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Enzymatic Treatment of Viscose Fibres Based Woven Fabric

Abstract

An enzyme-based process was applied in finishing viscose fabrics, which are very susceptible to pilling because of individual loose fibres ends which protrude from surface, and impurities and fuzzes. A commercial enzyme of cellulase type Econase CE (Röhm Enzyme Finland Oy) and experimental cellulases such as endoglucanase II (EGII), cellobiohydrolase I (CBHI) and cellulase enriched with EGII (Cell. F) from the Trichoderma reesei strain prepared at VTT Biotechnology, Finland were used for modification of viscose-woven fabrics. This paper presents some results of studies concerning the estimation of the effect of enzymatic treatment on the changes in molecular and morphological structure of viscose-woven fabrics.

Key words: *viscose fabric, cellulases, enzymatic modification.*

Introduction

The textile industry has used enzymes to remove starch sizing for over 50 years. Over the last ten years, the textile industry has become familiar with the use of cellulases for stone-washing blue jeans, and more recently for finishing of fabrics and garments made on cotton, linen, lyocel and other cellulosic fibres [1,2]. In the modern textile technology finishing process, employing environmentally friendly, fully biodegradable enzymes can replace a number of mechanical and chemical operations which have hitherto been applied to improve the comfort and quality of textile materials [3,4]. The expected technical advantages resulting from the utilisation of specified enzymes for fabric finishing are as follows:

- a cleaner fabric surface with less fuzz,
- a more even fabric surface appearance,
- a reduced tendency to pill formation,
- an improved hand,
- unique softness when combined with traditional softeners,
- a more environmentally responsible means of treating textiles.

Many of the latest development studies on textile enzyme producers have been focused on improving the characteristics of cellulosic textile materials with cellulase preparations. New enzyme products are still being developed for the finishing process of cellulosic materials based on cotton, linen, viscose, lyocel and their mixtures and blends with synthetic fibres. The target of biofinishing is to remove all impurities and individual loose fibre ends that protrude from the fabric surface simultaneously in order to retain the strength of fabric at an acceptable level [5-7].

The Institute of Chemical Fibres in Łódź, Poland specialises in processing and modifying natural polymers, especially cellulose, for the manufacture of cellulosic fibres and the processing of man-made fibres. The Institute belongs to the international consortium of COST ACTION 847 entitled "Textile Quality and Biotechnology", which is engaged in searching for new biotechnological processes useful for the textile industry. While carrying out these studies, a new method for finishing cellulosic fibres by enzymes has been investigated.

The biomodification of fibres and fabrics has been carried out by specially selected cellulase and xylanases from *Trichoderma* strains. On the basis on these studies, it was found that the enzymatic treatment of cellulosic fibres caused small changes in structural and mechanical properties, accompanied by significant changes in the microtopography of fibre surface [8-10].

VTT Biotechnology in Espoo, Finland within the COST ACTION 847 programme conducted studies on developing new cellulases purified from

Table 1. *Some properties of viscose woven fabric produced by Dolwis, Poland modified by commercial cellulase.*

Type of fabric	Enzyme type	Weight loss, %	$\overline{DP}$	WRV, %	Mechanical properties		
					breaking force, daN	breaking force per cm, daN/cm	strain extension, %
Initial viscose fabric A (92 g/m^2)	-	-	324	80.3	19.5	7.8	36.5
Modified viscose fabric A	Econase CE	1.35	314	79.4	16.3	6.5	41.8

Table 2. *Some properties of viscose woven fabric produced by Melocoton, Finland modified by VTT experimental enzymes (EGII - endoglucanase, CBHI - cellobiohydrolase, CELL.F - cellulase-enriched endoglucanase).*

Type of fabric	Enzyme type	Weight loss, %	$\overline{DP}$	WRV, %	Mechanical properties		
					breaking force, daN	breaking force per cm, daN/cm	strain extension, %
Initial viscose fabric B (102 g/m^2)	-	-	502	50.3	31.8	12.7	13.6
Modified viscose fabric B	EGII	0.87	509	50.9	23.7	9.5	11.6
	CBHI	0.90	519	50.4	30.4	12.2	13.7
	CELL.F	1.32	547	49.6	27.9	11.2	13.8

