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Effect of Enzyme Treatment and Wood Pulp Variation on Physical Characteristics and Fabric Hand of Lyocell Fabrics

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Abstract: The purpose of the research was to examine the effect of three different levels of enzyme treatment on the physical characteristics and the end-use suitability of the lyocell fabrics made with four different types of commercial wood pulp. The appropriate enzyme concentration for obtaining an optimum as well as consistent physical characteristics and fabric hand trait was 3 *g/l* for the concentration levels tested in the present investigation. Weight loss was more affected by higher enzyme concentration than other physical properties. H2 was least affected by enzyme treatment for all three physical properties and fabric hand. 5 *g/l* concentration exhibited little difference from 3 *g/l* in the physical characteristics, whereas the KES-FB values indicated a significant loss of fabric hand in most PHVs with the 5 *g/l* concentration level. Among different garment parameters, all four fabric types were relatively inappropriate for the men's slacks (MS) fabric due to the lower hand value of koshi required by the MS parameter. However, despite the relatively low koshi values, high fukurami values required for men's dress shirt (MWDS) resulted in the highest THV among the four garment parmeters. The four fabric types, which represent the usage of four different wood pulps, in general seem to exhibit a higher applicability to women's winter thin dress (WWTD) than women's winter suit (WWS) garment parameter.

Keywords: Lyocell fabric, Wood pulp, Enzyme finish, Kawabata, Fabric hand

Introduction

In the textile industry viewpoint, the closing of the twentieth century was marked by the development of manufactured cellulosic fiber named lyocell, the production of which has broken the thirty years of hibernation after the development of high performance aramid fibers. The most remarkable attribute of lyocell fiber is that it is environment friendly since it is derived from natural cellulose like rayon but the production involves direct dissolution of wood pulp with non-toxic spinning atmosphere and over 98 % recycling of spinning solvent [1,2]. For modern consumers lyocell provides both comfort and function with its excellent drapability and strength. The variability in lyocell fibers in both functional and aesthetic characteristics may rise at any point in production procedure, i.e. type of wood pulp, solvent spinning conditions, method of reducing primary fibrillation, and method of inducing an even distribution of short secondary fibrillation for peachskin texture.

In our previous research we found that wood pulp variation has effect on the physical characteristics of the resultant fabric and on the suitability of fabric toward selective Kawabata garment parameters [3]. Among the four types of wood pulp examined H4 pulp which had the highest DP value exhibited the highest physical properties in fiber, yarn, and fabric. The fiber spun from H4 pulp showed significantly higher DP value as well as higher tenacity and elongation. When the same H4 fiber was applied into yarn and fabric, it resulted in yarn with higher strength and elongation, and fabric with higher tenacity and tear strength. However, when the physical characteristics and the Kawabata fabric hand values were compared, the higher physical characteristics were less significant in characterizing the fabric with higher fabric hand value. Rather, fabrics made with yarns with higher CV% was likely to exhibit a better hand value of numeri, fukurami, sofutosa, and shari characteristics, which as a total were important requirements for women's suit fabric [3]. As a continuum to our previous study, this research purports to examine the effect of enzyme treatment on the physical characteristics and the end-use suitability of the lyocell fabrics made with four different types of commercial wood pulp. The suitability of fabric was measured using the Kawabata [4] garment parameters for women's winter suit, women's winter thin dress, men's slacks and men's winter dress shirt, which closely relate to the current apparel usage of lyocell fabrics.

Related Literature

The so-called primary fibrillation of lyocell fabric, which refers to the long surface fibers distributed unevenly throughout the fabric can give bad surface appearance to the fabric. Enzyme treatment is most commonly used to treat lyocell yarns and fabrics for eliminating the unfavorable fibrillation. For this purpose acid cellulase is considered to be the most effective medium [5]. Kumar *et al.* [6] and Watanabe [7] reported

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cellulase to be effective for removing surface fibrillation and also to alter fabric hand and drapability of lyocell fabrics and its blends. Morgado *et al.* [8] investigated the physico-chemical structure of the pills both attached and removed from the surface of lyocell fabric and reported that enzyme was a thorough surface finishing agent. Potter *et al.* [9] suggested an alternative way to reduce fibrillation tendency by aqueous treatment with organic crosslinking agent, which was reported to be cheaper in production cost without the usual rope marks of the enzyme finished fabrics. Other treatments for removing long surface fibrils include; alkali wash which also enhances color and hand [10], the use of oxidizing agent [11], and hydraulic treatment which could enable the following enzyme finish to be more effective [12].

