\text{TiO}_2$  can be incorporated in case of synthetic fiber during the spinning process to increase the UV protection. However, the natural fiber such as cellulose or protein fibers needs another means to increase the UV protection function of fabric. Especially, the cellulose fibers preferably worn during the summer season need UV protection. Some researches have been done to increase the UV protection of cellulose fabrics by incorporating benzophenone or  $\text{TiO}_2$  during the textile finishing process.<sup>4)</sup> However, these additives can be toxic to the human and can be easily detached out from the fiber.<sup>4)</sup> Therefore, we invented a process of green tea extract treatment of the various fibers to increase UV protection of the treated fabrics. The green tea contains catechin moiety, a polyphenonol family, responsible for the increase in UV protection.<sup>5)-8)</sup>

Green tea dyeing resulted in the increase in

the UV protection property of various fabrics in our previous studies.<sup>9)-10)</sup> Cellulose fibers showed the relatively lower increase in the UV protection than the protein fibers such as wool and silk.<sup>9)-10)</sup> Since the cellulose fiber has the low affinity to the catechin (the moiety responsible for the UV protection in the green tea extract) the cellulose fiber treated under the same condition showed the lower increase in the UV protection. The chitosan was used as natural mordant to increase the affinity of catechin to cellulose fiber, and as a result, the chitosan successfully increased the UV protection of cellulose in the green tea dyeing. Around 7% increase in the UV protection was increased upon the chitosan mordanting, which is the similar value with the metal mordant.<sup>9)-10)</sup> However, the UV protection of the chitosan mordanted and green tea dyed cotton was 91.3% in UV-A and 92.8% in UV-B.<sup>9)-10)</sup> The further increase in the UV protection was expected upon the repetition of chitosan mordanting and green tea dyeing. The repetition of chitosan mordanting and green tea dyeing increased the UV protection of various cellulose fabrics reported in our other study. However, it is expected that the physical property including hand would be significantly affected by the repeated treatment in the wet condition. The physical properties of the representative summer



<Figure 1> Structures of chitosan, (+)-catechin, and cellulose

fabrics, cotton and linen, treated in each condition were evaluated by KES-FB system to observe the changes upon the repeated chitosan mordanting and green tea dyeing in this study.

## II. Experimental

### 1. Materials

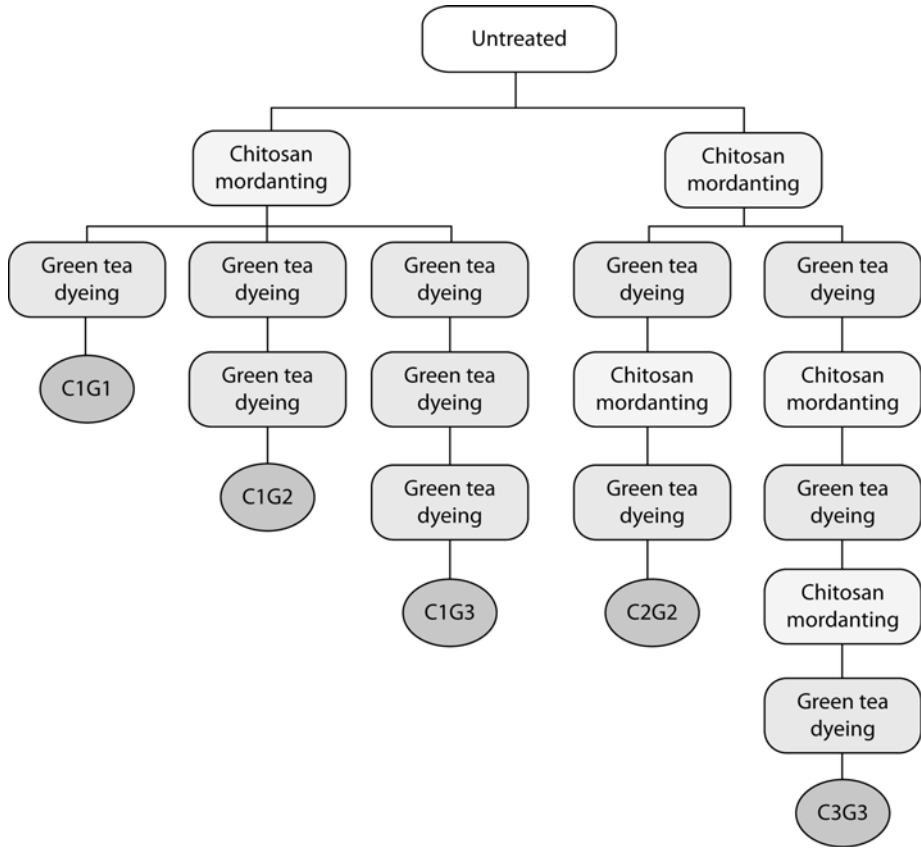
The properties of the cellulose fabrics used were shown in Table 1.

