Improving Dyeability of Soybean/Cotton Blend Fabric by Chitosan Treatment

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1. INTRODUCTION

Soybean protein fiber is a sustainable and botanical textile fiber made from renewable and biodegradable natural resources - the leftover soybean pulp from tofu and soymilk production. Its drawback is poor mechanical strength when wet. For improving poor wet strength, it is usually blended other fibers such as cotton [1]. Blend fabrics composed of cellulose and protein fibers like soybean/cotton have posed challenges because their dyeing properties are quite different. Natural dyes derived from plants generally are ionic so that their dyeing sites are supposed to be cationic. However, there are no cationic dyeing sites in cellulose fiber while protein fiber has cationic dyeing sites. Therefore, for better quality soybean/cotton blend fabric should be modified to impart cationic property for coloring with natural dyes. A green chemistry solution would be cationizing agent with more environmentally friendly to be viable.

Considering on this matter, chitosan can be used as cationizing agent for the modification of soybean/cotton fabric. Chitosan has been known by many researchers that it has biodegradability, biocompatibility, non-toxicity, antimicrobial activity, and useful chemical and physical properties. Thus, it has been applied in textile finishing and dyeing areas.

In this work, the effect of chitosan treatment on the dyeability of natural colorants extracted from pomegranate hull on soybean/cotton blend fabric was investigated to develop ecofriendly green textile products with functionality. Color strength, shade, colorfastness, antimicrobial activity, and physical properties including stiffness, wettability, and air permeability were evaluated.

2. EXPERIMENTAL

Materials

Soy/cotton (50/50) knit fabric was used after scouring and rinsing. Pomegranate colorants in hull was extracted in water at 100°C for 60 min, concentrated with a vacuum evaporator, and freeze-dried at -40°C to obtain colorants powder. Chitosan (degree of deacetylation; 81.9%, cps 9.0) was obtained commercially.

Methods

Fabric samples were padded with chitosan solution in 2% acetic acid in two dips and two nips method, dried at 70°C for 2 min, cured at 115°C for 3 min, rinsed, and dried for dyeing. Dyeing was carried out at a liquor ratio of 50:1 in 2%(owb) dye concentration, 100°C, 60 min with infra-red automatic dyeing machine(Ahiba Nuance, Data Color International, USA), and rinsed for further evaluation. Dye uptake was assessed by measuring K/S value at the maximum adsorption wavelength (λmax; 400nm) using a Macbeth Coloreye 3100 spectrophotometer. CIELab coordinates (Illuminant D_{65}/10°Observer) was measured with a Macbeth Coloreye 3100 spectrophotometer at 640 nm. H V/C values were obtained from $L^*a^*b^*$ data using CIE Munsell conversion program.

Fastness to washing of the dyed samples was evaluated by AATCC method 61-1989. Light fastness was assessed in terms of color difference (ΔE*) and color change against the appropriate Gray scale according to AATCC method 16-1998 with a Xenon Test Chamber(Q-Sun Xe-1-B, USA). Color differences after irradiating for 5, 10, 20, and 40 hours was measured to get fading curve. Dry and wet rubbing fastness also evaluated by AATCC method 8-2005.

Antimicrobial activity of dyed fabrics was measured by shake flask method in terms of bacterial reduction rate. *Staphylococcus aureus* (ATCC 6538) was the bacteria used.

3. RESULTS AND DISCUSSION

Effect of chitosan concentration on dye uptake and color

Table 1 shows the effect of chitosan concentration on dye uptake and color of soybean/cotton fabric when dye concentration was 1.0%(owb). As chitosan concentration increased, dye uptake(K/S) increased progressively from 4.31 to 8.21. Improving dye

uptake attributed to amine groups in chitosan structure, which bind with anionic pomagranate colorants. Main component of pomagranate colorants is ellagitannins having various repeat units of glucose [2]. Although dye uptake increased as chitosan treatment concentration increased, fabrics got stiffer at higher chitosan treatment concentration.