The fibrillation tendency and various defibrillation procedures can produce lyocell fabric with soft hand and suede-like appearance together with excellent drapability, and this characteristic has played an important role in the consumer-derived success of lyocell fiber. The KES-FB system developed by Sueo Kawabata [4] and the Japan Hand Evaluation and Standardization Committee in the 1970's has been used extensively for an objective evaluation of fabric hand. Specifically related to lyocell fabric analysis, Wakida *et al.* [13] adopted the KES-FB system to evaluate the fabric hand after the liquid ammonia treatment on lyocell fabric. Chattopadhyay [14], Karolia [15], and Barndt *et al.* [16] utilized the KES-FB technique to evaluate the hand of fabrics made of different fiber types after varying finish treatments. Kim *et al.* [17] and Kadole *et al.* [18] evaluated the objectivity of the measurement system and Chen [19] proposed a computerized data acquisition system for simplifying and reducing the time required for the KES-FB analysis. In most cases the KES-FB technique was proven to be a useful and an objective method for evaluating the fabric hand characteristics of the samples.

According to the Kawabata system [4], the hand of a fabric is quantified via physical measurements such as tensile, bending, shear, compression, surface characteristics, thickness, and weight obtained from a series of instrument called the 'KES-FB'. The physical measurements are mathematically converted to the sensual values within the Kawabata system denoted as the 'Primary Hand Value (PHV)' and in turn converted to the 'Total Hand Value (THV)' which describes the suitability of a fabric towards a specific garment type. While different garment parameters were developed for different garment types, the variability is yet limited to only a number of apparel items. And thus the garment parameters selected for this study were based on the availability of Kawabata parameters and the current apparel usage of lyocell fabrics [20].

Materials and Methods

Materials

Lyocell fabrics made of four different types of commercial pulp H1, H2, H3, and H4 were used and were labeled according to the pulp label. Specific characteristics of the pulp, fiber, yarn, and fabric of the four lyocell fabric samples were as follows. The four types of pulp incorporated in sample fabrics were all from the U.S.A. and the Canadian regions. Although the researchers had access to some specific characteristics of the pulps, the information was not consistently available for all four pulp types. H1, H2, & H4 were Kraft pulp made from soft wood species with H4 comprising 50:50 blend of two different pulp types. All four pulps were commercially recommended for the production of lyocell fabrics. And thus their physico-chemical characteristics should not drastically deviate from the requirements of lyocell production. However, among the four types of pulps there does exist some differences in their properties, and we examined that these differences have effect on the characteristics of resultant fabrics. One of the major characteristics which show differences among the four pulps is the D.P. values. The D.P.s of H1 and H2 pulps were around 820-840 and those of the two pulp types comprising H4 were around 600 and 1,800 each. H3 was a Sulfite pulp made from soft wood species and the D.P. value of this pulp was not provided by the manufacturer. Among H1, H2, and H3 of which the α-cellulose content was provided, H2 had the highest α-cellulose content (ca. 95 %) and H1 the lowest (ca. 85 %). With each of the above pulp, staple fibers (1.5D, 38 mm) were produced in the factory production setting (Hanil Synthetic Fiber Co., Ltd.). Yarns (20.4's ± 0.3, CV 10.5 ± 0.5 %) were spun, fabrics of denim structure were made successively and pretreated (Dongkook Corporation).

Methods

Fabrics were bio-finished in our lab using 2 different enzyme concentration levels 3 *g/l* and 5 *g/l* in a Drum Washer (size 600 mm × 400 mm, DL-3022A, Daelim Engineering, Korea). The two bio-finishing concentrations are labeled as 'BF1' (3 *g/l*) and 'BF2' (5 *g/l*) throughout the paper. For comparison, another set of sample was finished according to the same procedure but without the addition of enzyme and was denoted the 'Control'. The procedure was as follows: Fibrillation was carried out with 2 *g/l* sodium carbonate (liquor ratio 30:1 o.w.f., 2 *g/l* softner added) for 30min, followed by enzyme wash with 3 different concentration levels of acid cellulase (Bioblue®, Pacific Chemical, Korea, pH:5, 55 °C, 60 min, 2 *g/l* softner added), rinsing, softening (2 *g/l*, DK-500, Dong Kyung Corporation, Korea), and drying.

