

Enzymes in textile industry—An environment-friendly approach

Rashesh Doshi^a & Vinod Shelke
Zytex (India) Pvt Ltd, Mumbai 400 012, India

Environment-friendly uses of various enzymes in different textile processing steps have been discussed. It is observed that enzymes can replace harsh chemicals, catalyze reaction and operate under mild conditions. These are safe to use, easy to control and biodegradable.

Keywords: Bio-polishing, Bio-preparation, Cotton, Enzyme, Hydrolases, Wool

1 Introduction

Today, enzymes have become an integral part of the textile processing. Though the use of enzymes in desizing application was established decades ago, only in recent years the applications have widened with the introduction of new products. With the increased awareness and regulation about the environment concerns, the enzymes are the obvious choice. This is because the enzymes are biodegradable, work under mild conditions and save the precious energy. Enzymes, being biocatalysts and very specific, are used in small quantities and have a direct consequence of lesser packing material and lower transportation impact. In an overall consideration, the enzymes are the wonder products. The enzymes are large protein molecules made up of a long chain of amino acids which are produced by living cells in plants, animals and micro-organisms such as bacteria and fungi. Enzymes speed up a particular chemical reaction by lowering the activation energy for the reaction. They achieve this by forming an intermediate enzyme-substrate complex which alters the energy of the substrate such that it can be more readily converted into the product. As the enzyme itself does not alter at the end of the reaction, it acts as a catalyst. It has an amazing catalytic power. An outstanding example of the catalytic power of enzymes is the activity of catalase, an enzyme employed in the textile industry. One molecule of catalase can convert 5×10^6 molecules of hydrogen peroxide into water and oxygen in 1 min. This paper discusses the environment-friendly uses of different enzymes in various textile processing steps.

2 Application of Enzymes in Textile Industry

Enzymes are used in the textile industry because they can replace harsh chemicals, accelerate reaction, act only on specific substrates, operate under mild conditions, and are safe, easy to control and biodegradable. There are six different classes¹ of enzymes, namely Oxidoreductases, Transferases, Hydrolases, Lyases, Isomerases and Ligases. Most of the enzymes used in the textile industry belong to the class hydrolases. The present industrial applications² of different enzymes are shown in Table 1.

2.1 Cellulases

Until around 1980, practically all denim jeans, offered to the customer were unwashed or rinsed with traditional dark blue appearance associated with denim. On regular wear and repeated home laundering, these products faded and looked attractive than original. Around 1980, the treatment known as stone washing changed the denim materials dramatically. Now, the consumers are able to purchase a pair of jeans with faded look³. This abrasion effect was mainly obtained by locally removing the surface bound indigo dye by the use of pumice stones. Pumice stones are soft, light and porous in nature. About 1 - 2 kg pumice stones per pair of jeans were used to get the desired worn out look⁴. The major problem with stone washing is that lot of sludge gets deposited in the effluent tank due to wearing of pumice. This sludge has to be separated from effluent water and disposed off.

The use of stones was, therefore, replaced or reduced by enzymes called cellulases. This class of enzymes acts on cotton yarn and facilitates the removal of indigo dye from the yarn surface. Cellulase breaks the fibres on the yarn surface and thus loosens the indigo layer. The dye is then

^aTo whom all the correspondence should be addressed.
Phone : 4703231 ; Fax : 0091-022-4704874 ;
E-mail : rashesh@vsnl.com

Table 1 — Industrial applications of hydrolase enzymes

Enzyme	Substrate attacked	Industrial applications
Amylase	Starch	Desizing processes of cotton fabrics
Cellulase	Cellulose	Stone wash — Bio-polishing – Bio-finishing
Pectinase	Pectin	Bioscour replacing caustic
Laccase	Indigo dye	Improvement of the look of denim clothes
Catalase	Peroxides	Peroxide removal in dyeing processes

removed more easily by mechanical abrasion. Commercial cellulases are mixtures of endoglucanases, cellobiohydrolases and cellobiases. Endoglucanases attack cellulose randomly and hydrolyse internal glycosidic bonds whereas cellobiohydrolases remove terminal cellobiose residues from both cellulase chain ends. Cellobiases hydrolyse small cellobiose to glucose. This principle has allowed cellulase to be used to modify the surface and properties of cellulosic fibres and fabrics in order to achieve a desired hand or surface effect. The process is called as bio-polishing.

