TRENDS IN BIO-PROCESSING OF TEXTILES: A REVIEW

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This review highlights the use of enzymes in textile industry. Amylases have been used for desizing since the middle of the last century. The industrial use of biotechnology is bringing about new products and processes aimed at the use of renewable resources, as well as the application of green technologies with low energy consumption and environmentally acceptable processes. Textile processing is a growing industry that has traditionally used a lot of water, energy and harsh chemicals. Due to the ever growing costs of water and energy worldwide, the investigations are carried out to substitute conventional chemical textile processes by environmentally friendly and economically attractive bioprocesses using enzymes. The application of cellulases for denim finishing and laccases for decolourization of textile effluents, and textile bleaching are most recent commercial advances. New developments rely on the modification of natural and synthetic fibres. This work represents a review of enzyme applications in textile processes. The described bio-processings were accompanied by a significantly lower consumption of energy, water, chemicals, time and costs. So it has advantages as well as in terms of ecology as in economy.

Keywords: enzymes, biotechnology, textile fibres, textile bio-processing.

Introduction

Bioprocessing can simply be defined as the application of living organisms and their components to industrial products and processes. It is an important technology that will have a large impact on many industries in the future. Bioprocessing is the application of biological organisms, systems or processes to manufacturing industries. The application of enzymes in food processing, in the paper and leather industries, as additives in washing powders, and in the desizing process of cotton is well established. However, biocatalysis has also entered textile processing. Enzymes, biocatalysts with specific and selective activity are today produced by biotechnological processes in great amounts and constant quality, and are here for applicable to large-scale processes. In regard to new applications resulting from the design of enzymes for specific processes, there is a demand for extensive collaboration between bio and textile chemists. In textile processing the enzymatic removal of starch sizes from woven fabrics has been in use for most of this century. Bioprocessing also offers the potential for new industrial processes that require less energy and are based on renewable raw materials. Moreover, there is a potential for replacing the alkaline scouring in cotton pretreatment by the use of enzymes like, for example, pectinases. In wool finishing, enzymes, mainly proteases, are used to achieve shrink proofing. The properties of wool textiles like handle, whiteness and lustre are modified by enzyme catalyzed reactions as well. Furthermore, bioprocesses are described leading to pilling reduction and dye ability improvement. The degumming of silk, traditionally performed by the soap, alkali or acid, is achieved by proteases. There is a broad range of applications and a multitude of prospects for the use of enzymes in textile processing, leading to a positive impact on the environment [1, 2]. Biotechnological solutions enable not only such cleaner processes but can also create cost and time-saving, as well as other fabric quality advantages to textile manufacturers. Due to the constantly increasing level of pollutants, the governments of many countries have imposed stricter limitations on the release of pollutants. Therefore, there is the ever increasing demand for clean processes i.e. the processes that either cause no pollution or less pollution. Textile industry, particularly the chemical processing sector has always had a major share in the global pollution. Enzymes play a key role in such alternative processes. The use of enzymes in textile started as long as a century ago. Today enzymes have become the integral part of the textile processing. At present, the applications of pectinases, lipases, proteases, catalases, xylanases etc., are used in textile processing. There are various applications which entail enzymes included, the fading of denim and non-denim,

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bio scouring, bio polishing, wool finishing, peroxide removal, decolourization of dyestuff, etc. [3-6]. Some applications have become well established and routine, while some have not yet been successfully industrialized due to technical or cost constraints. A famous example is bio scouring or bio preparation, a process that specifically targets noncellulosic impurities within the textile fabrics with pectinases [7].

Role of Enzymes in Textile Processing

Enzymes are large protein molecules made up of long-chain amino acids which are produced by living cells in plants, animals and microorganisms. Enzymes are secretions of living organisms which catalyze biochemical reactions. They are grouped as:

- Oxidoreductases – Oxidation, reduction reaction.
- Transferases – Transfer of functional groups.
- Hydrolases – Hydrolysis reaction
- Lyases – Addition to double bond or its reverse
- Isomerases – Isomerization
- Ligases – Formation of bonds with ATP cleavages.

Hydrolases type of the enzyme is mostly used in textiles. Salient features of the enzyme application in textile process are:

- Accelerate the rate of the reaction
- Specific in action
- Low temperature operation
- Safe and the control is easy
- Replace harsh chemicals
- No pollution
- Biologically degradable

Bioprocessing of textiles

The use of enzymes has had a long tradition, especially in textile manufacturing. Enzymes used in textile and their effects are shown in Table 1.

