EFFECT OF ENZYME AND OXIDATIVE TREATMENTS ON THE PROPERTIES OF COARSE WOOL AND MOHAIR

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The main disadvantage of coarse wool and mohair is their harshness, making them unacceptable to the consumer. The best way to improve the softness of coarse fibres is by a chemical treatment. In this regard, a variety of options are available and the current study focused on the effect of enzymes, either alone or in combination with an oxidative (chlorine) treatment, on the softness and other properties of the fibres. It was found that an enzyme treatment reduced the feltability of wool. Furthermore, the scale height of the fibres was reduced by an enzyme treatment and this together with a decrease in the hardness of the fibres, improved the handle of the enzyme treated wool and mohair. The enzyme treatment also resulted in whiter fibres and did not cause any real damage to the wool and mohair. Better results were obtained, in general, if the enzyme treatment was applied to wool that was chlorinated first.

The wool and mohair industries are facing many challenges, amongst other, competition from other fibres, diminishing consumption, environmental pressures, etc. Innovative methods and processes should continuously be developed to produce products which will improve the competitiveness of the industry especially as far as the usage of the coarser component of the respective clips is concerned.

The main disadvantage of coarse wool and mohair is their harshness rending them unacceptable to the consumer. The best way to improve the properties of coarse fibres is by chemical treatment. Many different types of treatments such as plasma, enzymes, etc., are being used to improve the properties of wool in an environmentally friendly manner. Enzymes especially, are being researched and used extensively for the treatment of wool. Recently Prabhu and Kanoongo *(1)* have isolated a naturally occurring mould and extracted a new keratin-degrading enzyme suitable for use in shrinkproofing of wool. Levene and Shakkour *(2)* used enzymes to enhance the lustre of wool fibres. As far back as 1994, Fornelli *(3)* described the potential of enzymes for the bio-washing, bio-degreasing, bio-bleaching, bio-softening and enzymatic 'filing' of wool.

Hartzell-Lawson and Dinger *(4)* used protease enzymes to increase the end-use potential of coarse wool fibres. Schumacher et al *(5)* found that protease treated wool had a higher degree of whiteness, lower felting tendency and improved dyeability.

Enzymes were also used to reduce wool fibre stiffness and prickle *(6)* while the application of enzymes in fibre processing was elegantly explained by Heine *et al (7).* Jovancic *et al (8)* described a combined low-temperature plasma/enzyme wool shrinkresist process resulting in a machine washable level of shrinkresistance without excessive damage to the fibres.

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Cardamone *et al (9)* studied the combined bleaching, shrinkage prevention and biopolishing of wool fabrics, a process that resulted in wool with excellent whiteness and a soft handle. Finally, Nolte *et al (10)* reported on the effect of proteolytic and lipolytic enzymes on untreated and shrinkresist treated wool.

The purpose of the present study was to investigate the effect of a protease enzyme, either alone or in combination with an oxidative treatment such as chlorination, on properties such as feltability, tensile strength, whiteness, softness (handle), scale height, cuticle angle, surface roughness and hardness of wool and mohair fibres. A combined treatment was investigated since preliminary studies with the enzyme only treatment, did not yield acceptable results.

EXPERIMENTAL

Commercially available coarse wool (26µm, 90mm) and mohair (36µm, 80mm) sliver were used for experimental purposes. Some of the wool was chlorinated (oxidised) with 2% chlorine on a commercial wool shrinkresist line and removed prior to entering the Hercosett resin bowl. Hercosett treated (1,9% omf) wool was used as reference when the shrinkresistance imparted by the various treatments, was evaluated.

Enzymatic treatments of untreated and chlorinated wool and untreated mohair were carried out at a liquor:goods ratio of 15:1 in an Ahiba Turbomat dyeing machine as follows:

A protease enzyme, RUCOLASE EP3035 (Rudolf Chemicals) was applied at concentrations of 0,2% and 1,0% at a pH 8-8,5 (soda ash) and a temperature of 55°C for treatment times of 15 and 30 minutes. At the end of the treatment the pH was lowered with acetic acid and the bath run for 20 minutes to deactivate the enzyme.