<Table 1> Characteristics of the fabrics used.

Characteristics	Cotton	Linen	Ramie
Fiber type	Staple yarn	Staple yarn	Staple yarn
Fabric construction	Plain weave	Plain weave	Plain weave
Fabric count	78 X 65	63 X 45	44 X 47
Thickness	0.25 ± 0.02 mm	0.31 ± 0.02 mm	0.3 ± 0.02 mm
Weight	109 ± 5 g/m <sup>2</sup>	55 ± 2 g/m <sup>2</sup>	107 ± 5 g/m <sup>2</sup>

<Table 2> Characteristic values of basic 16 mechanical properties of fabrics

Parameter		Description	Unit
Tensile	EMT	Extension at maximum load	%
	LT	Linearity of load-extension curve	—
	WT	Tensile energy	gf•cm/cm <sup>2</sup>
	RT	Tensile resilience	%
Bending	B	Bending rigidity	gf•cm <sup>2</sup> /cm
	2HB	Hysteresis of bending moment	gf•cm/cm
Shearing	G	Shear stiffness	gf•cm•deg
	2HG	Hysteresis of shear force at 0.5 deg. of shear angle	gf/cm
Compression	LC	Linearity of compression thickness curve	—
	WC	Compressional energy	gf•cm/cm <sup>2</sup>
	RC	Compressional resilience	%
Surface	MIU	Coefficient of friction	—
	MMD	Mean deviation of MIU	—
	SMD	Geometrical roughness	μm
Thickness	T	Fabric thickness	mm
Weight	W	Fabric weight	mg/cm <sup>2</sup>



<Figure 2> The chitosan mordanting and the green tea dyeing repetition condition.

3. Physical property evaluation using KES-FB

Table 2 shows the characteristic values measured by KES-FB system. Tensile, shear, bending, and surface properties were tested 3 times in warp and weft directions respectively. Compressional property was tested 3 times. The test was done in the standard condition (20℃, 65%RH) and the tested values were averaged.

III. Results and Discussion

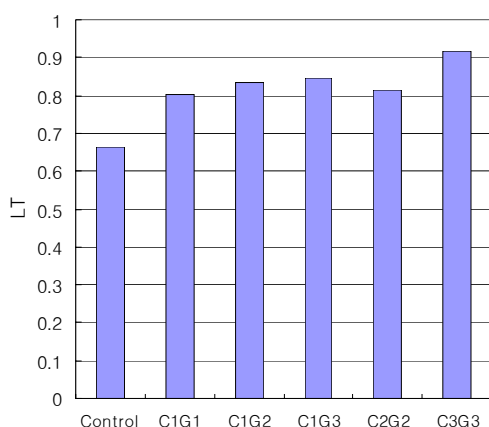
1. Tensile Property

The tensile properties of the treated cotton are

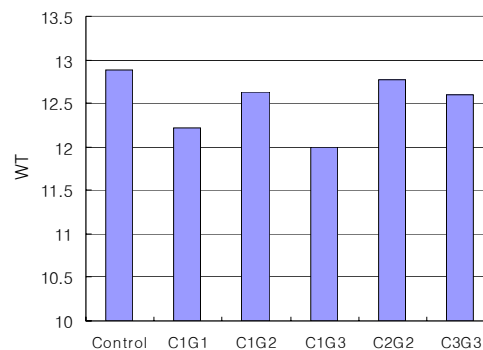
shown Figure 3. The linearity of tensile force, LT, of cotton increased over the chitosan mordanting and green tea dyeing. C3G3 showed the highest LT value among the treated samples. In case of the same number of chitosan mordanting, the LT value increased with the increase in number of the green tea dyeing. The tensile energy, WT, of the treated cottons was all lower than the untreated. No specific tendency was shown among the treated samples in the WT value. The tensile resilience, RT, of the treated cotton was all higher than that of the original. And C3G3 showed the highest RT value. The chitosan mordanting and green tea dyeing decreased the tensile energy and

increased the tensile resilience of the treated cotton.