Table 1. Enzymes used in textile and their effects

Enzyme	Effect
Amylase	Desizing
Cellulases and Hemicellulases	Biostoning of jeans Desizing of CMC
Pectinase	Stylish effect on cellulose fibres Scouring of vegetable as well as bast fibres e.g. cotton, jute
Proteases	Scouring of animal fibres, degumming of silk and modification of wool properties
Lipases	Elimination of fat and waxes

Enzymes find their application in the following areas:

Biocatalysis.

Enzymes have become an important class of biochemicals in textile processing. Being bio-catalysts, enzymes were not consumed in the reaction. The substrate was broken into degradation products making the enzyme available to attach itself to another substrate again and the cycle was repeated and thereby the enzyme became a biocatalyst. Enzymes can be used in catalytic concentrations at low temperatures and at pH-values near to neutral [8].

New fibre.

Biodegradable polymers and polyesters can be synthesized using common commercial soil bacteria. In future, synthetic fibres such as polyester [9] or polyacrylonitrile [10] will also be modified by the enzymatic treatment.

Bioscouring.

Scouring is the removal of non-cellulosic material present on the surface of cotton. Besides cellulose, cotton contains the so-called primary wall natural compounds such as pectins, hemicelluloses, proteins, waxes and lignin which can impair the finishing results. In a conventional pre-treatment these substances are removed by a strong alkaline treatment at high temperatures after the enzymatic desizing of raw cotton fabrics with α-amylases. This unspecific alkaline scouring process has a high energy, water and alkali consumption and can also cause a damage of the cellulosic material. In general, cellulase and pectinase are combined and used for Bioscouring. Pectinase destroy the cotton cuticle structure by digesting pectin and removing the connection between the cuticle and the body of cotton fibre, whereas cellulase can destroy a cuticle structure by digesting the primary wall cellulose immediately under the cuticle of cotton. The advantages of bioscouring were lower Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Total Dissolved Solid (TDS), and alkaline media of water, the extent of the cotton weight loss which was a boon to the knitting industry, less damage since it was specific to pectin and waxes and not cellulose, besides the increased softness. Handle is very soft in enzymatic scouring compared to harsh feel in alkaline scouring process. Enzymatic scouring makes it possible to effectively scour a fabric without negatively affecting the fabric or the environment. It also minimizes health risks, the operators are not exposed to aggressive chemicals [11].

Biobleaching.

The purpose of cotton bleaching is to decolorize natural pigments and to confer the pure white appearance to the fibres. The most common industrial bleaching agent is hydrogen peroxide. The conventional preparation of cotton requires high amounts of alkaline chemicals.

Consequently, huge quantities of rinse water are generated. However, radical reactions of bleaching agents with the fibre can lead to a decrease in the degree of polymerization and, thus, to severe damage. Therefore, the replacement of hydrogen peroxide by an enzymatic bleaching system would not only lead to the better product quality due to less fibre damage but also to substantial savings on the washing water needed for the removal of hydrogen peroxide. Mainly flavonoids are responsible for the color of cotton [12, 13]. It was applicable for all kinds of colors and a single enzyme could be used in the textile industry. Biobleaching was adapted for denim. Indigo specific lipases were used to bleach indigo. For the first time Tzanov et al. (2003) [14] reported the enhancement of the bleaching effect achieved on cotton fabrics using laccases in low concentrations. In addition, the short time of the enzymatic pre-treatment sufficient to enhance fabric whiteness makes this bio-process suitable for continuous operations. Also, Pereira et al. (2005) [15] showed that a laccase from a newly isolated strain of *T. hirsuta* was responsible for the whiteness improvement of cotton most likely due to oxidation of flavonoids. Compared with traditional clean-up methods, the enzymatic process results in cleaner waste water or reduced water consumption, in a reduction of energy and time.

Biopolishing.

Bio-polishing is a biological process in which cellulase acts on the surface of the fabric. They then easily break off from the surface, making it much smoother than before. The smoothing effect has several benefits. The fibre will have a lesser predisposition towards forming pills and will consequently have a clearer surface structure containing less fuzz. Biopolishing and fading or biopolishing and wash down degraded the cellulose due to the abrasion or friction between fibre to fibre or fibre to metal resulting in the removal first from cellulose and then surface bleeding. Biopolishing is a finishing process that improves the fabric quality. The objective of the process is the elimination of micro fibrils of cotton through the action of cellulase enzyme [16, 17]. Biopolishing gives cleaner appearance to the garment besides the wash down effect. The main characteristics imparted to the fabric during the biopolishing treatment are as follows:

- Cleaner surface is obtained conferring a cooler feel;
- Lustre is obtained as a side effect;
- Fabric obtains softer feel;
- Tendency of the fabric to pill ends.

