Comparative Study of The Finishing Effects Imparted by Enzymatic Treatments Applied to Undyed and Dyed Wool Fabrics

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Abstract: The use of enzymes in the finishing of wool fabrics could be an alternative to the traditional finishing with chemicals. The main objective is to obtain some finishing processes that are more environment-friendly than the traditional ones. Recently, the research on the application of different types of enzymes has been intensified in order to achieve different finishing effects. Concretely, the proteases are one of the types of enzymes that have shown to be efficient to confer the wool a better behaviour regarding felting shrinkage. They also improve the handle and the drape of the fabrics. The effectiveness of the enzymatic treatment appreciably varies depending on the type of protease and the application conditions. The enzymatic treatment has shown to be effective to improve the softness, handle and drape of the fabrics, as well as to increase their pilling resistance when the treatment conditions are intense enough. However, these treatment conditions can produce excessive losses on mechanical properties. The effects caused by the enzymatic treatment present, in general, the same tendencies in undyed and dyed fabrics. Nevertheless, in some parameters, significant differences are observed. The enzymatic treatments may also produce small changes in the colour of the dyed fabrics. These changes in colour are mainly due to luminosity variations.

Keywords: Protease, Enzimatic treatment, Finishing, Wool.

INTRODUCTION

The use of enzymes in the finishing of wool fabrics could be an alternative to the traditional finishing with chemicals. The main objective is to obtain some finishing processes that can be more environment-friendly than the ones that are traditionally used. Recently, research on the application of different types of enzymes has increased in order to achieve different finishing effects. Concretely, the proteases are one of the types of enzymes that have proved to be efficient in order to confer the wool a better behaviour regarding felting shrinkage and to improve the handle and the drape of the fabrics too. The effectiveness of the enzymatic treatment varies appreciably depending on the type of protease and the application conditions [1-8].

The authors have studied the action of several proteases applied on wool fabrics with several objectives: reducing their felting shrinkage, improving their softness and drape, improving their behaviour regarding tincture. The effects of the enzymatic treatment on the colour quality of fabrics that are dyed with different types of dyestuffs have been also studied, as well as the application possibilities of the enzymes as dyeing auxiliaries [9-16].

In the present work, a protease has been applied to a high quality wool fabric with the aim of improving its softness, handle and pilling. A comparative study of the effects produced by the enzymatic treatment when applied to an undyed wool fabric and to the same fabric dyed with a trichromy of pre-metalized dyes has been performed. After the enzymatic treatment, all the fabrics underwent the appropriate industrial mechanical finishing operations, so that they underwent a process which is identical to the one that would be industrially applied to a fabric with similar characteristics. The variables of the study are the conditions of the enzyme application: enzyme concentration, temperature and time of treatment. The enzymatic treatments were applied to the undyed fabric and to the fabrics dyed in three dyeing intensities: pale, medium and dark. The effectiveness of the enzymatic treatment when it comes to conferring the finishing effects is evaluated by determining the softness, compressibility, bending and pilling of the fabrics. The possible negative effects are evaluated by determining the tensile strength and abrasion resistance. In the dyed fabrics, the changes in the colour produced by the enzymatic treatment have been evaluated too.

EXPERIMENTAL

Materials

The textile material was a worsted 100% wool fabric, usually applied in high quality garments. The structural characteristics of this fabric are:

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Weave: step twill

Weight/m^2: 228 g/m^2

Density: Warp, 30 ends/cm

Weft, 25 picks/cm

Prior to the dyeing and the enzymatic treatment, the fabric was scoured (in a scouring-milling machine with a solution of calcium carbonate and non-ionic detergent), rinsed and acidulated at pH 5 and dried in a three floor rame, appropriate for wool articles.

Dyes, Dyeing Formula and Dyeing Process

The following pre-metalized 2:1 dyes were used: Yellow Lanaset 2R, Red Lanaset G and Blue Lanaset 2R. The formula and dyeing process are those recommended in the technical specification of Lanaset dyes [17]. Trichromatic combinations in three different intensities were carried out. The three dyes were in the same proportion for each of the intensities. The same dyeing formulas were used for all the intensities, and only the quantity of dyes varied:

Dye 0,2% (pale), 0,8% (medium), 2% (dark) o.f.w.

Albegal SET 1% o.f.w.

Sodium sulphate 10% o.f.w.