The shrinkresistance imparted by the various treatments was measured by 'The Aachen Felting Test' *(11)*. Potential damage to the fibres due to the various treatments was determined by bundle breaking strength measurements *(12)*. Whiteness index measurements (CIE 1982) were made with a Konica Minolta Spectrophotometer while handle (softness) was determined by means of a panel of independent judges.

AFM (Atomic Force Microscopy) using a Multimode AFM from Veeco, USA, was used to obtain topographical and phase images. The images were acquired in contact mode with a silicon cantilever (nanosensor) with a nominal spring constant of k = 0,2 N/m. The scan range was 60 x 60 μm^2 with a scan speed of 0,7 lines/sec. All measurements were performed under ambient conditions. From these images, scale height variations, cuticle angle and surface roughness values were obtained. Cuticle (scale) height and angle values were the average of 10 measurements along the length of the fibre. The surface roughness was determined as an arithmetic average of absolute values of the surface height deviations measured from the plain: $R_a = 1/n \sum_{i=1}^{n} |Z_i|$. It was measured 5 times on different scales in areas of 5 x 5 μm^2.

Force distance curves were acquired by lowering the cantilever on one point of the fibre (no scanning) until it touched the surface. Due to repulsive forces the cantilever was bent upwards and the **gradient** of this part of the curve is directly proportional to the surface hardness – a higher gradient means a harder surface. When the cantilever was retracted again, the tip will stick to the surface, due to **adhesive forces** (mostly polar forces, which means a measure for hydrophilicity),

until it suddenly snaps free. From this pull-off force, the adhesive force was calculated according to Hooke's law: F = -kx (k: spring constant, x: pull-off distance).

RESULTS AND DISCUSSION

The modern consumer demands a variety of properties in a single product. Of these, stable dimensional properties, retention of strength, aesthetic appeal (colour) and comfort (softness) are the most important. On the other hand, the use of chemical processes to satisfy these demands must abide by environmental legislation of not polluting or damaging the environment. This study therefore focussed on the use of enzymes either alone or in combination with an oxidative treatment namely chlorination.

The first investigation focussed on the effect of the various treatments on the feltability of the wool and mohair. The Aachen felt ball density of the various treated fibres are shown in Figure 1.

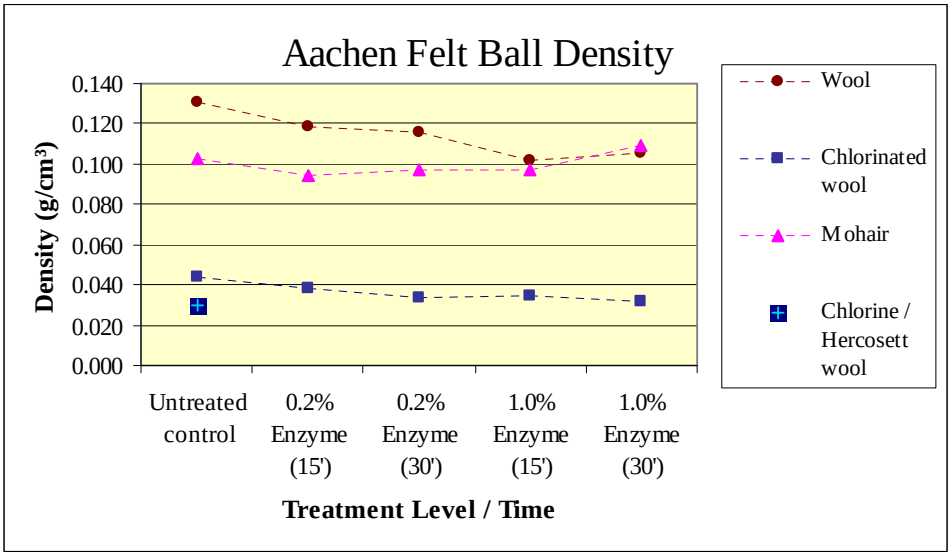

Figure 1: Aachen felt ball density of untreated and treated wool and mohair.