Using cellulase as a substitute for stones prevents the damages to washing machines and garments. It eliminates the need for disposal of the used stones and improves the quality of waste water. It also eliminates the need for large number rinses to remove dust from the garments and reduces effluent load⁵.

2.2 Pectinases

Traditional cotton production in a textile mill involves a sequence of processes that converts fibre to fabric. Grey fabrics or yarns are converted to a fully wettable, bleachable and dyeable form using different wet processing steps, such as desizing, scouring and bleaching. Scouring requires the use of high concentrations of sodium hydroxide and high temperature to ensure efficient removal of impurities, making the fabric suitable for dyeing.

A new concept called bio-preparation is gaining importance. This is an alternative to traditional alkaline scouring. Here, the enzymes pectinases in combination with cellulases are being used to scour cotton. The main target for scouring is the wax-rich cuticula which is the main hindrance for sufficient wettability. The principle behind the bio-preparation is that pectin acts as a glue for binding waxes to the fibre and by removing the major part of the pectin the waxes can efficiently be removed by emulsification.

The traditional scouring is performed with sodium hydroxide, which is extremely corrosive in concentrated form because of its high alkaline nature. Due to the unspecific nature and harsh conditions, an

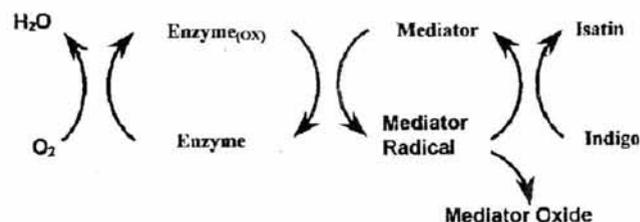
alkaline scouring causes some damage to cellulose, leading to high weight loss in cotton. This adds to environmental load, which further increases by the use of high concentration of sodium hydroxide (often neutralized by acids) which requires large amount of rinsing water and thus leads to high TDS.

The enzymatic scouring needs low temperature and mild alkaline conditions. As the enzymes are biodegradable, the BOD/ COD can be reduced to 50% of the normal. The salt content in the effluent is considerably reduced. The process is able to save more than 50 % of rinsing water⁶.

2.3 Laccases

Varieties of shades are created on denims by bleaching. Normally, sodium hypochlorite or bleaching powder is used to bleach denim garments. By controlling the bleaching processes, different washes such as ice wash and bata wash are created. The major drawback of this process is the use of chlorine-based bleaches that are not ecofriendly and also create hazardous working environment.

Laccase is an enzyme that is able to decolourise indigo. It is very important in the treatment and finishing of denim fabrics. The system is the combination of an enzyme and a mediator. Enzyme alone is not capable of breaking the indigo. However, in presence of an aqueous medium, the enzyme gets oxidized which attacks the mediator to convert it into free radicals. These free radicals attack indigo and



convert it into oxidized products. The mechanism of indigo decolorization is given below:

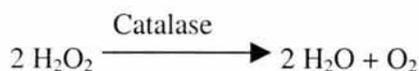
This enzyme system has made it possible to get rid off the chlorine-based bleaching agents. Also with

this system, the process is very much controlled than with hypochlorite⁷.

2.4 Catalases

In textile industry, peroxide bleaching is used as it is less toxic than the chlorine bleaching. If any trace of bleach chemicals is left on yarns or fabric, it leads to uneven dyeing. In the normal process, after bleaching, the traditional reducing agents like sodium bisulphate are used to neutralize the residual hydrogen peroxide. Most of the reducing agents require high temperature in order to react efficiently with hydrogen peroxide and thus increase the energy consumption.

An attractive alternative to neutralize the residual bleach chemical is catalase enzyme. It removes hydrogen peroxide without rinsing. It decomposes the hydrogen peroxide as follows:



The catalase acts in cold water and thus saves valuable energy. Normally, 30 – 40 liters of water per kg of fabric is required for rinsing to remove the excess of reducing agent. After catalase treatment, rinsing is not at all required, thereby a huge quantity of water is saved. Hydrogen peroxide is broken down to water and oxygen, neither of which adds to pollution load. There are no sulphates or nitrogen salts in the waste water which otherwise are present while using reducing agents. Thus, the use of catalase not only saves water, time and energy but also reduces the pollution load considerably⁸.