Sodium acetate 2 g/l

pH 4,5 with acetic acid

Liquor ratio 1/10

The dyeing process was a conventional process, with a maximum temperature of 100°C. The interval of time at the maximum temperature varied depending on the dyeing intensity. For the pale intensity the time was 20 minutes, 30 minutes for the medium intensity and 40 minutes for the dark intensity.

Enzyme and Enzymatic Treatment

For the enzymatic treatment the enzyme Novolan T (Novo Nordisk) was used. It is a protease produced by fermentation of a micro-organism of the Bacillus type that has been genetically modified. According to the technical information [18], it is especially suitable for improving the hand of the wool fabrics imparting a soft hand and a special fall, as well as to minimise the hairiness of the surface and the pilling.

Prior to the enzymatic treatment, the wool was conditioned in a water bath with 1% of sodium carbonate, for 30 minutes at 50°C. This way, the pH of the enzymatic bath was kept constant throughout the treatment.

The enzymatic treatment was carried out under the conditions shown in Table **1**.

Table 1: Conditions of the Enzymatic Treatments

	Intensity of the Enzymatic Treatment		
	Soft (S)	**Medium (M)**	**Intense (I)**
Enzyme concentration (% o.f.w.)	1	3	5
Temperature (°C)	45	50	55
Time (min)	15	30	45
pH (sodium carbonate)	8,5	8,5	8,5
Liquor ratio	1/10	1/10	1/10

After the enzymatic treatment, in order to denaturalise the enzyme, the fabric was held for 5 minutes at a temperature of 90 °C and a pH lower than 4 (with sulphuric acid). After the denaturalisation, the fabric was rinsed several times to eliminate the enzyme remains and free fibres released in the treatment.

Industrial Finishing Process

The finishing of either the dyed and enzymatically treated, or the untreated dyed fabrics were carried out in a company which is specialised in wool finishing, following a complete industrial process:

- Shearing: to eliminate the free fibres that stood out from the fabric surface.
- Ironing in melton: to obtain a plane surface, free of wrinkles.
- Continuous fixing: to fix the fabric dimensions.
- Free vaporising: to slightly fluff the fabric.in this treatment a certain fluffy was conferred to the fabric
- Decatizing in KD: to get a completely flat surface

Parameter Determination

The following parameters were determined:

- Softness test: according to method INTEXTER MO B9.1/08/24 [19].

- Compression properties: according to the Compression Tester method KES-FB3 [20].
- Bending properties: according to the Pure Bending Tester method KES-FB2 [21].
- Pilling resistance: according to EN ISO 12945-2, Martindale method [22].
- Tensile strength and breaking elongation: according to EN ISO 13934-1[23].
- Abrasion resistance: according to EN-ISO 12947-2, Martindale method [24].
- Colour differences: the change in colour on the dyed fabrics produced by the enzymatic treatment and the finishing process were evaluated by the CIELab colour differences, according to ISO 105-J03 [25].

RESULTS AND DISCUSSION

Softness

The softness of a fabric is associated with a great number of physical properties. Several of these properties were determined in this study, such as bending and compression. Nevertheless, despite the existence of a number of methods to assess the softness of fabrics, none of them accords with the highly subjective sense of what is soft or what is not.

Therefore, the evaluation of this property has been carried out by a subjective test, in which eleven experts in the evaluation of the feel of fabrics participated. The methodology was as follows: equally-sized samples of all the fabrics were prepared. Each evaluator compared all the possible binary combinations of these samples. The evaluation was carried out only by touch, as the evaluators were not allowed to see the samples. The order of softness of a fabric sample is the result of computing the number of times that each sample is chosen as softer by each evaluator. A table is made gathering the evaluation of the order of softness given by each evaluator.

According to the results of the test, the softness order of the undyed samples, from highest to lowest, is as follows:

Fabric treated under intense conditions > Fabric treated under medium conditions > Untreated fabric > Fabric treated under soft conditions

The results on the test of the dyed fabrics at any of the dyeing intensities are not solid enough to make any conclusions, as in all cases the evaluators had plenty of difficulties differentiating the softness of any pair of samples. It seems as if the dyeing process already produces a change in the touch of the fabrics. Thus, the changes produced by the enzymatic treatments are hard to detect.

Compression Properties

The results calculated from the compression curve given by the Compression Tester of Kawabata are shown in Table **2**. Compression properties are related to the sponginess and bulkiness of the fabric.