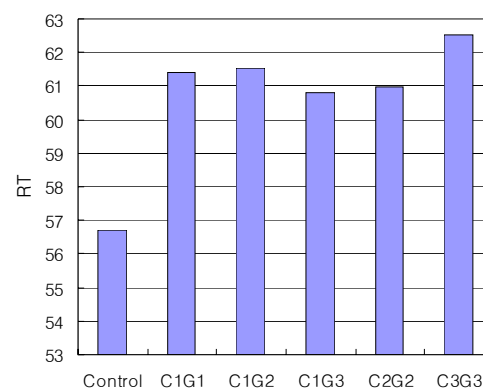
For linen, the linearity of tensile force, LT, of the chitosan mordanted and green tea dyed showed the higher values than the untreated as in cotton. C1G1 and C2G2 showed the highest value because the chitosan treatment seemed to increase the resistance to the tensile force. However, C3G3 showed the little lower value because the repeated wet processing such as chitosan mordanting and dyeing tempered the fiber little bit. The tensile energy, WT, value of the treated decreased little bit than the original except C1G2 and C1G3. The tensile resilience, RT, of the chitosan mordanted and green tea dyed linen fabrics increased in all samples and the degree of the increase in RT is proportional to the increase in the number of chitosan treatments. It seemed that the chitosan mordanting increased the RT value. And the tendency in decrease in the tensile resilience, RT, was shown as the number of dyeing increased in case of one time chitosan mordanted samples (C1G1, C1G2, and C1G3).



