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Research on the Enzymatic Treatment of Wool Fibres and Changes in Selected Properties of Wool

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Abstract
The enzymatic treatment of textiles significantly improves some of their properties as well as increases their aesthetic values and comfort of use. Enzymes can be used in order to develop environmentally friendly processes by reducing the concentration of chemical agents, water and energy consumption. In the case of wool fibres, it is possible to substitute conventional chlorine treatment by the enzymatic process, which enables to receive a fabric of the same level of anti-shrinking and anti-felting properties. The application of enzymes in the wool modification process was studied, and it was proven that the application of enzymes has an important influence on changes in the surface structure, which are accompanied by changes in certain physicochemical properties of wool fibres and fabrics.

Key words: *enzymes, wool fibres, fibre properties, electrical surface resistance, electrical volume resistance, shrinking degree, dye sorption ability.*

Introduction

Wool is a natural fibre composed (mainly) of a protein, called keratin, which is formed in the process of the biosythesis of α-aminoacids. The major parts of the wool fibre structure are the cuticule, the subcuticule, the cortex and the core. The external layer of the fibre - the cuticule - is a bundle of cells which have a structure of scales [1, 2]. The scales are responsible for the important properties of wool, such as wettability, felting behaviour, dyeability and printability [3]. A single cuticule cell has three layers. The outer surface of a scale is covered by a very thin layer called the epicuticle, which has significant resistance to enzymatic attack and fastness to alkali. Below this hydrophobic layer there are two further layers: the exocuticle and endocuticule. The exocuticule shows lower chemical, enzymatic and mechanical fastness, whereas the endocuticule has significant fastness to chemicals and enzymes. The subcuticule, separating scales from the more deeply situated cortex, is a thin layer which shows a significant chemical, enzymatic and mechanical resistance. The cortex, comprising 70 - 90% of the fibre, determines its physical and chemical properties and is not very resistant to chemical factors (fastness to chemicals), especially alkalium and enzymes. It is also a carrier of pigments, giving the fibre its specific colour. This part of the fibre consists of different kinds of cortex, orto- and paracortex cells. The core of the fibre is characterised by a cellular structure.

Wool fibre is difficult to analyse. A consequence of the specific surface structure of wool fibre, that is the scale structure of the cuticule, is the felting property of wool fibre. This characteristic worsens the final textile article's properties, especially during washing [1, 2]. The dimensional stability of textile goods influences consumer satisfaction [2]. The epicuticle, because of its smoothness and low reactivity, makes the superficial bonding of chemical reagents difficult. Taking into consideration that the epicuticule is a semi-permeable layer, the diffusion of chemical reagent molecules at and into wool fibres is hindered. For this reason, it is possible to change the superficial and dyeing properties of wool fibre and also reduce their tendency to felt by using chlorine in the form of gas or solution [1]. The most successful shrink-proofing process is based on the modification of the fibre surface by oxidative or reductive methods and/or by the application of polimer resins onto the surface [3]. The use of chlorine compounds results in the effluent pollution of the environment with adsorbable organic halogens compounds (AOX) [3, 4]. Moreover, treatment with chlorine is associated with significant water consumption. There is a possibility of substituting conventional chlorine treatment by the enzymatic process, which leads to a reduction in water, chemical and energy consumption [5, 6]. In recent years increasing interest has been observed in the modification of wool fibres with the use of enzymes, the aim of which is to weaken the fatty layer – the cuticle, being responsible for the strong hydrophobicity of wool surfaces. The enzymatic treatment of this layer leads to improvements in the functional quality of these fibres [3, 5 - 7].

Enzymes are currently more and more often applied in various areas of textile processing. From a chemical point of view, enzymes are complex proteins which act as catalysts [8]. In the case of interacting with protein fibres, the first position is occupied by proteases [9, 10] – multi enzymatic complexes, which can catalyse the process of the hydrolytic decay of protein fibres. They can be divided into the following: proteanases, which can cause the degradation of protein macromolecules, resulting in shorter polypeptide chains or single molecules of peptides; endopeptidases – causing the hydrolisis of the peptide chain at the end of the macromolecule and in accidental places; exopeptidases - causing only the decay of macromolecule endings; lipases - hydrolising lipids to become glicerine and fatty acids; lipoproteins -decomposing lipoprotein bonds and contributing to the violation of the hydrophobic barrier in the form of an epicuticle [9].