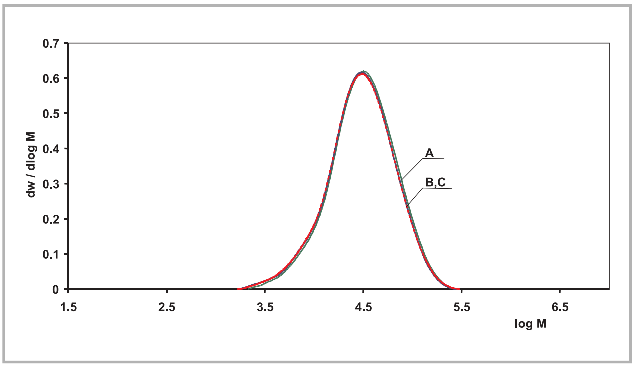

__Figure 1__. Molecular weight distribution; A - initial viscose fabric A; B - treated by Econase CE; C - Individual fibres after treatment.

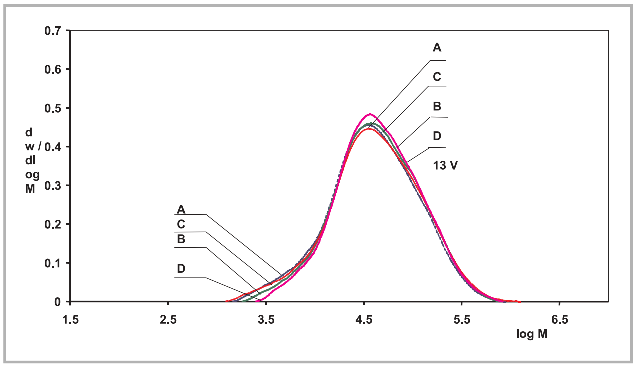

__Figure 2.__ Molecular weight distribution; A - initial viscose fabric B; B - treated by endoglucanase EG II; C - treated by celobiohydrolase CBH I; D - treated by cellulase F.

Trichoderma reesei for the biofinishing of natural and man-made fibres [11].

This paper presents some results of the common studies of IWCh and VTT realised within the COST ACTION 847 programme which concern the estimation the effect of enzymatic treatment using commercial and experimental cellulases on the changes of molecular and morphological structure of viscose woven fabrics.

__Table 3.__ Molecular characteristic of viscose woven fabric modified by commercial cellulase.

Type of fabric	Type of enzyme	Molecular characteristic						
		$\bar{M}_n x10^3$	$\bar{M}_w x10^3$	Pd	$\bar{DP}_w$	Percentage of DP fraction		
						200>	200-550	>550
Initial viscose fabric A	-	22.7	40.1	1.8	248	52	40	8
Modified viscose fabric A	Econase CE - cellulase	21.3	39.2	1.8	242	54	39	7
Residual modified fibres	Econase CE - cellulase	21.3	39.4	1.9	243	54	39	7

__Table 4.__ Molecular characteristic of modified viscose fabric modified by VTT experimental enzymes (EGII - endoglucanase, CBHI - cellobiohydrolase, CELL.F - cellulase-enriched endoglucanase).

Type of fabric	Type of enzyme	Molecular characteristic						
		$\bar{M}_n$x103	$\bar{M}_w$x103	Pd	$\bar{DP}_w$	Percentage of DP fraction		
						200>	200-550	>550
Initial viscose fabric B	-	22.3	71.3	3.2	440	41	35	24
Modified viscose fabric B	EG II	26.5	73.7	2.8	455	36	37	27
	CBH I	22.1	66.2	2.9	409	42	35	23
	CELL. F	28.2	71.2	2.5	440	37	38	25

Materials and Methods

A commercial enzyme of cellulase type Econase CE (Röhm Enzyme Finland Oy) and experimental cellulases such as endoglucanase II (EGII), cellobiohydrolase I (CBHI) and cellulase enriched with EGII (Cell. F) from the *Trichoderma reesei* strain prepared at VTT Biotechnology, Finland were used for modification of viscose-woven fabrics produced by DOLWIS, Poland and Melcoton Oy, Finland.