(a) LT

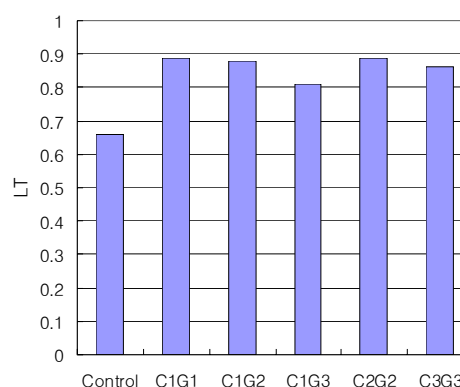


(b) WT

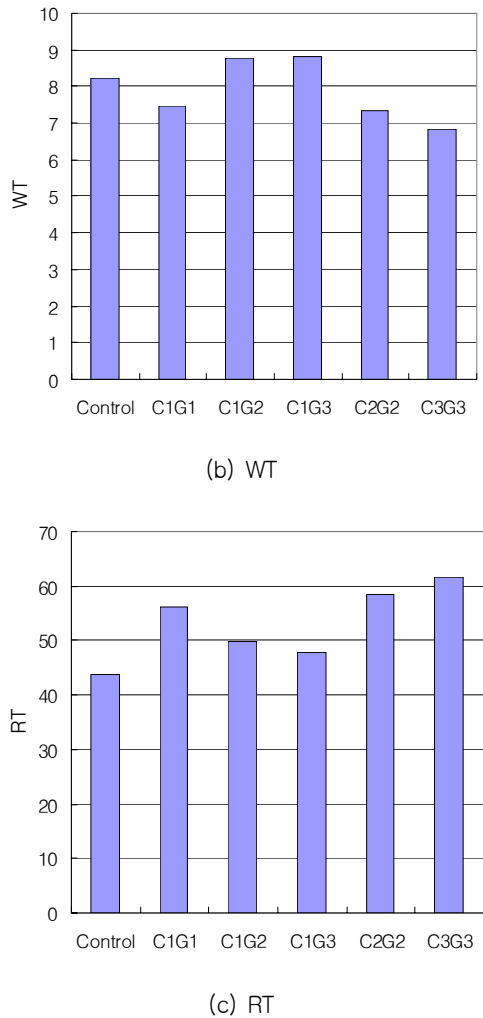


(c) RT

<Figure 3> Tensile properties of chitosan mordanted and green tea dyed cotton



(a) LT



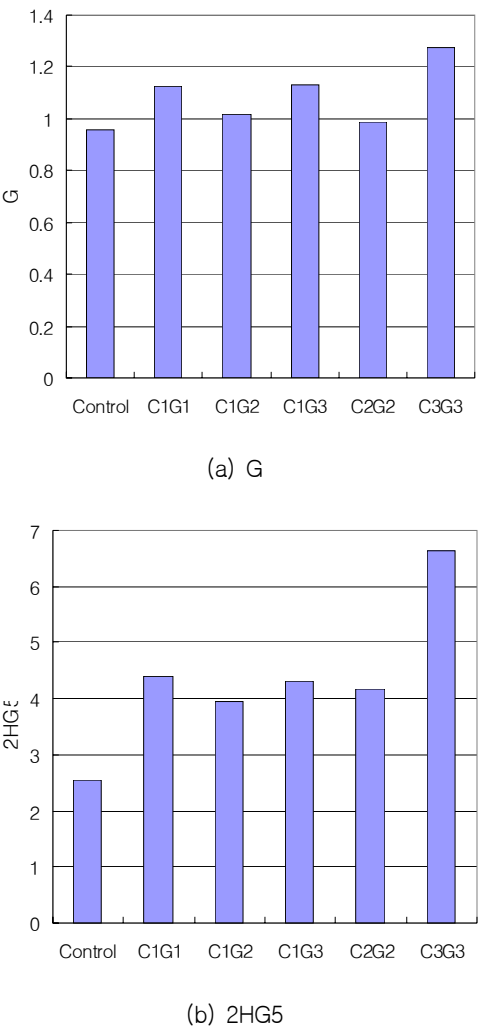
<Figure 4> Tensile properties of chitosan mordanted and green tea dyed linen fabric.

2. Shear Property

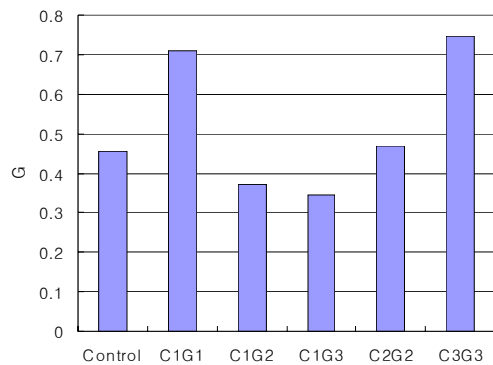
Shear properties of cotton fabrics are shown in Figure 5. Shear stiffness, G, increased in all chitosan mordanted and green tea dyed cotton fabrics and C3G3 showed the highest shear stiffness. Shear hysteresis, 2HG5, also showed the increased values in all treated fabrics. It seemed that chitosan mordanting increased both

shear stiffness and shear hysteresis.

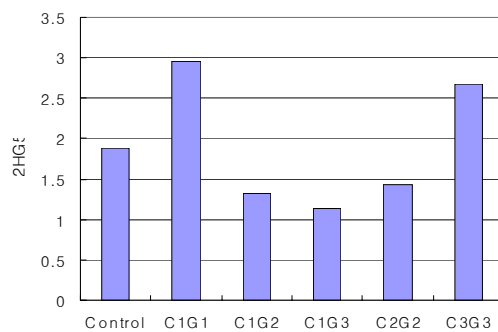
Chitosan mordanted and green tea dyed linen showed higher G values than the control except C1G2 and C1G3. 2HG5 showed the higher values in C1G1 and C3G3 while C1G2, C1G3, and C2G2 showed the low shear hysteresis than the untreated original linen. (Figure 6)



<Figure 5> Shear property of chitosan mordanted and green tea dyed cotton.