The samples were weighed prior to and after the bio-finishing treatment and the amount of weight loss was calculated as such;

$$\text{Weight Loss}(\%) = (W_t - W_o/W_t) \times 100$$

where W_t is the weight before enzyme treatment and W_o is the weight after the enzyme finish.

Tear strength was measured with Elmendorf Tear Strength Tester (HS-225, Han-Won Instrumental) following ASTM

D1424 (Test Method for Tear Resistance of Woven Fabrics by Falling-Pendulum Apparatus). Fabric stiffness was measured using Cantilever method following ASTM D1388 (Test Methods for Stiffness of Fabrics).

Individual KES-FB measurements of tensile, bending, shear, surface, compression, and thickness were obtained using Handle Ometer (Kato Tech Co., Ltd., Japan). Primary hand values (PHV) of koshi (stiffness), numeri (smoothness), fukurami (fullness and softness), sofutosa (soft feeling), shari (crispness), and hari (anti-drape stiffness) characteristics and the total hand values (THV) were calculated according to the Kawabata equations for four different Kawabata fabric parameters; women's winter suit (denoted 'WWS' in the following), women's winter thin dress (WWTD), men's dress shirt (MWDS), and men's slacks (MS) [4,21]. The Kawabata garment parameters for converting physical measurements into PHV and THV were KN-201-MDY and KN-301-Winter for women's winter suits, KN-203-LDY and KN-302-Winter for women's winter thin dress, KN-202-DS and KN-303-DS-Winter for men's dress shirt, KN-101-Winter and KN-301-W-Slacks for men's slacks. PHVs examined were koshi, numeri, fukurami, sofutosa for WWS, koshi, numeri, fukurami for WWTD, koshi, shari, fukurami, and hari for MDS, koshi, numeri, fukurami for MS following the Kawabata system. The suitability of fabric toward four garment parameters was defined as the THV of each sample following Kawabata [4]; higher than 5- excellent, 4-good, 3-average, 2-below average, 1-poor, 0-out of use.

Results and Discussion

Effect of Enzyme Finish Concentration on the Physical Characteristics

The effect of different enzyme concentrations on the physical characteristics is shown in Table 1. Higher concentration of enzyme finish resulted in greater weight loss in all fabric types. Generally, the difference in the degree of weight loss was greater between Control and BF1 than between BF1 and BF2, and H1 exhibited the highest weight loss. Higher concentration of enzyme finish resulted in a greater decrease in tear strength in all fabric types. The decrease was more significant from Control to BF1, but less or no decrease from BF1 to BF2. There was almost no difference in tear strength in H2 with the variation in enzyme concentration. There was a significant difference in fabric stiffness between Control and BF1 where latter was more softer. However, from BF1 to BF2, all four fabric types exhibited either no difference or a slight increase in stiffness.

When the rank order of the four fabric types was compared on the above physical characteristics, the overall rank order was H4, H2&H3, H1 (in the descending order) when higher rank was given to more stiff fabric. Such result was in agreement with the result of our previous study [3] that H4 pulp was ranked highest in the physical characteristics such as strength and dimensional stability.

Effect of Enzyme Concentration on the Kawabata Fabric Hand

Physical Characteristics Measured by the KES-FB System

The result of KS-FB test on the measurement of physical characteristics is shown in Table 2. Regardless of the fabric type tensile characteristics decreased with the addition of higher enzyme concentrations and the decrease was more significant between Control and BF1. Tensile resilience (RT), however, was higher in bio-finished fabrics than the Control and in most cases higher RT values were obtained from BF1 treatment. Similar to the overall tensile characteristics, the Control sample exhibited the highest bending and shearing characteristics. Generally BF2 fabrics exhibited the highest coefficient of friction (MIU) data whereas the geometric roughness (SMD) was the highest in the Control samples. More variation was observed within the compression characteristics in which measurement data varied across different fabric types.