2.5 Proteases

Proteases catalyze the hydrolysis reaction of certain peptide bonds in protein molecules. In textile industry, proteases are being used to remove the stiff and dull gum layer of sericin from the raw silk to achieve improved lustre and softness. Protease treatments can modify the surface of wool and silk fibres to provide new and unique finishes.

2.6 Degumming of Silk

The fibroin filaments of cocoon silk are naturally gummed together with the protein sericin. The removal of sericin from raw silk is known as degumming. The traditional methods of degumming, such as soap degumming and alkaline degumming, consume tremendous amount of energy and harsh chemicals like soda ash, marseilles' soap, etc. Enzyme degumming involves proteolytic degradation of sericin using a specific protease enzyme which

does not attack fibroin. As a milder mechanical treatment may be used with enzymatic degumming, the finished silk is smoother than that degummed with soap. Silk affinity to reactive dyes is significantly improved by the enzymatic treatment and the load on the environment is greatly reduced.

2.7 Wool Processing

Natural wool clothing has the tendency to shrink, and felting is unwelcome by customers. Washable wool is the today's requirement. The felting properties are due to the scale-like surface structure of the wool. Various chemical modification processes have been adapted, and most commonly the active chlorine-based chemicals and polymers are used. The use of chlorine leads to AOX-charges in the waste water. The use of protease enzyme leads to uniform degradation of the cuticle and imparts antifelting properties. Enzymatic antifelting is an ecologically clean process.

2.8 Carbonization of Wool

Carbonization of wool is similar to the scouring of cotton where the contaminating vegetable matter is removed from the protein fibres before dyeing, since the dyeing characteristics of wool and cellulosic materials are very different. Carbonization usually involves a treatment with a strong acid. The wool fabric is incubated in sulphuric acid solution and heated. The vegetable matter is converted to carbon and then removed by beating or in subsequent scouring steps. However, care has to be taken that the treatment does not damage the wool.

Research has been carried out to replace the acid treatment by the treatment with cellulases and pectinases to hydrolyse the cellulose and lignin of the vegetable contaminants to water-soluble substances. This process is harmless to the wool, require lower operational costs and environment friendly.

2.9 Modification of Polyester by Lipase

Polyethylene terephthalate (PET) is a hydrophobic fibre, and an effective way to improve its wettability is by alkaline hydrolysis. The major drawback of alkaline hydrolysis is strength loss and caustic discharge. It has been observed that lipase enzyme improves the water wetting and retention properties more than alkaline hydrolysis. The enzyme reaction requires 10 min treatment at 25°C and does not affect the strength. Lipase has also been effective on sulphonated and microdenier polyester fabrics⁹.

3 Future

A turning point has come and now with the modern biotechnology tools, like Directed Evolution and Gene Shuffling, many new enzymes will be available in commercial quantities in near future. We should not be surprised to see the bio-finishing processes, like bio-bleaching, dispersion booster, and mercerization in near future¹⁰.

References

- 1 <http://www.chem.wsu.edu/chem102/102-enzstrclassmech>.
- 2 Chris Byrne, *Biotechnology in textile*, paper presented at the Textile Institute Dyeing and Finishing Group Conference, Nottingham, November 1995.
- 3 Paul R & Naik S R, *Text Dyer Printer*, 29 (17) (1996) 15.
- 4 Lars O S, *Biotechnology in denim finishing*, paper presented at the seminar on Revolution of Enzymes in Textile Industry, Brazil, November 1991.
- 5 Paul R & Naik S R, *Text Dyer Printer*, 30 (11) (1997) 13.
- 6 Lange N K, Hussain P, Liu J & Candon B, *Book of Papers, International Conference & Exhibition (AATCC)*, 1998, 463.
- 7 Anon, *BioTimes*, 1 (2000) 10.
- 8 <http://www.science.ntu.ac.uk/research/EnzyTex/EnzRep1.htm>, 10.
- 9 You-Lo H & Lisa A Cram, *Text Res J*, 68 (5) (1998) 311.
- 10 Lise Vestbirk, *Textile 2000* (Novo Nordisk), 2000, 8.