(a) G



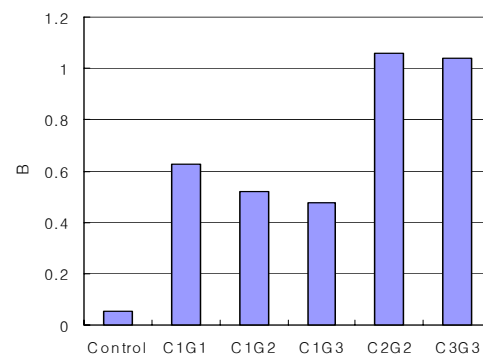
(b) 2HG5

&lt;Figure 6&gt; Shear property of chitosan mordanted and green tea dyed linen.

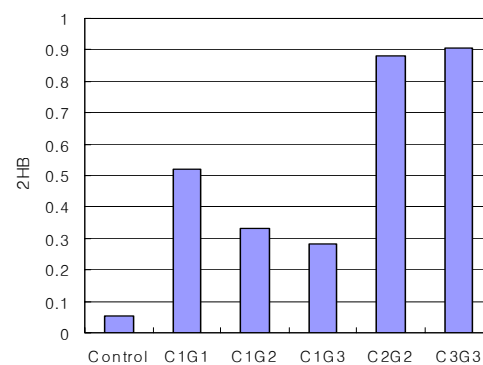
### 3. Bending Property

Bending stiffness, B, increased allover the chitosan mordanting and green tea dyeing. In case of one time chitosan mordanting (C1G1, C1G2, C1G3), the B decreased over the increase in the number of green tea dyeing. Chitosan mordanting affected the bending characteristics of the treated cotton. The same tendency was observed in the bending hysteresis (2HB and 2HB5). The treated fabrics showed the increased bending hysteresis than the original. And the extent increased significantly over the repetition of chitosan mordanting.

In case of linen, the bending stiffness, B, increased in all treated linen fabrics. As the increase in the number of repetition of chitosan mordanting increased significantly the bending stiffness of the treated fabrics. In case of the same number of chitosan mordanting (C1G1, C1G2, C1G3), the bending stiffness decreased over the repetition of the green dyeing probably due to the some chitosan removal during the wet processing. The bending hysteresis (2HB and 2HB5) also showed the same tendency as in bending stiffness. The bending hysteresis significantly increased over the number of the repetition of the chitosan mordanting in the treated linen.

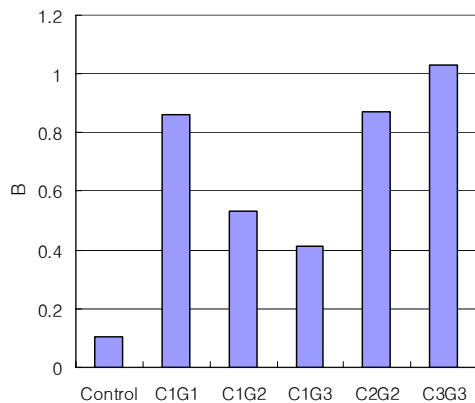


(a) B

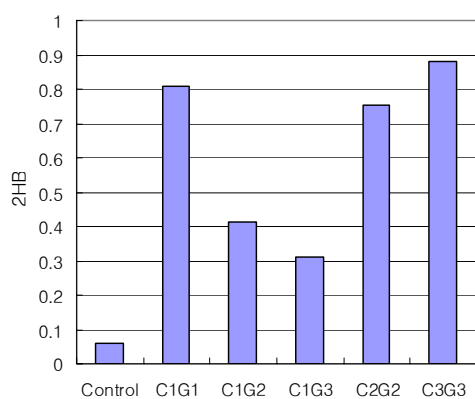


(b) 2HB

&lt;Figure 7&gt; Bending properties of chitosan mordanted and green dyed cotton.



