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Enzymatic Process for The Wool Fabric Anti-felting Finishing

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Abstract
Recently washable wool is strongly requested in order to avoid dry cleaning with chlorinated solvents such as perchlomethyiene. In this paper, a new enzymatic process direction is described for obtaining machine washable wool with acceptable quality. The principle of enzymatic process is introduced. To get a good result, proper pre-treatment process and proper enzyme is discussed. The conclusion gives advice to improve the quality of enzymatic wool fabrics.
Keywords: Enzyme, Wool, Fabric, Anti-felting finishing, Pre-treatment

Introduction

Wool is a natural protein fiber with good wearing properties[1,2], but have some short-cuts either -- Wool textiles in the wet state are sensitive to felt and shrink when applying mechanical action as in the case of washing.This can be explained by the scaled fiber structure. On the fiber surface, the friction of the wool fiber in the scale direction is therefore lower than the friction against the scale direction, a phenomenon which is called the differential frictional effect[3]. The anti-felting treatment is to get the scales partly removed, or the edges from the overlapping scales smoothed.After the treatment, fabric felting tendency is reduced, which make the wool costumes washable.

For this purpose, three anti-felting processes are commercially practiced[4-8]: subtractive (oxidation, reduction), additive (synthetic resin layer) and a combined process (e.g. chlorine/ hercosett process). However, these processes are the same in using strong oxidants, thus cause the contamination of wastewater and change the natural wool character to a more synthetic handle. The necessity to use more environmental friendly processes leads to the replacement of conventional chemical treatments by enzymatic ones.

Enzyme is a biocatalyst, it can act stably in a certain mild temperature. Compare with chemical treatments in anti-felting, enzymes have lot advantages[9,10]:

Water saving. Conventional treatments need repeated rinsing to ensure no chemical residues on the fabric. In most enzymatic treatments, because it is non-toxic, rinsing often take one time, this can save plenty water and cut the production's cost.

Low temperature. Enzyme often acts in mild temperature below 70℃, only few enzyme is active on above 70℃, while chenmical process often need a tenmerature higher than 100℃. So enzyme method can save money in heat energy spent.

Circulation use. Enzyme acts as a biocatalyst, it can't get consumed in the treatment, moreover, it can be used in circulation. Small mount enzymes can treat blocks of fabrics in one batch.

Devices protection. Enzyme treatment act in a neutral-ph (usually 8~10), thus have little corrosion on devices.The course is mild too, there is neither any evaporative emission nor any irritant gas generated in enzymatic process.

Enzyme has been researched for decades, but in wool anti-felting treatment, there are some essencial processes as latter discussed.

1. Pre-treatment

As Fig.1 shows, the structure of wool scales arrays like roof tiles. In fact, one scale contains the epicuticle and the inner layer, the epicuticle has many cross-linked amide bonds on surface, many adipoids also in good arrangement, which made epicuticle chemical stable and water proof. Current enzymatic processes have less weight loss rate, they are difficult to control and are not sufficiently predictable. Such treatment can easily cause excessive damage to the fiber cuticle or enhance the inhomogeneous along fiber. Under the epicuticle is full of proteins formed by Cysteines, this is the part to be removed. So it is essencial to use some oxidants as pretreatment, after being oxidized, the proteins in the scales can be hydrolyzed homogeneously, this will bring a good anti-felting effect.

Usually, some oxidizes such as chlorite salts, hypophosphites, dichloro isocyanates, potassium permanganate and persulfuric acids can act well in the pretreatment. But on considering the pollution they cause, especially chlorite salts, so hydrogen peroxide were used as a replacement. In Fig.2 we can find, after the pretreatment by sodium hypochlorite solution and hydrogen peroxide solution, scales are roughened. But at the same concentration, more upwarpped part of the scale were dissolved in the former. In the fabric, sodium hypochlorite pretreatment(Fig.2.b) can cause 5.7% weight loss and 19.7% in strength loss, which is obviously higher than the hydrogen peroxide one(Fig.2.c: 3.8% in weight loss, 12.6% in strength loss). To reduce the strength loss, pretreatment should taken in saturated aqueous salts solutions, this can conserve a strength loss to 7.2% and 4.9% in Fig.2.b&c's treatment.

Judging from many reaearch reports[11], a feasible pretreatment process is: wool plan knitted fabrics immersed into a ammonia sulfate saturated solution containing 2~8w.t.% hydrogen peroxide, 0.5%owf wetting agents and above 1%owf catalysts. The bath ratio is 1:30, treating time is mainly decided by the concentration of the hydrogen peroxide but less than 15min. After the treatment, fabrics should get washed by plenty water to get further enzyme treatment.

2. Enzymatic treatment

In early days, enzymes only come from common animals and plants, wool treatment enzymes are rather few, the pawpaw proteinase, trypsinase and pepsase are mostly used. Due to the quick development of microbial technology, new enzyme specis come out frequently. For wool fabric anti-felting treatment, proper enzymes can be divided into three groups.

2.1 Animal origined enzymes

Porcine trypsin is the mostly used, because it can be easily extracted from animal visceras. Porcine trypsin's active PH is 7.6~9.5. It's dosage is about 1.5~3owf%[12].