Results corresponding to the undyed fabrics show that the linearity of the compression curve decreases with the increase of the enzymatic treatment intensity. A lower linearity means that the fabric can be easily compressed by exerting small increases of pressure. Regarding the compression energy results, they show that the highest values are obtained for the fabrics that were treated with enzyme. This means that the treated fabrics require a higher energy to reach a specific load. The compression resilience of the fabric decreases with the increase of the intensity of the enzymatic treatment. Hence the recoverability from compression deformation decreases as the intensity of the enzymatic treatment increases, that is, treated fabrics show more inelastic compression properties. The compressibility values are related to the variation of the fabric thickness under different pressure values. From the values exposed in Table **2** it can be deduced that the fabrics treated with enzyme are thicker than the untreated ones. The compression rate is also higher on the treated fabrics and it increases slightly with the treatment intensity.

Dyed and undyed fabrics follow, in general, the same trend. That is, the enzymatic treatment seems to affect the compression properties of the undyed and dyed fabrics in a similar way. The values of compression energy WC are somewhat lower in the dyed fabrics, while the resilience RC does not differ practically. For the dyed fabrics, the compressibility of the fabrics treated with enzyme is higher than the compressibility of the untreated fabric, as found for the undyed fabrics. However, in these cases, a clear dependence between the compressibility rate and the treatment intensity has not been found.

Bending Properties

Results deduced from the KES Standard Chart given by Kabata "Pure Bending Tester" are shown in Table **3**. Bending properties are related to the behaviour of clothing regarding draping and wrinkles.

Table **3** shows that, in the weft direction, the undyed fabric that exhibits the lowest rigidity, that is, the fabric that can be more easily bent, is the fabric that has been treated with enzyme under intense conditions. Although the other two treated fabrics cannot be considered significantly different, they show a somewhat higher rigidity. The fabric treated under the soft conditions has the highest rigidity. These results are in agreement with the subjective evaluation of the softness, *i.e*. the fabrics assessed as the softest are also the most flexible ones. In the direction of the warp, the values seem to be less coherent. The untreated fabric and the fabric treated with enzyme under intense conditions, show the lowest rigidity values. The values are very similar among those fabrics. The fabric treated under the soft conditions has, once again, the highest rigidity. Regarding the hysteresis of the undyed fabrics, the enzymatic treatment produces, in general, a decrease of its values. A lower hysteresis means that the fabrics recover more easily after a bending deformation. The fabrics with a better draping will not only have lower bending rigidities, but smaller hysteresis values as well.

Dyed fabrics, whether untreated or treated with enzyme, have somewhat lower rigidity values than the undyed fabrics. This seems to point out that the fabric is less stiff after the dyeing. The dyed samples have as well lower hysteresis, hence, an improvement in the recovery after bending deformation is produced with the dyeing. The variation in the rigidity and hysteresis values of the dyed fabrics do not present a correlation with the intensity of the enzymatic treatment and, thus, a general conclusion about whether the enzymatic treatment improves the bending properties of all these fabrics or not, cannot be drawn.

Table 2: Compression Properties (where LC is the Linearity of the Compression-Thickness Curve, WC is the Work for Compression in gf·cm/cm^2, RC is the Compression Resilience in %, TO is the Fabric Thickness at Pressure 0.5 gf/cm^2 in mm, TM is the Fabric Thickness at Pressure 50 gf/cm^2 in mm, and EMC is the Compressibility in %)

Dyeing	Enzymatic Treatment	Compression Properties					
		LC	WC	RC	TO	TM	EMC
Undyed	Untreated	0,729	0,409	63,655	0,757	0,531	29,8
	Treated under soft conditions	0,665	0,453	64,128	0,869	0,596	31,4
	Treated under medium conditions	0,646	0,441	60,687	0,852	0,578	32,1
	Treated under intense conditions	0,622	0,446	59,497	0,868	0,581	33,1
Pale intensity	Untreated	0,687	0,388	63,922	0,778	0,551	29,1
	Treated under soft conditions	0,677	0,386	64,037	0,755	0,526	30,3
	Treated under medium conditions	0,609	0,419	59,839	0,835	0,559	33,0
	Treated under intense conditions	0,630	0,373	61,047	0,793	0,550	30,3
Medium intensity	Untreated	0,706	0,363	64,482	0,721	0,514	28,7
	Treated under soft conditions	0,638	0,398	63,615	0,790	0,539	31,7
	Treated under medium conditions	0,682	0,412	64,974	0,790	0,548	30,7
	Treated under intense conditions	0,666	0,474	63,948	0,830	0,544	34,4
Dark intensity	Untreated	0,693	0,350	64,631	0,753	0,548	27,1
	Treated under soft conditions	0,710	0,373	63,415	0,750	0,540	28,0
	Treated under medium conditions	0,676	0,389	63,834	0,774	0,544	29,7
	Treated under intense conditions	0,709	0,391	62,673	0,750	0,528	29,6