Primary Hand Values (PHV) of Specific Garment Parameters

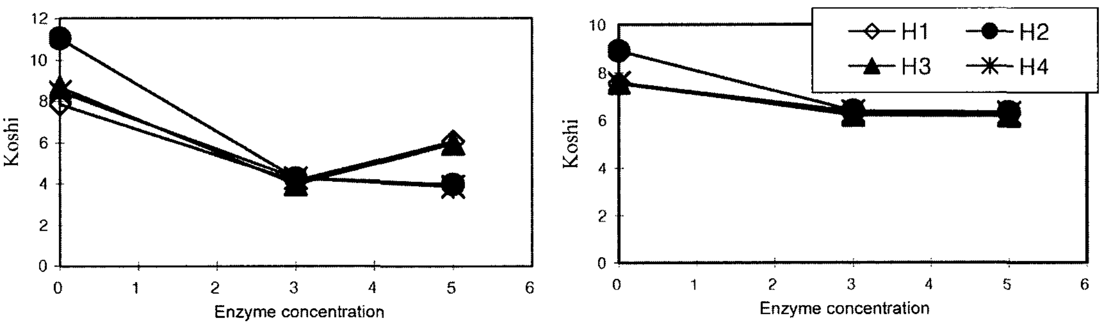
Overall, enzyme finish resulted in a decrease of koshi in all fabric types with little to no difference of koshi hand value between BF1 and BF2 treatments (Figure 1). However, in case of women's winter suit (WWS) BF1 resulted in a slight increase of koshi in H3 and H4 fabrics and then a

Table 1. Physical measurements after different bio-finishing treatments

	Enzyme finish	H1	H2	H3	H4	Mean
Weight loss (%)	Control	1.14	1.33	1.08	1.14	1.17
	BF1	3.85	1.90	2.19	2.44	2.59
	BF2	4.21	3.57	2.46	3.35	3.39
Tear strength (gf)	Control	4250	3450	3450	4566	3929
	BF1	3075	3333	2350	3475	3058
	BF2	2975	3300	2183	2366	2706
Fabric stiffness/softness (cm)	Control	3.30	3.13	3.33	3.60	3.34
	BF1	2.03	2.21	2.16	2.25	2.17
	BF2	2.21	2.11	2.15	2.21	2.17

Table 2. Kawabata test results of the pulp/bio-finish combination samples

Kawabata	Sample	H1			H2			H3			H4		
		Control	BF1	BF2	Control	BF1	BF2	Control	BF1	BF2	Control	BF1	BF2
Tensile	EM (%)	9.9838	9.8490	8.3800	8.0115	6.5905	5.9780	8.6363	7.1540	6.4900	7.4480	6.7743	5.7453
	LT	0.7241	0.6229	0.6550	0.7640	0.6537	0.6492	0.7583	0.6320	0.6660	0.7994	0.6514	0.6349
	WT (g · cm/cm^2)	17.9830	15.2145	13.5950	15.2880	10.8045	9.6530	16.2435	11.2700	10.8300	14.8715	11.0250	9.1140
	RT (%)	38.5860	48.6386	46.6600	40.2913	51.9669	51.2019	39.0815	52.3889	49.5400	40.7946	49.7946	54.2785
Bending	B (g · cm^2/cm)	0.3253	0.1135	0.1220	0.2560	0.1247	0.1198	0.2213	0.1149	0.1313	0.0682	0.1277	0.1240
	2HB (g · cm/cm)	0.2164	0.0539	0.0600	0.2687	0.0618	0.0626	0.2417	0.0652	0.0661	0.1937	0.0706	0.0620
Shearing	G (g/cm · deg)	0.7044	0.2744	0.2650	1.0400	0.2695	0.2389	1.2777	0.2573	0.2750	1.2397	0.2634	0.2401
	2HG (g/cm)	0.3748	0.2279	0.1600	0.6884	0.2426	0.1641	0.6394	0.3136	0.1750	0.7276	0.1421	0.1348
	2HG5 (g/cm)	3.1115	0.7668	0.4000	5.3728	0.9923	0.8183	5.9584	0.9873	0.6950	5.5370	0.9628	0.8575
Surface	MIU	0.1793	0.2065	1.9230	0.1874	0.1994	0.1864	0.1857	0.2252	1.8815	0.1806	0.1703	0.1899
	MMD	0.0172	0.0142	0.0157	0.0180	0.0139	0.0155	0.0169	0.0128	0.0145	0.0163	0.0212	0.0110
	SMD (μm)	3.4006	2.7097	2.6365	3.6040	2.9008	2.2761	3.7730	2.8837	2.7860	4.0425	4.0964	2.8151
Compression	LC	0.3184	0.3092	0.9850	0.3668	0.3620	0.3309	0.3277	0.3194	0.6970	0.3053	0.3382	0.3187
	WC (g · cm/cm^2)	0.3675	0.2989	0.0269	0.2881	0.3391	0.2960	0.2852	0.3165	0.0421	0.3303	0.3597	0.3293
	RC (%)	44.5333	37.3770	58.2880	52.0408	37.2832	40.3974	47.4227	35.2941	65.2056	48.3680	39.2371	36.9408
Thickness	T (mm)	1.0669	0.9302	0.1392	0.9131	0.8984	0.8594	0.9595	0.9155	0.1965	1.0034	0.9399	0.9106
Weight	W (mg/cm^2)	27.2123	26.4433	25.9280	26.3513	24.8393	24.4335	26.6893	25.2283	24.7425	26.5100	23.3715	24.7305