In the case of wool fibre, when the fibre is a polipeptyde substrate, the kinetic of the catalityc enzymatic reaction does not only depend on the substrate concentration, the temperature and pH values of the bath but also on the enzyme diffusion rate on and to the inside of the stable phase of the substrate, as well as on the diffusion of reaction products from the stable phase to the solution; these products (peptides in the case of wool fibre) are soluble substrates, with which some enzymes in the bath can bind. Regarding the process of enzyme diffusion from the solution to the inside of the wool fibre, it

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can be noticed that this process ensures dye diffusion in the fibres. The following four phases can be distinguished: enzyme diffusion in the bath, enzyme adsorption on the fibre surface, successive catalytic enzymatic hydrolysis of the surface layer of the fibre material, and the reaction of the enzymatic catalysis [11].

The complex structure of natural fibres, especially wool fibres, makes enzymatic modification difficult. Enzymes such as proteases and lipases catalyse the degradation of different components of wool fibres, making the reaction difficult to control. During uncontrollable diffusion to the fibre, proteases can cause the hydrolisis of the endocuticle and subcuticule, causing damage to the wool fibre. Thus, at least for some applications, the effectiveness of enzyme action must be limited to the fibre surface only. The aim of this process is to improve wool fibre properties, that is, to reduce shrinkage, soften the product for handle improvement, increase pilling fastness, as well as improve the course and effectiveness of the dyeing and bleaching processes [12]. The hydrolytic attack of an enzyme usually cannot be limited only to the fibre surface. Enzymes can diffuse inside the fibre, causing strength loss [5]. Longer proteolytic treatment leads to a higher loss of tensile strength [13]. Alkaline peroxide pretreatment improves enzyme diffusion inside wool fibre [5]. Proteolytic treatment improves the whiteness of wool samples [13]. Proteases can cause a loss of fabric strength and shape, as well as poor colour fastness [14].

Wool dyeing is a process which requires high temperature, lots of time and an acidic-to-neutral pH medium. This process leads to harsh handle and discomfort [15]. Applying enzymes in the process of dyeing improves the sorption properties of wool, which makes it possible to decrease the temperature, shorten the duration of the process and level the colour along the whole hair length [4]. The enzymatic treatment of wool gives more rapid kinetics in the dye adsorption of reactive dyes, acid dyes and 1:2 metal complex dyes in comparison to untreated wool samples [13].

It is also possible to use chemically modified proteases with improved thermal stability of enzymes. This kind of enzyme modification does control the reaction of the enzyme with wool, causing less degradation. Modified enzymes produce an anti-felting effect on fabrics. After treatment with the use of modified enzymes, the dyeing properties of wool fabrics appear to be unaffected. Dyed fabrics show good colour fastness properties [7].

Recently an environmentally friendly enzymatic treatment for wool fibre and fabric has been investigated. With this aim, different proteases such as papain, pronase, Bactosol WO, Alcalase 2.0T, savinase and other enzymes were used in literature [13]. Wool samples were treated with the use of these enzymes at different conditions (different pH values, treatment times, temperatures and enzyme concentrations), and changes in different properties were checked. The use of enzymes to improve white colour, shrinking behaviour, dyeing affinity [15], pilling behaviour [5, 16] and tensile strength [5] in the woollen sector is particularly interesting.

The application of enzymes in the wool modification process was studied. The enzymes Bactosol WO and Savinase/ Novozym were used in accordance with producer recommendations. It has been proven that the application of enzymes has an important influence on changes in the surface structure, which are accompanied by changes in certain physicochemical properties of wool fibres and fabrics. The aim of the study was to determine the influence of enzymatic treatment on the following wool fibre properties:

- the surface electrical resistance and volume electrical resistance;
- the half decay time of the electric charge in the fabric;
- the fulling capacity of fabric in alkali and degree of shrinkage;
- the dye sorption ability and general dyeability effect.