The results in Figure 1 show that the feltability of wool was reduced when increasing concentrations of enzyme were applied to untreated wool or to chlorinated wool. An enzyme treatment of chlorinated wool resulted in fibres having a feltability level approaching that of chlorine/Hercosett treated wool. On average, treating mohair with increasing amounts of enzyme, even for longer times, did not result in a significant reduction in the level of feltability.

From the above it is obvious that an enzyme treatment only did have a beneficial effect on the wool fibre as far as reducing its feltability is concerned. This effect was further investigated by a study of the changes induced to the fibre surface as a result of the treatments. Scale angle, surface roughness and adhesive force (hydrophilicity) changes were determined by means of AFM studies. Figures 2a and 2b depict the values obtained for these properties before and after enzyme and chlorination/enzyme treatments.

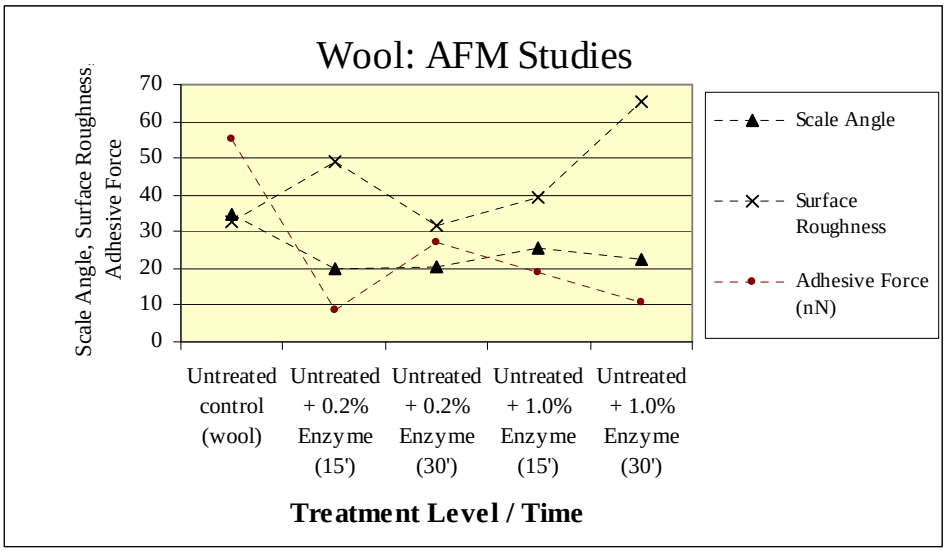

Figure 2a: Scale angle, surface roughness and adhesive force (hydrophilicity) of wool after an enzyme treatment.

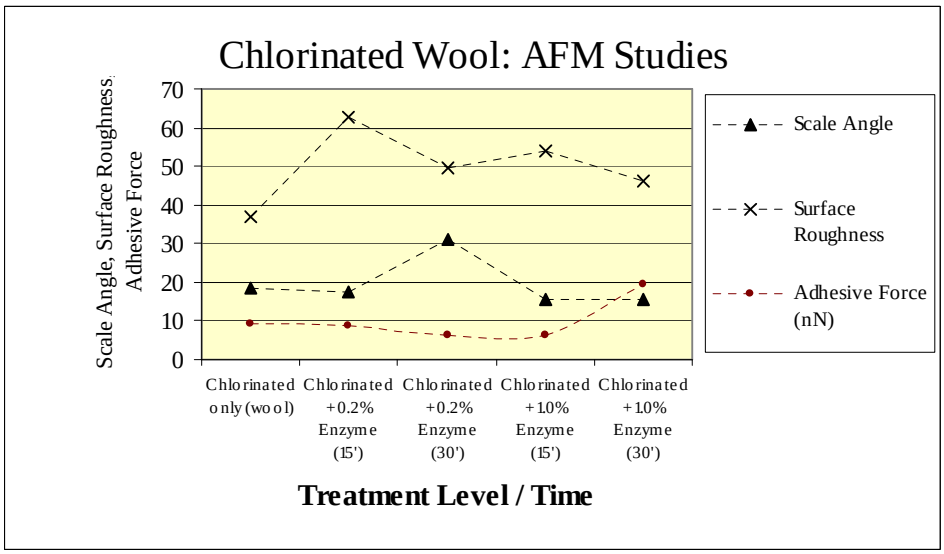

Figure 2b: Scale angle, surface roughness and adhesive force (hydrophilicity) of chlorinated wool after an enzyme treatment.