(a) Men's dress shirt (b) Women's winter thin dress

Figure 1. Effect of enzyme concentration on koshi primary hand value according fabric type.

decrease with BF2 treatment. This indicates that H3 and H4 fabrics were more affected by the enzyme treatment when women's winter suit (WWS) parameter was concerned.

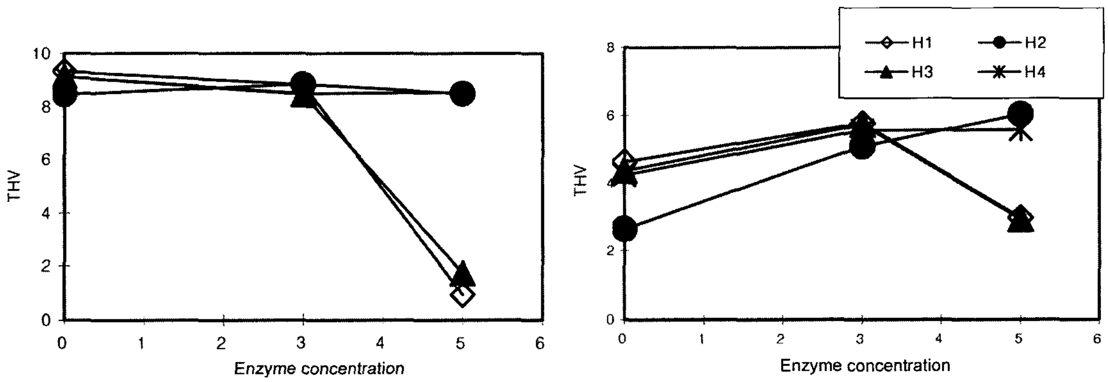
Within BF1 treatment the rank order of koshi for the four garment parameters examined were women's winter thin dress (WWTD), women's winter suit (WWS), men's dress shirt (MWDS), men's slacks (MS) in the descending order (Table 3). Overall, H2 and H4 fabrics exhibited the higher koshi value than H1 and H3 fabrics. However, H3 fabric which exhibited the lowest koshi in other garment parameters exhibited the highest koshi in women's winter suit (WWS). The numeri value generally resulted in a slight increase with BF1 treatment when compared to that of the Control. In BFl treatment there were no differences in numeri values among the four fabric types. However, with BF2 treatment H1 and H3 fabrics consistently showed a marked decrease in all PHVs, resulting in 'out of use' [4] values. The rank order of the four garment parameters for numeri in BF1 treatment was women's winter thin dress (WWTD), men's slacks (MS), women's winter suit (WWS) in the descending order (Table 3). The PHV of fukurami were similar to that of numeri with little to no difference in the fukurami values between Control and BF1 treatment. The rank order of fukurami in BF1 treatment was men's dress shirt (MWDS), women's winter thin dress (WWTD), men's slacks (MS), women's winter suit (WWS) in the descending order (Table 3). The PHVs of shari of men's dress shirt (MWDS) were negative or lower than 1 proposing a 'out of use' value in BF1 and BF2 treatments. PHV of hari for men's dress shirt (MWDS) exhibited a significant decrease from Control to BF1 treatment and none or slight decrease in BF2 treatment.