The aim of this experiment was also to evaluate the relation between the treatment used, loss of fibre weight, and its water sorption ability, expressed by the humidity and water retention.

Experimental part

An experiment was carried out with raw wool fabric samples of plain weave and the following loose fibres:

- wool originating from sheep (the Lublin region) – NIZ/L,
- merino wool from the Opole region– MER/O,
- merino wool from the Poznań region– MERYNOS P.

Those loose fibre samples were washed only in order to remove the fats of wool fibres, and raw wool fabric samples were used without any pretreatment.

The results were compared with those obtained for untreated raw fabrics and raw loose fibres.

Characteristics of the chemical reagents used:

- Sirrix 2 UD (Clariant Produkte AG) – its aim is to remove natural impurities, which improves the effects of pretreatment and wool fibre bleaching. Sirrix 2 UD shows strong effects in both an acid and alkali environment. Thanks to Sirrix 2 UD, bleaching processes are effective. Intentional effects can be achieved with a reduced amount of hydrogen peroxide, a reduced bath module and reduced treatment time;
- Sandozin MRN (Sandoz Chemikalien AG)– a non-ionic, silicone- and solvent- a free wetting, washing and cleaning agent with strong wetting properties in the whole range of pH and temperature. This reagent has a very good level of emulsification capability. It is very stable in both an acid and alkali environment;
- Bactosol WO (Sandoz Chemikalien AG) – biocatalyst based on hydrolase enzymes which acts on protein fibres. These enzymes cause the degradation of scales on the wool fibre surface, which means the scales are softened or removed. Bactosol WO is active and stable in the range of pH = 7 - 11. The optimum temperature of application is 40 - 60 °C.
- Savinase/Novozym (Novo Nordisk) – biocatalyst of alkali character. A bath with appropriate pH values must be prepared. The optimal pH equals 7 - 8 and temperature 60 - 70 °C. To increase its action, non-ionic surfactants can be added.

Both enzymes were used in accordance with producer recommendations.

Two research processes were carried out: *pretreatment* at 60 °C for 20 minutes in a bath containing 3 ml/l of Sirrix 2 UD and 1 ml/l of Sandozin MRN; *enzymatic treatment* with use of Bactosol WO and Savinase, with two pH values of the bath: 7.5 and 8.5, at 60 °C for 40 minutes in a bath containing 1% and 3% of enzyme, 1 g/l of Sandozin MRN. Suitable pH values of the baths were achieved by using

NaOH. These treatments were carried out in an AHIBA sample dyeing machine.

Investigation methods

The electrical resistance of the samples was assessed according to polish standards [17] using a Keithley electrometer type 610C and Statron voltage source type 4Z18.

The fabric samples were placed in an arrangement of three electrodes which were connected to a constant tension source. Electrical resistance tests were performed in order to measure the stationary value of current intensity that flows through the sample, which was put in a constant electric field. The surface electrical resistance and volume electrical resistance were assessed for each fabric sample.

For loose wool fibres, the surface electrical resistance was assessed using the same electrometer and voltage source. The fibre samples were put in a cell in a system connected to the electrometer and constant current source. Electrical resistance tests were performed in order to measure the stationary value of current intensity that flows through the sample, which was put in a constant electric field.

The half-decay time of the electric charge in the fabric was tested using a DR measuring instrument, produced in Poland.

The degree of shrinkage in a fulling condition in alkali was assessed according to polish standards. The wool fabric samples (10 × 6 cm) were put in metal cubic measures together with 30 stainless steel balls with a diameter of 0.6 cm. The treatment was carried out in an AHIBA sample dyeing machine in a bath containing 50 g/l of Pretepon G and 10 g/l of anhydrous Na_2CO_3 at 40 °C for 2 h. After this treatment, the samples were rinsed in cold water and dried. The degree of shrinkage was assessed using the following formula:

$$K_w = (I_0 - I_1) / I_0$$

where:
I_0 – dimension of fabric sample along the weft - before treatment,
I_1 – dimension of fabric sample along the warp - after treatment.