It is clear from the values in Figure 2 that the scale angle of wool decreased after an enzyme treatment only. This decrease was similar whether the wool was treated with 0,2% or 1,0% enzyme for either 15 or 30 minutes. Generally, there was also a slight decrease in the scale angle after a chlorination treatment followed by an enzyme treatment with the latter only contributing very little to this decrease.

The reduced scale angle possibly contributed to the lower degree of feltability obtained after these treatments. As expected, the surface roughness increased after these treatments. Another interesting finding was that of the adhesive force values obtained after the enzyme treatment. Adhesive force gives an indication of changes in surface functionalities specifically hydrophilicity. It is clear from Figure 2 that the hydrophilicity of the wool fibre was significantly reduced by an enzyme treatment applied to untreated wool. This, in turn, should improve the uptake of dyestuffs etc. Similar trends regarding scale angle and hydrophilicity variations were obtained for mohair.

Another very important property of wool that consumers are sensitive about is the phenomenon of scratchiness. Although fibre diameter is generally regarded as the major cause of scratchiness, it is also possible that scale height can contribute towards this phenomenon. A lower scale height might result in a lower level of scratchiness. Figure 3 shows the scale height value of wool after various levels of enzyme treatment.

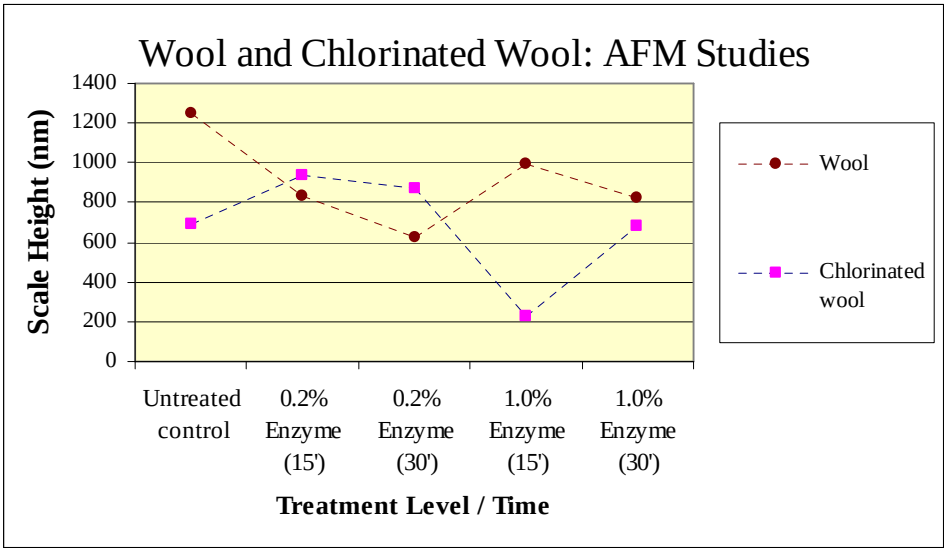

Figure 3: Scale height of enzyme treated wool.

The scale height of wool, on average, was reduced by an enzyme treatment. An enzyme treatment of chlorinated wool did not result in any further reduction in scale height. An enzyme treatment with or without prior chlorination should therefore result in a less scratchy fibre which will be to the advantage of the consumer.

Comfort (handle or softness) is another property high on the priority list of consumers. The effect of an enzyme treatment on the handle of wool was determined by means of an objective assessment of the softness of various treated fibres by a panel of judges as well as by the measurement of the hardness of the fibre derived from the gradient values given by AMF studies. The findings of the objective assessment are shown in Table I.

The results in Table I show that, although the chlorination treatment improved the handle of the wool slightly, the biggest improvement in handle (softness) was obtained when wool was treated with enzyme for increasing times and concentrations, with a treatment at a 1% level for 30 minutes resulting in the best performance. The handle of mohair also improved after the enzyme treatment.

Table I: Objective assessment of the softness of enzyme treated fibres.