The untreated and chitosan treated cotton fabrics showed YR-Y colors observed as brownish yellow. But the color of dyed fabric shifted more yellowish shade as chitosan treatment concentration increased. As chitosan treatment concentration, L* decreased and a* increased slightly, b* increasedas (+) value. Shades were shifted to darker including more red and yellow character. Color difference (△E*) increased progressively as chitosan treatment concentration increased. H (hue) number got larger within YR color, shifting toward Y color with the increase in chitosan treatment concentration. V (brightness) decreased and C (saturation) increased, indicating duller and deeper shade with the increase in chitosan treatment concentration.

Table 1. Effect of chitosan concentration on color properties of treated fabrics

Dye (%owb)	Chitosan (%owb)	K/S	H V/C	L^*	a^*	b^*	ΔE^*
0.2	-	2.40	7.4YR 7.6/1.5	77.30	3.04	8.87	22.45
	0.5	4.50	1.5Y 7.3/2.7	73.73	2.54	18.59	32.16
0.5	-	3.22	8.3YR 7.0/2.2	71.53	4.50	13.32	29.79
	0.5	5.28	10.1YR 6.7/3.3	67.58	5.17	20.93	38.04
1.0	-	4.31	8.3YR 6.4/2.5	65.29	5.35	14.67	35.43
	0.2	5.38	9.6YR 6.3/3.1	64.42	5.57	19.57	39.31
	0.5	6.16	9.4YR 6.1/3.3	62.53	6.07	20.32	41.25
	0.8	7.12	10.0YR 6.2/3.7	62.65	6.15	23.27	43.21
	1.0	8.21	10.1YR 5.9/3.8	60.01	6.28	23.64	45.35
2.0	-	5.17	8.6YR 6.1/2.8	62.52	5.72	16.37	38.68
	0.5	7.38	9.9YR 6.0/3.7	60.99	6.29	22.89	44.13
4.0	-	6.49	9.1YR 5.9/3.1	59.80	5.98	18.45	42.11
	0.5	9.68	10.1YR 5.7/3.8	58.33	6.48	23.80	46.71

Colorfastness

The colorfastness of samples dyed in 1.0% dye solution is compared in Tables 2. It was found that chitosan treatment Soybean/cotton samples were Washing fastness of the chitosan treated fabrics(L2-L4; rating 2) was lower than that of the untreated sample(rating 2/3), because large chitosan molecules are located on the surface of fiber rather than inside fiber and so they washed away with colorants during laundering. Light fastness of the chitosan treated fabrics showed generally good showing above rating 3.

Antimicrobial activity

Table 3 shows the effect of chitosan treatment and pomegranate colorants on growth reduction against *Staphylococcus aureus*. The fabrics dyed without chitosan treatment showed bacterial reduction rate above 97% dyed at above 0.5% dye concentration. This indicates that pomegranate colorants have antimicrobial activity in itself. As it is well known, chitosan treated fabrics showed high bacterial reduction rate. There are two proposed mechanisms of antimicrobial activity by chitosan. In one mechanism, the polycationic nature of chitosan interferes with bacterial metabolism by stacking at the cell surface[5]. The other mechanism is the binding of chitosan with DNA to inhibit mRNA synthesis. In the latter mechanism, chitosan must be hydrolyzed to a molecular weight less than 5000 which is easy to permeate into the cell [3]. It is interesting that bacterial reduction rate decreased with the increase in chitosan treatment concentration. It is speculated that amino groups in chitosan may bind with carboxyl groups in soybean fiber, resulting in the decrease of the effective number of amino groups in chitosan capable to impart antimicrobial activity. As expected, chitosan/dyed samples showed synergic effect in bacterial reduction rate. The dyed(0.2%) sample showed very low bacterial reduction(8.5%) and chitosan treated(0.5%) sample showed 91.4% of bacterial reduction, while chitosan treated(0.5%)/dyed(0.2%) sample exhibited 98.5% of bacterial reduction rate.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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