The humidity of the fibre was evaluated after acclimatisation in dry and normal climate conditions. The water retention of the fabric was evaluated according to American Standard ASTM D 2402 – 94. The dyeability of the fibre was evaluated on the basis of the results obtained at a temperature of 100 °C after 1 h. The samples were dyed with the following : C.I. Acid Blue 40 and C.I. Acid Yellow 194. The dyeing process was carried out in baths containing 2% of dye and 4% of CH_3COOH (30%). The degree of dye sorption was measured with the use of colorimetric methods (colorimeter "Spekol" – Karl-Zeiss-Jena).

The weight loss of the fibre was evaluated using the gravimetric method.

Results and discussion

Results of the surface electrical resistance and volume electrical resistance at

Table 1. *Electrical surface resistance ρ_s, in Ω of the fabric at RH = 25% and RH = 65%.*

Treatment condition	$\rho_s \times 10^{-13}$, Ω			
	ρ_s at RH = 25%		ρ_s at RH = 65%	
	pH of bath		pH of bath	
	75	85	75	85
Untreated fibre	75		003	
Sirrix 2 UD + Sandozin MRN	56		021	
(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	108	144	0.38	0.48
(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	120	130	0.46	0.53
(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	102	110	0.38	0.48
(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	84	95	040	042

Table 2. *Electrical volume resistance ρ_v, in Ωm of the fabric at RH = 25% and RH = 65%.*

Treatment condition	$\rho_v \times 10^{-10}$, Ω			
	ρ_v at RH= 25%		ρ_V at RH= 65%	
	pH of bath		pH of bath	
	75	85	75	85
Untreated fibre	297		024	
Sirrix 2 UD + Sandozin MRN	406		245	
(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	526	547	2.73	3.53
(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	506	627	3.30	3.72
(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	841	511	1.41	3.49
(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	682	596	2.97	2.83

Table 3. *Electrical surface resistance ρ_v in Ωcm of the fibres (NIZ/L, MERYNOS P and MER/O) at RH = 25%.*

Fibre	Treatment condition	$\rho_v \times 10^{-11}$, Ωcm			
		ρ_v at RH=25%		ρ_v at RH=65%	
		pH of bath		pH of bath	
		7.5	8.5	7.5	8.5
NIZ/L	Untreated fibre	334		5.32	
	Sirrix 2 UD + Sandozin MRN	184		1.11	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	204	402	1.91	2.62
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	352	437	2.25	3.25
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	285	260	2.33	2.32
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	280	287	2.43	2.59
MERYNOS P	Untreated fibre	311		6.34	
	Sirrix 2 UD + Sandozin MRN	139		1.43	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	187	131	2.25	2.03
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	186	159	1.96	2.15
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	247	229	3.67	3.80
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	232	277	5.49	4.28
MER/O	Untreated fibre	406		9.20	
	Sirrix 2 UD + Sandozin MRN	116		2.29	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	167	191	2.39	3.14
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	176	204	2.59	3.20
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	179	209	3.27	3.75
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	204	197	2.32	4.00

RH=25% and RH=65% are presented in ***Tables 1*** and ***2***.

Results of the surface electrical resistance of the fibres are given in ***Table 3***.

The half-decay time of the electric charge in the fabric is presented in ***Table 4***.

In natural climate conditions, values of the surface and volume electrical resistance of the fabrics and fibres (***Table 1, 2 & 3***) are about two orders of magnitude smaller than in dry climate conditions. Values of the surface electrical resistance of the fabric is at a level of 10^{15} Ω in dry climate conditions and 10^{13} Ω in normal climate conditions. The value of the volume electrical resistance of fabric is at a level of 10^{12} Ωm in a dry climate and 10^{10} Ωm in a normal climate. The value of the volume electrical resistance of loose fibres is at a level of 10^{13} Ωcm in a dry climate and 10^{11} Ωcm in a normal climate. For fabrics, enzymatic treatment causes a slight rise in surface and volume electrical resistance. In the case of the fibres, the influence of enzymatic treatment was a reduction in volume electrical resistance, different for individual kinds of fibres.