(a) B



(b) 2HB

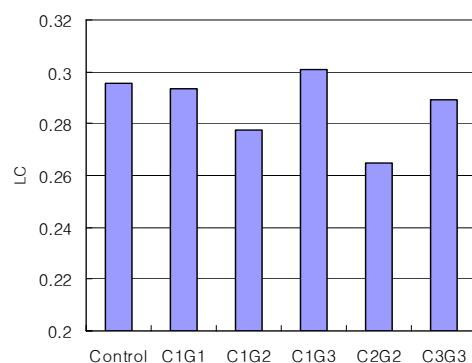
**<Figure 8> Bending properties of chitosan mordanted and green dyed linen.**

#### 4. Compressional Property

Compressional properties of chitosan mordanted green tea dyed cotton are shown in Figure 9. The linearity of compression of cotton decreased little bit over the chitosan mordanting and green tea dyeing process except C1G3. There is no specific tendency in LC. Compressional energy, WC, increased over the chitosan mordanting increases. There was no increase in WC in case of C1G1, C1G2, and C1G3, however, C2G2 and

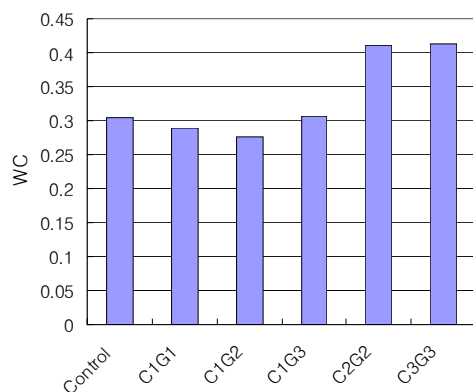
C3G3 showed the higher WC than that of the untreated cotton. Compressional resilience increased in all samples over the chitosan mordanting and green tea dyeing. The higher increases were observed in C2G2 and C3G3 samples. The WC and RC values increases in C2G2 and C3G3 were seemed the result of the increase in thickness of sample fabrics by the chitosan mordanting.

Compressional properties of linen were shown in Figure 10. The linearity of compression, LC, increased little bit in all samples except C1G3. C1G3 showed the similar LC with the control. The compressional energy, WC, also increased in all samples except C1G1. And C2G2 showed the highest value. In case of the one time chitosan mordanted samples, the WC value decreased over the dyeing number increased. Compressional resilience of linen also increased over the chitosan mordanting and green tea dyeing. C1G1, C2G2, and C3G3 all showed the higher RC values than others. It seemed that the chitosan mordanting was responsible for the increase in WC and RC because the thickness of the fabric samples increased. The following repeated dyeing decreased the chitosan mordants somehow and decreased the WC and RC values.