	Mean grading values			
	0.2% Enzyme (15')	0.2% Enzyme (30')	1.0% Enzyme (15')	1.0% Enzyme (30')
Wool	2.6	2.2	1.9	1.6
Chlorinated wool	2.4	2.2	2.0	1.6
Mohair	2.1	1.4	1.3	1.3

Grading: 1=soft, 2=course, 3=harsh

Figure 4 gives the gradient (hardness) values of fibres treated with various concentrations of enzymes for various fibres.

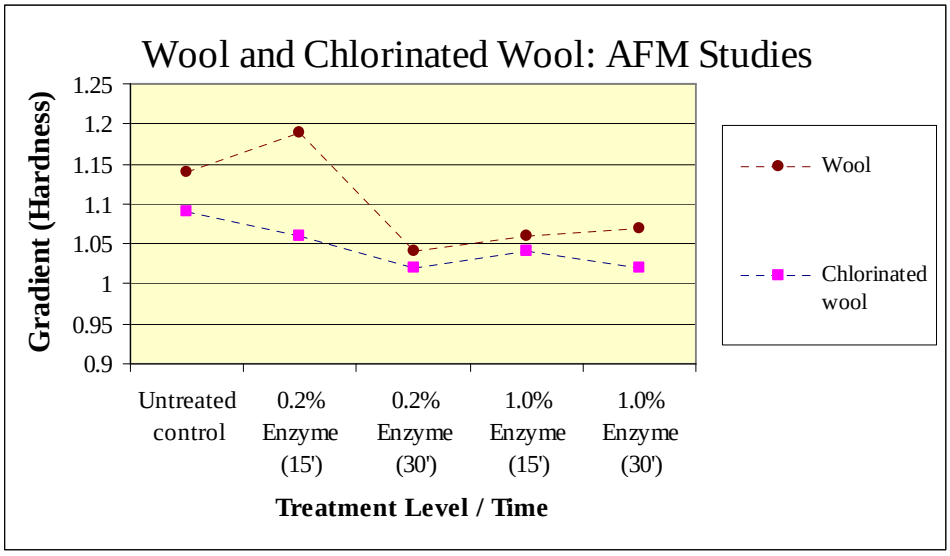

Figure 4: Hardness values of enzyme treated fibres

It is obvious from these values that the hardness of the fibres was reduced by an enzyme treatment and with a chlorination treatment followed by an enzyme treatment, resulting in softer fibres. A similar trend was observed for mohair fibres. These results confirm the trends observed during the objective assessment (Table I).

The above results indicate that a RUCOLASE EP3035 treatment had a positive effect on various fibre properties. It will, however, defeat the object if these positive outcomes are achieved with a negative effect on other important properties such as strength and colour. Figure 5 shows the bundle tenacity of enzyme treated fibres while Figure 6 depicts the effect on the whiteness index (aesthetic appeal) of the fibres.