Enzymatic treatment of viscose fabrics
Viscose-woven fabrics were exposed to the action of the enzyme solution in an acetic buffer of pH=4.8 at temperature of 50°C by the dynamic method in a Linites machine under the following process conditions:

- The modulus of Econase CE activity (of endo-1,4-β-glucanase) to the sample weight (E/S) equalled 100 U/g.
- The dosage of Econase CE was 8 mg of total protein per gram of fabric.
- The dosages of experimental enzymes (EGII, CBHI and Cell.F) were 5 mg of total protein per gram of fabric.
- The time of reaction was 60 min.

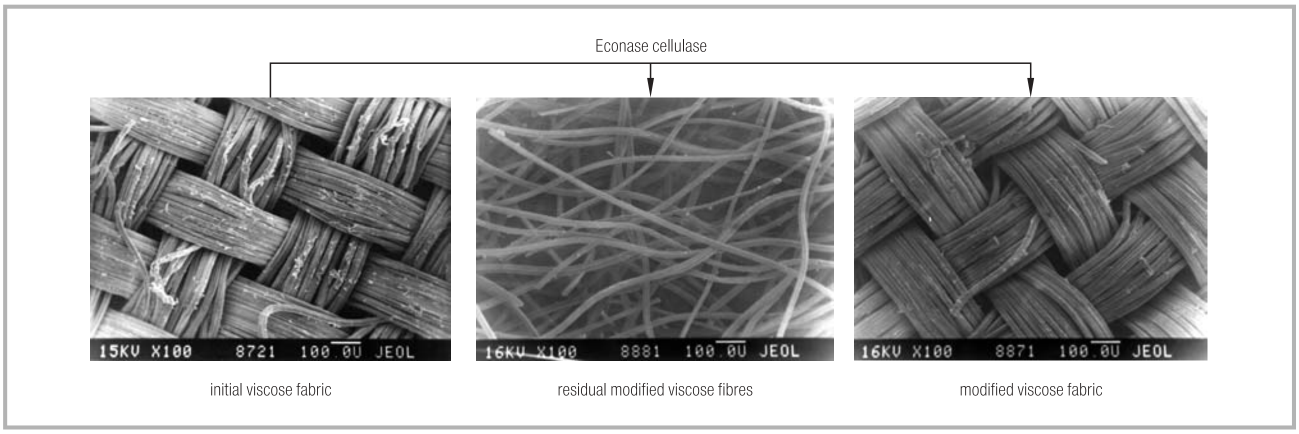

__Figure 3.__ SEM appearance of modified viscose fabric A modified by Econase CE.

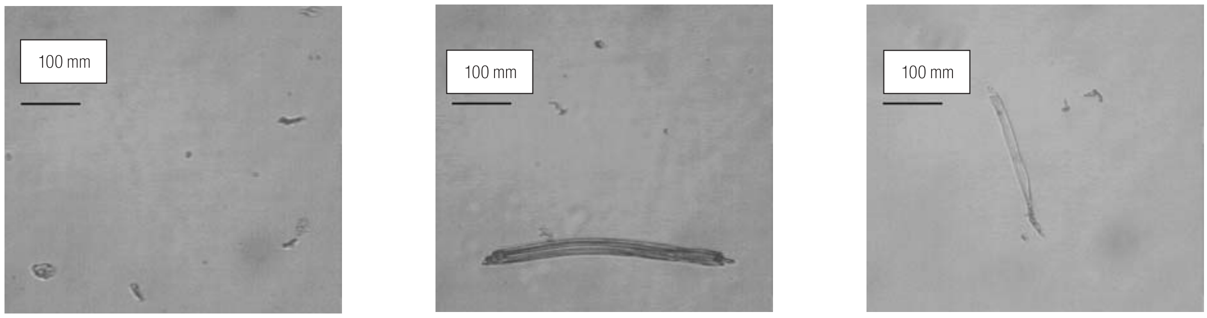

Figure 4. Microscopic photo of residual particles after enzymatic treatment of viscose fabric A.

After the treatment, the enzyme solution was filtered, and the fabrics were washed, first with hot water and then several times with cold water. The fabrics were dried at a temperature of 20±2°C.