Table 3: Bending Properties (where B is the Rigidity per unit Length in gf·cm^2/cm and 2HB is the bending Moment of Hysteresis per unit Length in gf·cm/cm)

		B (gf.cm^2/cm)			2HB (gf.cm/cm)		
Dyeing	**Enzymatic treatment**	**Warp**	**Weft**	**Average**	**Warp**	**Weft**	**Average**
Undyed	Untreated	0,133	0,123	0,128	0,078	0,053	0,065
	Treated under soft conditions	0,168	0,124	0,146	0,079	0,047	0,063
	Treated under medium conditions	0,141	0,110	0,127	0,071	0,043	0,057
	Treated under intense conditions	0,139	0,106	0,122	0,065	0,046	0,056
Pale intensity	Untreated	0,138	0,089	0,113	0,063	0,036	0,049
	Treated under soft conditions	0,149	0,098	0,123	0,068	0,040	0,054
	Treated under medium conditions	0,145	0,089	0,117	0,069	0,034	0,051
	Treated under intense conditions	0,130	0,108	0,119	0,063	0,041	0,052
Medium intensity	Untreated	0,139	0,116	0,128	0,060	0,041	0,051
	Treated under soft conditions	0,139	0,113	0,126	0,064	0,044	0,054
	Treated under medium conditions	0,133	0,108	0,120	0,060	0,034	0,047
	Treated under intense conditions	0,143	0,100	0,121	0,064	0,035	0,049
Dark intensity	Untreated	0,123	0,100	0,111	0,054	0,044	0,049
	Treated under soft conditions	0,131	0,090	0,111	0,064	0,044	0,054
	Treated under medium conditions	0,134	0,103	0,118	0,061	0,042	0,051
	Treated under intense conditions	0,129	0,110	0,119	0,059	0,039	0,049

Table 4: Resistance to Pilling Formation

		Number of Rubbing Cycles				
Dyeing	**Enzymatic Treatment**	**125**	**500**	**1000**	**2000**	**5000**
Undyed	Untreated	2-3	1-2	1	1	3-4
	Treated under soft conditions	3-4	3	2-3	3	4
	Treated under medium conditions	3	2	1-2	2-3	5
	Treated under intense conditions	3	2-3	2-3	3-4	5
Pale intensity	Untreated	3	2-3	2	1-2	3-4
	Treated under soft conditions	4	3	2-3	2	4
	Treated under medium conditions	3	2	1-2	1-2	4-5
	Treated under intense conditions	3-4	3	2	1-2	4-5
Medium intensity	Untreated	3-4	2	1	1	3-4
	Treated under soft conditions	4	3	2-3	3	4
	Treated under medium conditions	4	3	1-2	1	4-5
	Treated under intense conditions	3-4	2-3	1-2	1-2	5
Dark intensity	Untreated	3-4	2	1	1	3-4
	Treated under soft conditions	4	3-4	2	3	4
	Treated under medium conditions	4	2-3	1	2-3	4-5
	Treated under intense conditions	3-4	3	2-3	3-4	5

Pilling Resistance

The results are shown in Table **4**.

As for the pilling formation in undyed fabrics at the beginning of the test (125 rubbing cycles) some pilling formation in the fabrics can be observed. The fabric with the highest proneness to pilling is the untreated fabric. In all the fabrics the pilling formation gradually increases till the test reaches 1000-2000 rubbing cycles. From this point on the pilling formation decreases, that is, all or a part of the pilling comes off. Considering the results the end of the test, *i.e.* after 5000 rubbing cycles, the untreated fabric exhibits an intermediate pilling rate. The fabrics treated with enzyme show a better behaviour than the untreated fabrics. The fabrics treated with enzyme under medium and intense conditions show excellent results: no pilling is observed on the fabric surface.

On the dyed fabrics, the action of the enzymatic treatment follows the same behaviour than on the undyed ones. The enzymatic treatment improves the pilling performance and such an improvement is more noticeable as the intensity of the treatment increases. It must be pointed out, however, that the effect produced by the enzymatic treatment under medium conditions on the dyed fabrics has turned out to be lower than on the undyed ones.