When the relationship between the mean values of the three major PHVs and the four fabric types was considered, the rank orders of the fabric type which exhibited the higher

Table 3. Kawabata summary of fabric type vs. garment parameters

PHV \ Type	Garment	BF1 Treatment H1	H2	H3	H4	Mean	BF2 Treatment H1	H2	H3	H4	Mean
Koshi	MWDS*	4.13	4.28	3.97	4.28	4.17	6.05	3.88	5.96	3.95	4.96
	WWTD**	6.24	6.39	6.21	6.36	6.30	6.23	6.30	6.19	6.34	6.26
	WWS***	4.75	4.97	6.21	6.08	5.50	4.91	4.85	4.91	4.93	4.90
	MS****	2.83	3.25	2.75	3.16	3.00	3.15	3.01	3.12	3.16	3.11
	Mean	4.48	4.67	4.78	4.97	4.74	4.29	4.51	5.04	4.59	4.80
Numeri	WWTD	8.47	8.61	8.42	8.27	8.44	0.15	8.30	1.16	8.83	4.61
	WWS	6.30	5.30	6.21	6.08	5.97	−2.17	6.06	−1.48	6.63	2.26
	MS	7.59	6.02	7.40	7.23	7.06	−8.12	7.23	−7.19	8.11	7.53
	Mean	7.45	6.64	7.34	7.19	7.15	−2.53	7.19	−2.50	7.85	4.80
Fukurami	MWDS	16.03	15.81	15.47	15.37	15.67	3.96	15.68	6.99	15.50	10.53
	WWTD	10.46	10.00	10.39	10.29	10.29	3.61	10.23	5.23	10.67	7.43
	WWS	5.60	5.14	5.50	5.47	5.43	−1.93	5.29	−0.47	5.81	2.17
	MS	6.99	6.32	6.86	6.83	6.75	−6.42	6.51	−4.16	7.36	0.82
	Mean	9.77	9.31	9.55	9.49	9.53	−0.19	9.42	1.89	9.83	5.23
Shari	MWDS	−1.48	−0.03	−1.18	−0.88	−0.89	−7.86	−1.62	−9.16	−1.12	−4.94
Hari	MWDS	2.37	3.14	2.98	3.31	2.95	1.82	2.64	1.73	2.88	2.26
Sofutosa	WWS	4.18	3.79	4.09	4.09	4.04	−5.96	4.04	4.96	4.61	1.91
THV	MWDS	8.82	8.84	8.46	8.49	8.65	0.94	8.53	1.72	8.47	4.91
	WWTD	5.77	5.08	5.72	5.56	5.53	2.98	5.58	2.94	6.04	4.38
	WWS	3.82	3.34	3.76	3.72	3.66	−0.30	3.69	0.59	4.04	2.00
	MS	2.35	2.45	2.31	2.53	2.45	−10.81	2.58	−8.06	2.48	−3.45
	Mean	5.19	4.92	5.06	5.07	5.07	−1.79	5.09	−0.70	5.25	1.96

*men's winter dress shirt, **women's winter thin dress, ***women's winter suit, ****men's slacks.



(a) Men's dress shirt (b) Women's winter thin dress

Figure 2. Effect of enzyme concentration on THV according to fabric type.

PHV values were H4, H3, H2, H1 for koshi, H1, H3, H4, H2 for numeri, and H1, H3, H4, H2 for fukurami in the descending order (Table 3). All four fabric types exhibited higher fukurami hand followed by numeri and koshi.

THV and the Suitability Toward Specific Garment Parameters

H2 and H4 showed little or no difference in the total hand value (THV) throughout the three enzyme concentration levels tested in this study, and this result was consistently observed in all four garment parameters (Figure 2). However, the THV of H1 and H3 decreased significantly with BF2 enzyme concentration in all garment parameters. THVs were lower than 2 or negative number indicating that H1 and H3 were not suitable for all four garment parameters. Considering that our previous research [3] suggested a relatively low strength