Analytical methods

The content of reducing sugars in enzyme solutions was assessed by a colorimetric method with dinitrosalicylic acid (DNS) [12]. The endo-1,4-β-glucanase activity of the cellulases was estimated by the colorimetric method with caroboxymethylcellulose (CMC) used as a substrate [13].

The fabric weight loss was assessed by the gravimetric method. The average polymerisation degree ($\overline{DPv}$) was estimated by the viscometric method with an alkali sodium-ferric-tartrate solution (EWNN) [14]. The α-cellulose content was determined in a sodium hydroxide solution according to the Polish Standard [15]. The water retention value (WRV) was estimated by the gravimetric method [16]. The molecular weight distribution was determined by gel permeation chromatography using a GPC system consisting of an HP 1050 pump and an HP 1047 refractive detector [17].

The mechanical properties of fabrics such as breaking force, breaking force per cm and strain extension were measured using an Instron 5544 machine in the weft direction using the Polish Standard [18].

The appearance of the fabric's surface before and after enzymatic treatment was examined using a Jeol JSM-35C (Japan) scanning electron microscope at 100× magnification. The presence of residual fibrous particles in the enzyme solution after treatment were estimated by a BIOLAR ZPO (Poland) type polarisation microscope with a IMAL computer analyser.

Results

The results of previous studies on the biomodification of cellulosic fibres [19] such as viscose, Lyocel, and Celsol which were conducted in the Institute of Chemical Fibres formed the basis for the experiments concerning the application of cellulases for finishing viscose woven fabrics. Investigations related to the modification of viscose fabrics (A and B) on a small lab scale were carried out both in the presence of commercial cellualse (Econase CE) and experimental enzymes (EGII, CBHI and CELL.F) from *Trichoderma reesei* strains at 50°C for 60 min. with continuous shaking. The course of the biomodification process was evaluated on the basis of molecular and morpho-

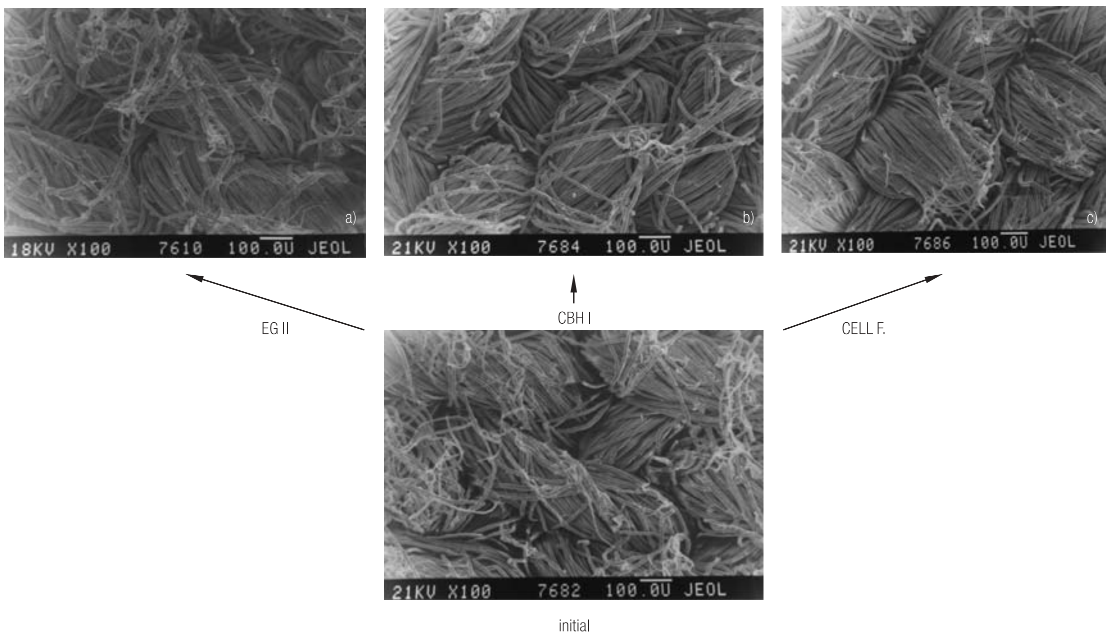

Figure 5. SEM of viscose fabric B modified by: a) endoglucanase EG II, b) celobiohydrolase CBH I, c) cellulase CELL.F.

logical characteristics as well as mechanical properties.