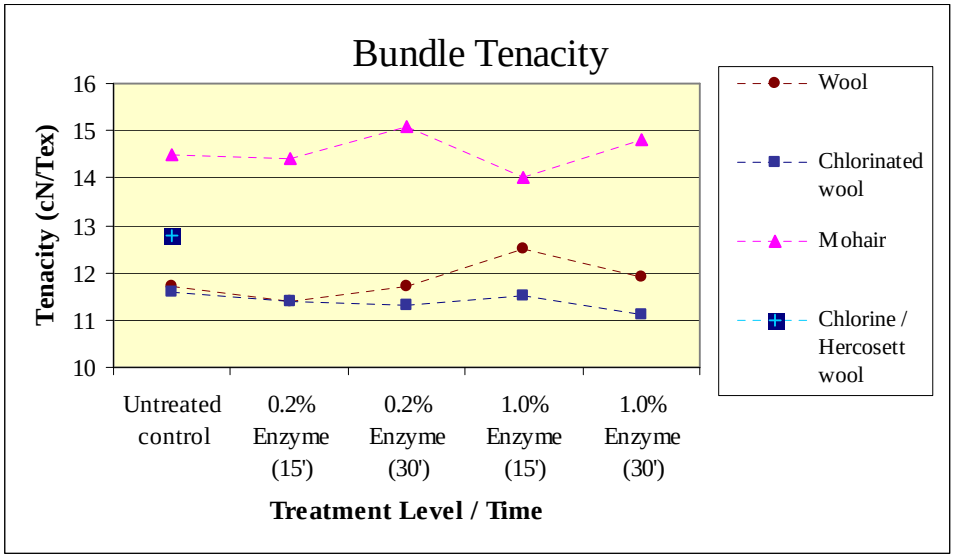

Figure 5: Bundle tenacity of enzyme treated wool

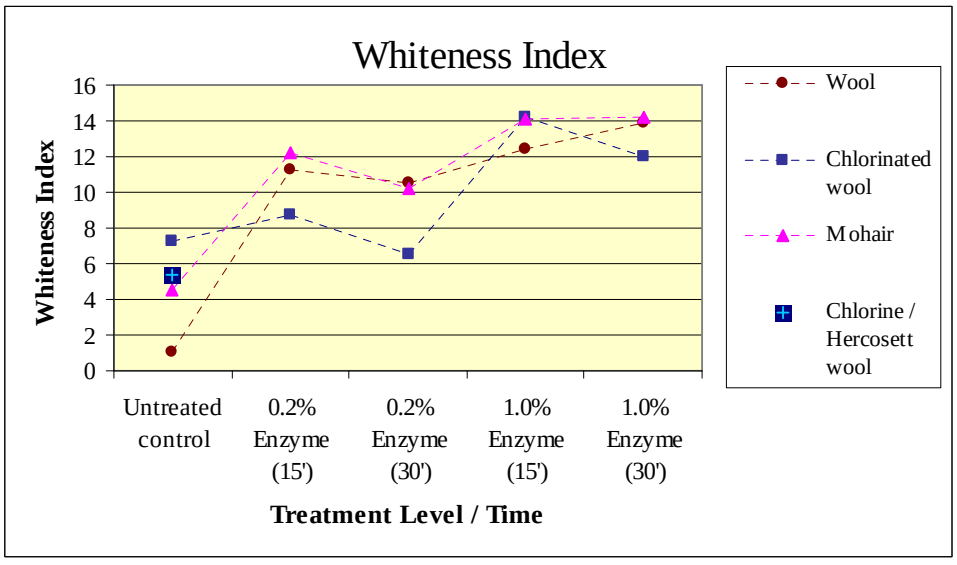

Figure 6: Whiteness index of enzyme treated wool.

It is clear from Figure 5 that the strength of the fibres was not affected by the various treatments. This is applicable to both wool and mohair. Figure 6 shows that the enzyme treatment resulted in a whiter wool with the wool that was chlorinated first and then enzyme treated showing a slightly lower increase in whiteness than the enzyme only treated wool.

SUMMARY AND CONCLUSIONS

The wool industry is under severe pressure to produce innovative solutions to satisfy consumer demands regarding fibre properties such as shrinkresistance, handle, strength retention and aesthetic appeal. These requirements must also be achieved in an environmentally friendly manner i.e. without damaging the environment. This study therefore focussed on certain aspects of using an enzyme treatment to satisfy the above requirements. Firstly, the effect of an enzyme treatment at different concentrations and time of treatment on untreated wool, was investigated. Secondly, the effect of an enzyme treatment on pre-chlorinated wool was also carried out.

It was found that an enzyme treatment reduced the feltability of wool but it was not at a machine washable level. When enzymes were applied to prechlorinated wool, feltability levels equivalent to that obtained after a chlorine/Hercosett treatment, were obtained although the main effect was due to the chlorination treatment. The enzyme treatment also resulted in fibres with a lower hydrophilicity, reduced scale height which resulted in a reduced degree of scratchiness. This, together with the finding of a softer fibre after an enzyme treatment, clearly illustrates the potential of this particular protease enzyme to achieve fibre properties which will satisfy the demands of consumers. Finally, an enzyme treatment also resulted in a whiter fibre which retained its strength after treatment.

It can thus be concluded that this particular protease shows a lot of promise to impart the required properties to wool and mohair which will satisfy the demands of modern day consumers especially when applied to chlorinated wool.

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