A remarkable decrease in the half-decay time of the electric charge T in the fabric (***Table 4***) can be observed. The value T in a normal climate is ten times lower than in a dry one. The results show quite quickly the decay of the electric charge in the fabric.

Results of the fabric shrinking degree W in %, fibre humidity W_{wzg} in %, water retention R in % of the fabric and weight loss of the fibres U in % are given in ***Tables 5, 6, 7*** and ***8***, respectively.

The untreated fabric samples and fabric samples after pretreatment show the highest value of the shrinking degree, which is at a level of 4%. After enzymatic treatment with Bactosol WO (3%) at a value of 7.5 pH of the bath and after enzymatic treatment with Savinase (1%) at a value of 8.5 pH of the bath, the fabric samples achieve the smallest value of the shrinking degree – at a level of 1.84%. For other enzymatic treatment variants, the shrinking degree is in the value range of 2.67 – 3.67.

Merino wool (MER/O) absorbs the most humidity. The values of fibre humidity are at a level of 8 – 16%. The smallest values of fibre humidity are for fibres Merynos P. (7.1 – 10.8%).

After enzymatic treatment with Bactosol WO at a value of 8.5 pH of the bath, fibres NIZ/L and MER/O show the highest values of fibre humidity. After pretreatment, the value of this degree is smallest. For other variants, the values of fibre humidity are of the same level.

Untreated fabric shows the highest value of water retention (83.2%). The smallest value of water retention is for fabric after pretreatment. The application of enzymatic treatment, especially with Bactosol WO (3%), causes water retention.

The weight loss of the wool fabric samples is an indirect measure of enzyme activity. It is also important in terms of excessive fibre strength deterioration. In the case of MERYNOS P, one can clearly observe the greater effects of the Savinase enzyme than those of Bactosol WO.

Table 9 shows results of the degree of dye sorption c_f in mg of dye/1g of fibre.

Table 4. *Half-decay time of the electric charge in the fabric T.*

Treatment condition	T, s			
	T at RH = 25%		T at RH = 65%	
	pH of bath		pH of bath	
	7.5	8.5	7.5	8.5
Untreated fibre	271.35		0.2518	
Sirrix 2 UD + Sandozin MRN	187.65		0.274	
(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	468.90	348.85	3.5750	2.0875
(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	277.70	280.70	2.0815	2.0145
(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	211.60	219.90	2.1045	1.8495
(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	216.15	212.30	1.8085	1.9325

Table 5. *Degree of fabric shrinkage W, in % of the fabric.*

Treatment condition	W, %	
	pH of bath	
	7..5	8.5
Untreated fibre	4.00	
Sirrix 2 UD + Sandozin MRN	4.00	
(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	2.67	2.67
(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	1.84	3.17
(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	2.84	1.84
(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	3.67	3.17

Table 6. *Fibre humidity W_{wzg} in % of wool fibres.*

Fibre	Treatment condition	W_{wzg}, %	
		pH	
		7.5	8.5
NIZ/L	Untreated fibre	10.0	
	Sirrix 2 UD + Sandozin MRN	8.0	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	7.7	12.2
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	11.0	11.0
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	8.8	9.2
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	8.1	9.3
MERYNOS P	Untreated fibre	9.8	
	Sirrix 2 UD + Sandozin MRN	7.7	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	9.5	9.7
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	8.6	9.3
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	8.0	7.2
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	10.8	7.1
MER/O	Untreated fibre	10.0	
	Sirrix 2 UD + Sandozin MRN	7.7	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	10.2	10.0
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	10.0	16.0
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	9.6	10.0
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	8.0	9.3

Table 7. Water retention R in% of the fabric.