2.2 Plant origined enzymes

Papain is an endolytic cysteine protease which is isolated from papaya latex. The papain has strong biological activity of about 3,000,000 u/g and good water-solubility. It can incorporate any of a wide variety of enzymes and increase the rate of biological changes such as the ripening of fruit. Hence it can help stimulate keratin protein synthesis and repair. It's active PH is 8~10, and the dosage is about 2~5owf%[7,12].

2.3 Synthetic enzymes or enzymes for industrial use

Nowadays, with the rapid bio-technic progress, more synthetic enzymes are desighed for wool treatment, they are cheap in price. In china, a Synthetic enzyme is desighed for wool products called woolase, it is active in PH 8.5~9, 45℃[13]. But enzymes from bacteria have a bright future --- enzyme production is 'green', the residues of the production are good fertilizers; moreover, after the selection and purification, the enzyme have better activity to wool scales. Currently, there have some enzymes act significantly to wool. e.g. Savinase active in PH8~9,45~55℃, Esperase in PH8.5~9, 45℃[14,15].

From Tab.1 we can find, animal and plant origined enzymes are less active than the refined enzymes as savinase etc. But the specificity of the refined enzyme are not so good because it caused only 43~55% strength retain. Comparing this three propeties, esperase is better than the other two refined enzymes. To get a better result, new enzymes with goal to hydrolysis wool scales need to be developed by advanced enzyme refining technique.

3. Conclusion and Prospect

Enzymes in wool anti-felting is a most promising area in order to achieve high-grade, comfortable and washable effects. To sum up the applations of enzymes in wool industry, the developing trend were obtained.

(1) With the environmental consideration, enzymes consumption in wool industries will have a rapid increase. This will call for a simple, low cost technique in enzyme production.

(2) The stability and the specificity of enzymes need to be enhanced. Enzyme is a special protein, its activity can easily be affected by temperature and other chemical reagents. The wool mill should find a proper process to keep enzymatic fabrics quality stability. As previous mentioned, new enzymes should be developed in order to improve the anti-felting effect with less strength loss.

(3) Compound of various enzymes to improve enzyme efficiency. There were questions on enzyme compatibility need future studies to discover.

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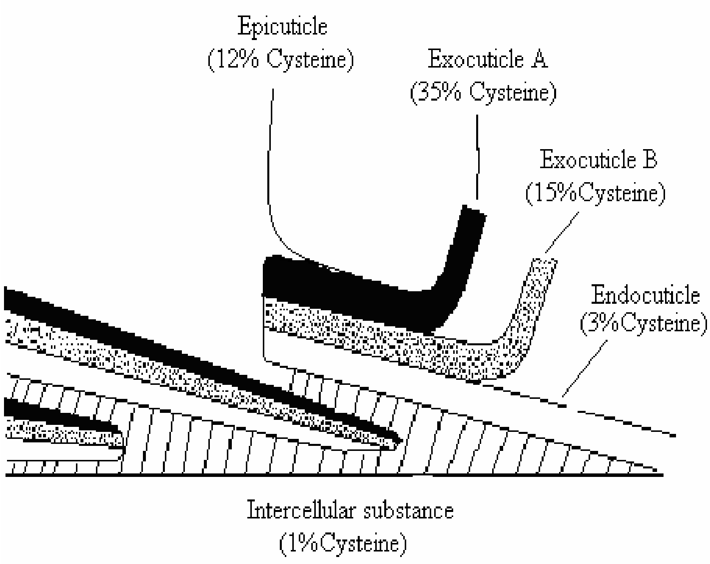
Table1. Performances of wool plan knitted fabrics treated by different enzymes(55℃, PH8.5 for 15min, after the H_2O_2 pretreatment)

	Savinase	Esperase	Woolase	Papain	Porcine trypsin
Felting shrinkage(%)	0.83	4.32	0.95	2.49	3.83
Strength retain(%)	43.00	54.70	74.10	75.80	75.10
Weight loss(%)	12.27	4.56	6.59	6.83	5.81



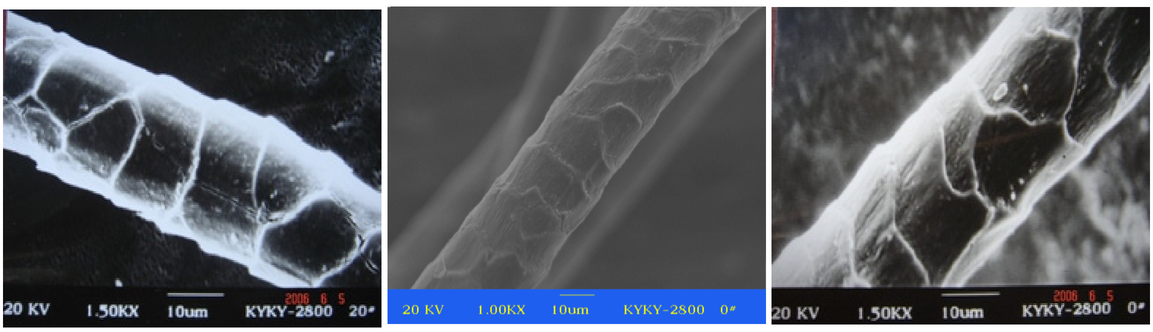


Figure 1. The structure of wool fiber scales and their Cysteine content

a b c

Figure 2. SEM graphs of rough wool fiber(a) and wool fiber treated with (b)3w.t.% hydrogen peroxide solution, PH=10, 10min and (c) 3w.t.% hydrogen peroxide solution, PH=10 for 10min.