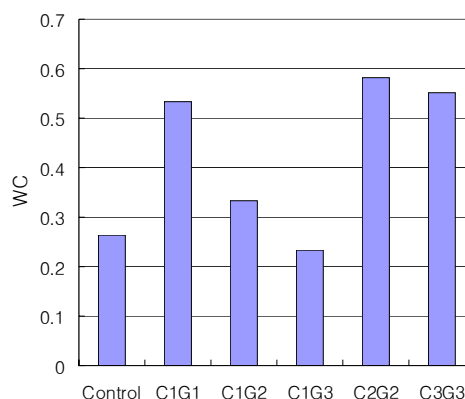


(a) LC

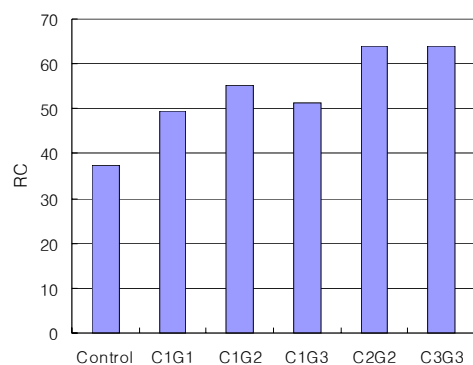




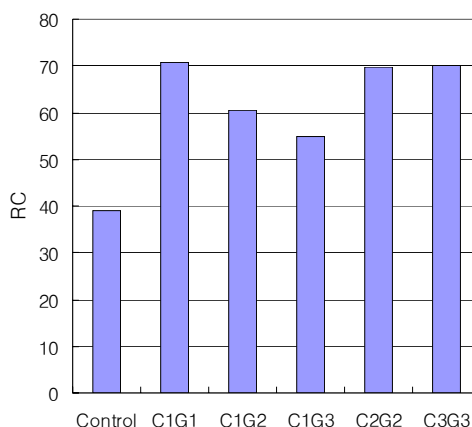
(b) WC



(b) WC



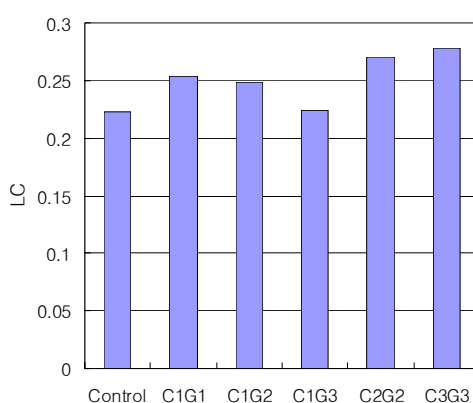
(c) RC



(c) RC

<Figure 9> Compressional properties of chitosan mordanted and green dyed cotton.

<Figure 10> Compressional properties of chitosan mordanted and green dyed linen.



(a) LC

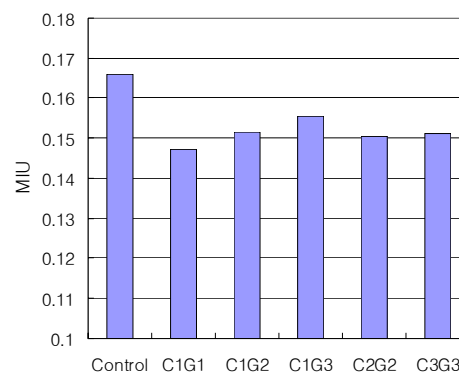
## 5. Surface Property

Surface properties of the chitosan mordanted and green tea dyed fabrics are shown in Figure 11. Coefficient of friction, MIU, decreased in all treated samples. It seemed that chitosan coated the coarse surface of cotton fiber, and as a result, the surface friction decreased. However, at the same number of chitosan mordanting (C1G1, C1G2, and C1G3), the surface friction tended to increase over the repeated number of

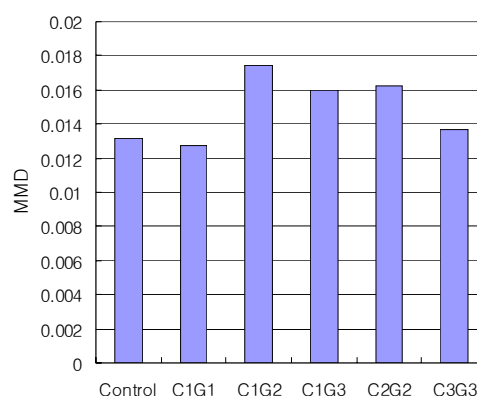
dyeing which would remove some chitosan from the fiber surface. C1G3 showed the highest MIU among the treated samples which had the lowest number of chitosan mordanting and the highest number of green tea dyeing processing. Mean deviation of MIU, MMD, showed a little bit higher value in all treated samples except C1G1. The deviation tended to be large possibly because the chitosan mordanting resulted in the different surface characteristics throughout the cotton fiber surface. The assumption can also be supported the fact that the surface roughness, SMD, tended to increase in all treated samples (Figure 11, (c)). It seemed that the chitosan mordanting covered the cotton fiber surface, however, the surface covering by chitosan was irregular. And therefore, the surface roughness value, SMD, increased in all samples.

Figure 12 shows the surface properties of the chitosan mordanted and green tea dyed linen. The coefficient of friction, MIU, decreased in all samples except C1G3. The same assumption as in cotton can be applied to the linen fabrics. The chitosan mordanting decreased the surface friction and the repeated dyeing could remove some of the chitosan coated parts. Mean deviation of MIU, MMD, was all lower in the treated samples than the control. Surface roughness, SMD, of the treated linen samples also tended to decrease except C1G3, which is different in the treated cotton fabric samples. The SMD value of control is much higher than that of cotton (SMD of the untreated linen is around 5, while SMD of the untreated cotton is around 2), which means the linen surface is much rougher than the cotton surface. Therefore, the chitosan coating variations over the linen fiber did not change or increase the surface roughness contrary to cotton. Therefore, the chitosan mordanted and green tea dyed linen

fabrics would have smoother and sleeker surface than the original linen fabric.



(a) MIU



(b) MMD



(c) SMD

<Figure 11> Surface properties of chitosan mordanted and green dyed cotton.