Treatment condition	R,%	
	pH of Bath	
	7.5	8.5
Untreated fibre	83.2	
Sirrix 2 UD + Sandozin MRN	51.5	
(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	68.6	71.2
(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	80.2	76.8
(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	61.4	61.1
(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	66.7	70.6

Table 8. Weight loss U in % of the fibres.

Fibre	Treatment condition	U,%	
		pH of bath	
		7.5	8.5
NIZ/L	Untreated fibre	-	
	Sirrix 2 UD + Sandozin MRN	5.04	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	6.50	7.60
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	6.70	7.00
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	7.27	7.38
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	6.87	7.54
MERYNOS P	Untreated fibre	-	
	Sirrix 2 UD + Sandozin MRN	2.96	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	0.17	1.30
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	0.30	0.91
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	5.51	4.43
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	4.35	4.43
MER/O	Untreated fibre	-	
	Sirrix 2 UD + Sandozin MRN	2.96	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	1.56	2.43
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	1.75	3.58
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	4.82	4.00
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	4.34	5.73

Table 9. Degree of dye sorption c_f (mg of dye/ 1g of fibre).

Fibre	Treatment condition	Dye			
		C.I. Acid Blue 7		C.I. Acid Yellow	
		pH		pH	
		7.5	8.5	7.5	8.5
NIŻ/L	Untreated fibre	0.6		1.8	
	Sirrix 2 UD + Sandozin MRN	14.8		19.2	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	16.0	12.7	19.2	18.6
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	13.3	10.8	19.0	19.6
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	13.3	14.0	19.2	19.4
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	14.4	15.7	19.0	18.6
MERYNOS P	Untreated fibre	3.9		3.4	
	Sirrix 2 UD + Sandozin MRN	16.3		19.7	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	14.8	12.4	19.4	18.5
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	10.8	10.8	19.7	18.8
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	16.9	14.8	19.4	19.6
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	16.9	17.2	19.2	19.8
MER/O	Untreated fibre	4.3		9.4	
	Sirrix 2 UD + Sandozin MRN	14.0		19.7	
	(Sirrix 2 UD + Sandozin MRN) + 1% Bactosol WO	16.6	16.6	19.4	18.9
	(Sirrix 2 UD + Sandozin MRN) + 3% Bactosol WO	14.4	16.3	19.6	19.8
	(Sirrix 2 UD + Sandozin MRN) + 1% Savinase	12.4	12.7	19.6	19.2
	(Sirrix 2 UD + Sandozin MRN) + 3% Savinase	17.2	15.8	19.7	19.2

The application of the enzymatic treatment of fibres gives a significant increase in the degree of dye sorption, different for individual kinds of wool fibres and dyes. The best growth of dye ability after enzymatic treatment occurs for wool fibres from the eastern region after treatment with acid and metal complex dyes. For merino wool from the southern and western regions, the growth of the degree of dye sorption is also high, especially for acid dye. In the case of metal complex dye, merino wool from the western region shows an insignificantly lower level of the dye sorption degree than fibre after enzymatic treatment. The application of enzymes causes changes in dye sorption, but the reduction or increase is not significant. Pretreatment has the most important influence on the increase in dye sorption.

Conclusions

In general, it can be concluded that enzymatic treatments had a positive influence on the wool fibre properties selected, irrespective of the kind of enzymatic preparation.

In the case of fibres, the following can be observed:

- Decrease in the volume electrical resistance of fibres –different levels for different kinds of wool.
- Significant increase in dye sorption values for acid and metal complex dyes.
- Weight decreased by ca. 3 – 7%.

For fibres in the form of woven fabrics, the following were noted:

- No significant increase in surface electrical resistance and volume electrical resistance.
- Decrease in shrinkage.
- Decrease in the water retention degree of the fabric.
- Decrease in the half-decay time of the electric charge in the fabric.

It is important to state that enzymatic processes cause the modification of wool fibre surfaces. From the electron microscopy observation [4], it can be deduced that from the scales surrounding the fibre, the thin layer of epicuticle is removed, which is a barrier for dye diffusion, influencing the anisotropy of the friction coefficient and creating advantages from the point of view of wool mechanical processing in the form of nonwoven products.

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