Tensile Strength and Breaking Elongation

Results are shown in Table **5**.

The enzymatic treatment produces, as expected, a significant decrease in the tensile strength of the undyed fabric, which indicates that enzymatic treatments with proteases can cause serious damage to wool fibres. This decrease is more noticeable as the intensity of the treatment increases and it could even be deemed as excessive for the more intense treatment conditions. The values on the breaking elongation also decrease when the intensity of the treatment increases.

Either in dyed or undyed fabrics, the enzymatic treatment causes a worsening in their tensile strength and their breaking elongation, albeit being more intense in the case of the dyed ones. Depending on the treatment conditions, such a worsening effect could be considered as severe. To that extent, treatments that require intense conditions should be avoided.

Abrasion Resistance

Table **6** shows the results on the abrasion resistance of the fabrics.

The abrasion resistance is, together with the tensile strength, one of the physical parameters that better represent the damage that the fibres undergo. In Table **6** can be seen that the enzymatic treatment produces a decrease in the abrasion resistance of the undyed

Table 5: Tensile Strength and Breaking Elongation

Dyeing	Enzymatic Treatment	Tensile Strength (N)	Breaking Elongation (%)
Undyed	Untreated	355,0	35,5
	Treated under soft conditions	350,1	28,9
	Treated under medium conditions	298,1	29,2
	Treated under intense conditions	246,2	24,3
Pale intensity	Untreated	333,6	34,5
	Treated under soft conditions	332,7	35,2
	Treated under medium conditions	313,7	33,1
	Treated under intense conditions	303,7	31,4
Medium intensity	Untreated	325,1	41,0
	Treated under soft conditions	323,4	41,1
	Treated under medium conditions	301,9	36,1
	Treated under intense conditions	290,8	29,6
Dark intensity	Untreated	320,7	42,0
	Treated under soft conditions	326,3	37,2
	Treated under medium conditions	296,9	35,6
	Treated under intense conditions	217,1	26,7

Table 6: Abrasion Resistance

Dyeing	Enzymatic Treatment	Abrasion Resistance (cycles)
Undyed	Untreated	34750
	Treated under soft conditions	31000
	Treated under medium conditions	24250
	Treated under intense conditions	23500
Pale intensity	Untreated	29750
	Treated under soft conditions	27250
	Treated under medium conditions	22250
	Treated under intense conditions	23500
Medium intensity	Untreated	31000
	Treated under soft conditions	29750
	Treated under medium conditions	29750
	Treated under intense conditions	27250
Dark intensity	Untreated	27250
	Treated under soft conditions	26000
	Treated under medium conditions	20250
	Treated under intense conditions	23000

fabric that is more and more noticeable as the intensity of the enzymatic treatment increases. The loss of resistance in the fabrics treated with enzyme under medium and intense conditions can be deemed as serious.

The dyeing seems to produce a certain decrease in the abrasion resistance. A further enzymatic treatment additionally worsens the abrasion resistance of the dyed fabrics, although this effect does not have a clear correspondence with the intensity of the treatment.

Colour Changes

The colour differences between the fabrics treated with enzyme under the different conditions and untreated fabrics are shown in Table **7**. Colour differences where measured after the enzymatic treatment and the industrial finishing process.

The dyed fabrics treated with enzyme and finished following an industrial process underwent a noticeable variation of their original colour. The fabrics dyed in a darker intensity present the highest colour differences between treated and untreated fabrics. Most of these colour differences are due to the finishing process. Hence, the enzymatic treatment alters the colour less than a standard finishing process. The colour differences produced by the enzymatic treatment do not seem to be correlated to the intensity of the treatment, except for the case of a darker dyeing. The total colour difference, DE, does not show whether the changes in colour are due to changes in luminosity, chrome or hue. In order to establish which component is more or less affected by the treatment colour DE, luminosity DL, chrome DC and hue DH differences produced by the enzymatic treatment are gathered in Table **8**.

The enzymatic treatment affects mainly the luminosity of the fabrics. There are no significant changes in the chrome or the hue of the colours. This means that all the dyestuffs of the trichromy are equally affected by the enzymatic treatment.

The values in the Table **8** show that the enzymatic treatment produces a lightening of the colour, that is, the treated samples are lighter than the untreated ones.

Apart from the above parameters, the colour fastness to washing, to alkaline and acid perspiration, to rubbing and to light were determined as well. The enzymatic treatment, even under the most intense conditions tested, does not affect colour fastness, for all dyeing intensities.