Degumming of silk.

Silk is made up of two types of proteins like fibroin and ceresin. The aesthetic appeal of silk can be improved by better degumming. The fibroins of cocoon silk are naturally gummed together with impurities like wax, protein, sericin, pectin and pigments. They are removed by conventional treatments with soap, alkali and oxidizing agents under rather general conditions of the treatment such as high alkalinity, high temperature and highly oxidative environment for the extended length of time. In the case of the enzymatic treatment, a ceresin specific protein was used to degum the silk without causing damage, impart softness and increase the dye uptake. If silk was degummed by the alkaline treatment, there was damage to fibroin and heavy weight loss. Degumming of silk with proteolytic enzyme gives a better gum loss compared with soap. Irrespective of color, the percentage shade, the dye uptake of acid dyed by silk fabric value - color and strength can be improved by the treatment with protease enzymes before dyeing. The extent of improvement in the dye uptake depends on concentrations of enzymes as well as on duration, pH and temperature of the enzyme treatment. The higher the concentration of enzymes and correct pH treatment, the better will the dye uptake be. Washing, rubbing, pressing and light fastness properties of the enzyme degummed silk fabric are unaffected by the enzyme treatment [18, 19].

Enzymes effect on color.

Hydrolases and oxidoreductases constituted an important class of enzymes dealing with color in the textile application. Cellulases are hydrolytic enzymes that catalyze the breakdown of cellulose to smaller oligosaccharides and finally glucose. Cellulases have achieved their worldwide success in textile and laundry because of their ability to modify cellulosic fibres in a controlled and desired manner, so as to improve the quality of fabrics. Although cellulases were introduced in textile and laundry only a decade ago, they have now become the third largest group of enzymes used in these applications [20]. Bio-stoning and bio-polishing are the best-known current textile applications of cellulases. Cellulases are used in bio- stoning of denim garments for producing softness and the faded look of denim garments, thus replacing the use of pumice stones which were traditionally employed in the industry [21, 22]. Cellulases have also been used in softening defibrillation and in the processes for providing a localized variation in the color density of fibres [23].

Conclusion

The use of various enzymes is in the early stages of development but their innovative applications are increasing and spreading rapidly into all areas of textile processing. The textile industry can greatly benefit from the expanded use of these enzymes as non-toxic, environmentally friendly compounds. Enzymes are a sustainable alternative to the use of harsh chemicals in industry, and reduce energy and water consumption and the chemical waste production during manufacturing processes. With modern biotechnology tools, especially in the area of microbial genetics, novel enzymes and new enzyme applications will become available for various industries.

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Izvod

TRENDOVI U BIO-PRERADI TEKSTILA: PREGLED

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Ovaj rad naglašava primenu enzima u tekstilnoj industriji. Amilaze se koriste za odskrobljavanje još od sredine prošlog veka. Industrijska primena biotehnologije uvodi nove proizvode u cilju korišćenja obnovljivih izvora energije kao i primene zelenih tehnologija sa niskom potrošnjom energije i ekološki prihvatljivim procesima.Tekstilna industrija u tehnološkim procesima dorade tekstila koristi mnogo vode, energije i jake hemikalije. Usled sve većih troškova za vodu i energiju širom sveta, sprovode se istraživanja koja će konvencionalne hemijske tekstilne procese zameniti ekološki i ekonomski atraktivnim bioprocesima uz upotrebu enzima. Primena celulaza za doradu teksasa, lakaza za dekolorizaciju tekstilnih otpadnih voda i tekstilno beljenje predstavljaju najnoviji komercijalni napredak. Nova dostignuća se oslanjaju na modifikaciju prirodnih i sintetičkih vlakana. Ovaj rad predstavlja pregled aplikacija enzima u tekstilnim procesima. Opisane bio-prerade su praćene značajno nižom potrošnjom energije, vode, hemikalija, vremena i troškova tako da imaju prednosti kako u pogledu ekologije tako i u ekonomiji.

Ključne reči: enzimi, biotehnologija, tekstilna vlakna, tekstilna bio-prerada