Some results of the studies concerned with the estimation of the effect of cellulases used on the changes of fabric properties (i.e. average polymerisation degree $\overline{DPv}$, water retention value WRV, weight loss, breaking force and strain extension) are presented in Tables 1-2.

On the basis of the results obtained (Table 1), an insignificant degradation process during the treatment of viscose fabric (A) with Econase CE was observed, which leads to a decrease in the average polymerisation degree from $\overline{DPv}=324$ for initial fabric to $\overline{DPv}=314$ for the biomodified, and also to an increase in weight loss to 1.4%.

The purified enzymes EGII and CBHI as well as CELL. F which were used for the treatment of viscose fabric (B) (Table 2) caused slight weight loss ranging from 0.9 to1.3%, and also to an increase in the average polymerisation degree, from $\overline{DPv}=502$ for the initial to $\overline{DPv}=547$ for the modified fabric by CELL.F, which resulted mainly from the solubilisation of low molecular fractions. Neither the commercial nor the experimental cellulases used affected the water retention value of the modified fabrics in comparison to the untreated ones.

The practical application of enzymes for fibre/fabric modification is strongly connected with estimating the changes in mechanical properties occurring during treatment. On the basis of the results presented in Table 1 and 2, it was observed that the breaking force of modified viscose fabric (A) dropped by about 17%, whereas the breaking force of viscose fabric (B) decreased by 25% with EGII, 4% with CBHI and 12% with CELL. F in comparison to the initial. The strain extension of viscose fabric (A) increased by about 15% after Econase CE treatment, and that of viscose fabric (B) decreased by about 15% with EGII, and was permanent with CBHI and CELL. F. Further investigations concerning the biomodification of viscose fabrics by Econase CE will focus on estimating process conditions which will cause any changes in mechanical properties.

To determine the structural changes of fabrics which occurred as a result of cellulase action, the molecular characteristic of initial and biomodified viscose fabrics was estimated by gel permeation chromatography (GPC). The results obtained are presented in Tables 3-4. The functions of molecular weight distribution of these fabrics are shown in Figures 1-2.

Based on the results obtained, it was found that no significant changes in the molecular structure of viscose fabrics (A and B) were caused after enzymatic treatment as can be clearly seen in Figures 2 and 3.. Some of the residual modified fibres which occurred in enzyme solution after fabric treatment are characterised by molecular parameters on the same level as for modified fabric (Table 1).

Within the studies of the biomodification process, the surface changes of viscose-woven fabrics treated with both commercial and experimental cellulases was evaluated using scanning electron microscopy (SEM). Some residual particles appeared in the enzyme solution after treatment of viscose fabric (A) was estimated using the polarisation microscope. The results obtained are presented in Figures 3-5.

Based on the results, it can be noted that the surface of initial viscose fabric (A) is characterised by the presence of protruding individual fibre ends and impurities, which must be removed in order to improve the fabric quality. Application of cellulase type Econase CE to treat the viscose fabric cleanses its surface by removing both the individual fibres (Figure 3) as well as impurities and fuzzes (Figure 4). When the purified cellulases (EGII, CBHI and CELL.F) are applied, no significant changes in the microtopography of modified viscose fabric (B) are observed (Figure 5).

To summarise, it can be concluded that for the experimental cellulases used, it is necessary to optimise the parameters of the enzymatic process in order to improve the effect of cleaning and smoothing of woven fabrics.

Conclusions

- Based on the results obtained, it was found that no significant changes in the molecular structure of modified viscose fabrics were caused after enzymatic treatment with either commercial or experimental cellulases.
- On the basis of these studies, we can state that enzymatic treatment carried out in presence of cellulase type Econase CE allows smoothing of the surface of viscose fabric, and the removal of impurities and individual loose fibre ends which protrud from the surface of the untreated fabric.
- Further investigations related to the scope of the problems discussed will be devoted to improving the parameters of the viscose fabric's biomodification, in order to eliminate the effect of enzymes on the changes in the mechanical properties of the fabrics.

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