Table 7: Colour Differences DE

		Colour differences DE		
Dyeing	**Enzymatic Treatment**	**Enzymatic Treatment**	**Industrial Finishing**	**Total**
Pale intensity	Untreated	-	2.9	2.9
	Treated under soft conditions	1.0	2.9	3.9
	Treated under medium conditions	1.4	2.3	3.4
	Treated under intense conditions	1.0	2.2	3.2
Medium intensity	Untreated	-	3.7	3.7
	Treated under soft conditions	0.7	3.6	4.1
	Treated under medium conditions	0.7	2.8	3.4
	Treated under intense conditions	0.6	2.5	3.1
Dark intensity	Untreated	-	3.6	3.6
	Treated under soft conditions	0.1	4.1	4.0
	Treated under medium conditions	1.4	2.1	3.5
	Treated under intense conditions	1.9	2.5	4.5

Table 8: Colour Differences DE, DL, DC and DH during the Enzymatic Treatment

Tejido		Colour Differences			
Dyeing	**Enzymatic Treatment**	**DE**	**DL**	**DC**	**DH**
Pale intensity	Untreated	-	-	-	-
	Treated under soft conditions	1.0	1.0	0.2	0.1
	Treated under medium conditions	1.4	1.2	0.4	0.4
	Treated under intense conditions	1.0	1.0	-0.1	0.1
Medium intensity	Untreated	-	-	-	-
	Treated under soft conditions	0.7	0.6	0.2	0.2
	Treated under medium conditions	0.7	0.5	-0.4	-0.1
	Treated under intense conditions	0.6	0.6	-0.2	-0.1
Dark intensity	Untreated	-	-	-	-
	Treated under soft conditions	0.1	0.1	0.0	0.0
	Treated under medium conditions	1.4	1.4	0.0	-0.1
	Treated under intense conditions	1.9	1.9	-0.2	-0.2

CONCLUSIONS

The enzymatic treatment with the studied protease produces an improvement on the softness of the undyed fabric when the treatment is carried out under medium and intense treatment conditions. For all the dyed fabrics, no differences in the softness have been observed whatever the enzymatic treatment intensities.

Fabrics treated with enzyme show, in general, a better compressibility than the untreated, but at the same time, they exhibit a worse recovery from compressional deformation. In the undyed fabric, the effect is more evident as the intensity of the treatment increases, however, in the dyed fabrics no clear relation between effect and treatment intensity has been found.

Bending properties of the undyed fabric are improved on account of the enzymatic treatment under medium and intense conditions, whereas no correlation with the enzymatic treatment intensity has been found for the dyed fabrics. Dyed fabrics are, in general, more flexible than the undyed ones.

The pilling resistance of either the undyed or the dyed fabrics is improved as a consequence of the enzymatic treatment. Such an improvement increases with the intensity of the treatment, reaching an excellent pilling resistance when the fabrics are treated under medium and intense conditions.

The tensile strength values of either undyed or dyed fabrics decrease notably when the intensity of the enzymatic treatment increases. The treatment under medium and intense conditions produces an excessive loss of tensile strength.

The abrasion resistance of either undyed or dyed fabrics decreases with the enzymatic treatment too. The dyed fabrics present a somewhat lower abrasion resistance. In the case of undyed fabrics, the loss of abrasion resistance increases with the intensity of the treatment, whereas a clear relation is not detected for the dyed fabrics. Such a decrease is considerable for fabrics treated under medium and intense conditions.

The enzymatic treatment produces little variations in the colour of the dyed fabrics, but no correlation between the changes in colour and the intensity of the treatment has been established. The changes in colour are due mainly to a variation of the luminosity component, being the treated samples lighter than the untreated.

The colour fastness to washing, perspiration, rubbing and light are not affected by the enzymatic treatment no matter the dyeing intensity of the tested trichromy of dyestuffs.

To summarise, the enzymatic treatment with the studied protease has shown to be effective in order to improve the softness, compressibility, flexibility, and pilling of the undyed fabric, when the treatment conditions are intense enough. However, under such treatment conditions important losses of tensile strength and abrasion resistance can be produced, which indicates an excessive attack to the fibre. In the dyed fabrics, the enzymatic treatment produces, in general, similar changes in the properties of the fabrics. However, a clear correspondence between the effects and the intensity of the enzymatic treatment has not been found.

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