Table 4. Rank order of THV and PHV for the four fabric types

Treatment	Kawabata / Garment	THV	Koshi	Numeri	Fukurami
BF1 treatment	MWDS	H2>H1>H4>H3	H2&H4>H1>H3	N/A	H1>H2>H3>H4
	WWS	H1>H3>H4>H2	H2>H4>H1>H3	H1>H3>H4>H2	H1>H3>H4>H2
	WWTD	H1>H3>H4>H2	H2>H4>H1>H3	H2>H1>H3>H4	H1>H3>H4>H2
	MS	H4>H2>H1>H3	H2>H4>H1>H3	H1>H3>H4>H2	H1>H3>H4>H2
BF2 treatment	MWDS	H2>H1>H4>H3	H2&H4>H1>H3	N/A	H1>H2>H3>H4
	WWS	H1>H3>H4>H2	H2>H4>H1>H3	H1>H3>H4>H2	H1>H3>H4>H2
	WWTD	H1>H3>H4>H2	H2>H4>H1>H3	H2>H1>H3>H4	H1>H3>H4>H2
	MS	H4>H2>H1>H3	H2>H4>H1>H3	H1>H3>H4>H2	H1>H3>H4>H2

and low dimensional stability for H1 and H3 pulp types, the present result indicates that the lyocell fabrics made of wood pulp with low physical characteristics are more affected by high concentrated enzyme finish in terms of the fabric hand characteristics. The highest THV was observed in men's dress shirt (MWDS) in both Control and BF1 treatment of all four fabric types, whereas the lowest THV was observed in men's slacks (MS) consistently over all four fabric types and all enzyme concentration levels. The overall THVs of women's winter suit (WWS) or women's winter thin dress (WWTD) were 3 to 5 indicating a good to average suitability based on the Kawabata standard. The specific rank order was men's dress shirt (MWDS), women's winter thin dress (WWTD), women's winter suit (WWS), men's slacks (MS) in the descending order.

Rank Comparison of THV and Individual PHVs

According to Kawabata [15], koshi, numeri, and fukurami are three PHVs especially important for men's winter garments in the order of numeri > koshi > fukurami. Therefore the rank order of the three PHVs may affect the ultimate THV in the Kawabata system of evaluation. And by knowing the pattern of influence of these PHVs on the THV, it is possible to develop a production system for fabrics which will enhance the specific PHVs of the aimed end-use. According to Table 4 which summarizes the result displayed in Table 3, higher koshi tends to result in a lower THV for women's winter suit (WWS) and women's winter thin dress (WWTD) parameters, whereas higher numeri and fukurami tends to result in a higher THV for the same. On the other hand, men's slacks (MS) tends to require a higher koshi and lower numeri, fukurami PHVs to maintain the higher THV.

In summary, the appropriate enzyme concentration for obtaining an optimum as well as consistent physical characteristics and fabric hand trait was 3 *g/l* for the concentration levels tested in the present investigation. Weight loss was more affected by higher enzyme concentration than other physical characteristics. H2 was least affected by enzyme treatment for all three physical properties and fabric hand. Although some loss in weight and strength is inevitable, the strength loss in lyocell is considered to be a minor problem [22], while fabric hand required by the Kawabata garment parameters applicable to current apparel usage of lyocell fabric highly support the enzymatic treatment. 5 *g/l* concentration exhibited little difference from 3 *g/l* in the physical characteristics, whereas the KES-FB values indicated a significant loss of fabric hand in most PHVs with the 5 *g/l* concentration level. Among different garment parameters, all four fabric types were relatively inappropriate for the men's slacks (MS) fabric due to the lower hand value of koshi required by the MS parameter. However, despite the relatively low koshi values, high fukurami values required for men's dress shirt (MWDS) resulted in the highest THV among the four garment parmeters. In the case of Kawabata parameters for women's wear the differences in the numeri values among the four fabric samples may have had an effect on the THV rankings of two garment parameters. The four fabric types, which represent the usage of four different wood pulps, in general seem to exhibit a higher applicability to women's winter thin dress (WWTD) than to women's winter suit (WWS) garment parameter.

Conclusion

The result of the present investigation suggests that the enzyme concentration should be adjusted to a certain level in the lyocell defibrillation procedure in accordance with the type of wood pulp the fabric is made of and the fabric hand required by the target end-product. The present result also suggests that lyocell fabrics made of different types of wood pulp differ in their end-use applicability rather than in quality. Fabric hand or suitability of a garment parameter was more dependent upon the combination of the type of wood pulp and the degree of enzyme treatment than up on one variable alone. With the four pulp types used in this study, there was no difference among the pulp types in the suitability toward specific garment type. However, with the higher enzyme treatment, some variations may be expected of their performance. Therefore careful screening of the pulp characteristics is needed for each intended enduse and finishing procedure.

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