## IV. Conclusions

Physical properties of the chitosan mordanted and green tea dyed cotton and linen fabrics were tested by KES-FB system and the following conclusions were made:

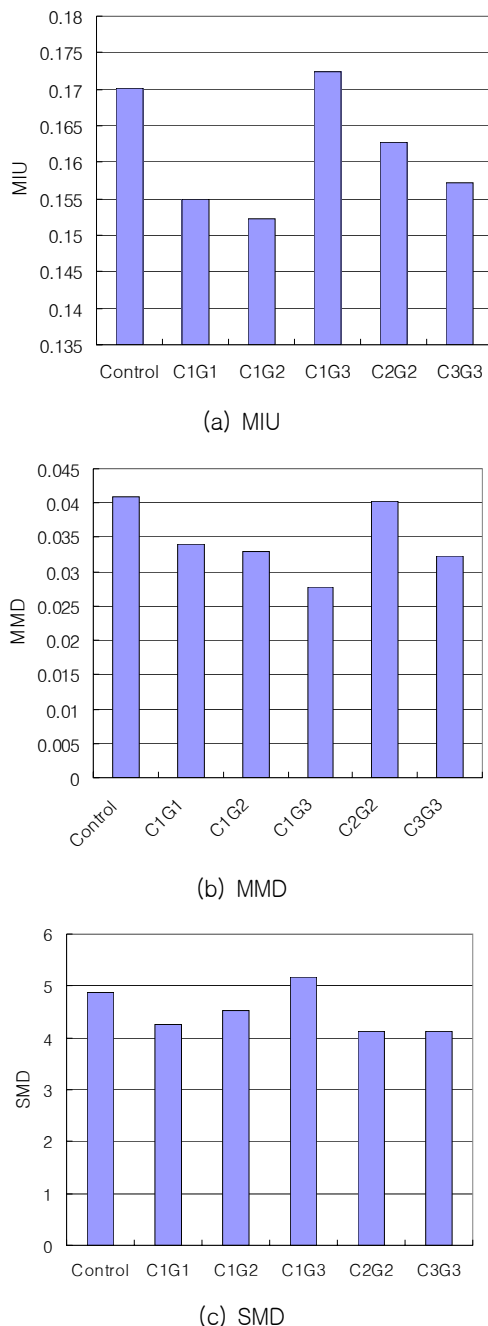
1. Linearity of tensile force increased in all treated cotton samples, while the tensile energy and tensile resilience decreased. Linearity of tensile force of the treated linen fabrics increased than the control except C1G1 and C1G3. The tensile energy and resilience of the treated linen samples decreased as in the treated cotton.

2. Shear stiffness and shear hysteresis increased in all treated cotton samples. Shear stiffness of the treated linen fabrics were also increased except C1G2 and C1G3. The shear hysteresis of the C1G1 and C3G3 increased while the shear hysteresis of other samples decreased.

3. Bending rigidity increased in the one time chitosan mordanted cotton samples (C1G1, C1G2, and C1G3). However, B decreased as the chitosan mordanting number of cotton increased. Shear hysteresis of the treated cotton increased except C3G3. In case of linen, the bending rigidity and hysteresis increased in all treated samples.

4. Linearity of compression of the treated cotton decreased little bit except C1G3. No specific tendency was observed in LC. Both compressional energy and compressional resilience increased over the increased number of chitosan mordanting. This result would be due to the increased thickness of the repeated chitosan mordanting. The same tendency in WC and RC was observed in the treated linen samples.

5. Coefficient of friction of the treated cotton fabrics decreased, while surface roughness increased in all samples. It seemed that the chitosan mordanting coated the surface of coarse cotton fiber to decrease friction. However, the surface coating would be irregular resulting



<Figure 12> Surface properties of chitosan mordanted and green dyed linen.

in the increase of the surface roughness. Coefficient of friction of the treated linen fabrics also decreased except C1G3. But the surface roughness of the treated linen also decreased in the treated linen due to the initial high roughness of linen fiber.

The chitosan mordanted and green tea dyed cotton and linen fabrics did not change their physical properties significantly. Some changes shown in tensile and surface would be more desirable than the original untreated fabrics. Chitosan mordanting seemed to play the major role in the physical property changes than the green tea dyeing process.

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