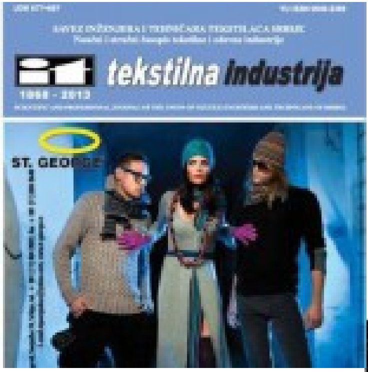

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INDUSTRIAL ENZYMES IN TEXTILE PROCESSING AND THE HEALTY ENVIRONMENT: A REVIEW

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Review Article

Abstract: Textile processing is a growing industry that traditionally has used a lot of water, energy and harsh chemicals. They are also not easily biodegradable. Textile industries are third largest polluters in the world. Biotechnology in textiles is one of the revolutionary ways to advance the textile field. Industrial enzymes offers the potential for new industrial processes that require less energy and are based on renewable raw materials, as well as the application of green technologies with low energy consumption and environmentally healthy practices. The use of enzymes in textile industry is one of the most rapidly growing field in industrial enzymology. Textile processing has benefited greatly on both environmental and product quality aspects through the use of enzymes. The best known enzymes used in the textile field are amylases, catalases and laccases which are used to removing the starch, degradation excess hydrogen peroxide, bleaching textiles and degradation lignin.The application of cellulases for denim finishing and laccases for decolourization of textile effluents and textile bleaching are the most recent commercial achievements.

Keywords: industrial enzymes, textile processing, eco-friendly characteristics, healthy environment.

INDUSTRIJSKE ENZIME U TEKSTILNOJ OBRADI I ZDRAVA SREDINA: PREGLED

Apstrakt: Tekstilna obrada je rastuća industrija koja tradicionalno je koristila dosta vode, energije i jake hemikalije. Oni takođe nisu lako biorazgradive. Tekstilne industrije su treći najveći zagađivači u svetu. Biotehnologija u tekstila je jedan od revolucionarnih načina da unaprediti oblasti tekstila. Industrijski enzimi nude potencijal za nove industrijske procese koji zahtevaju manje energije i zasnivaju se na obnovljivim sirovinama, kao i primenu zelenih tehnologija sa niskom potrošnjom energije i ekološki zdrave prakse. Upotreba enzima u tekstilnoj industriji je jedan od najbrže rastućih oblasti industrijske enzimologije.Tekstilna obrada kroz upotrebu enzima ima u velikoj meri koristi na životne sredine i aspekata kvaliteta proizvoda. Najpoznatiji enzimi koji se koriste u oblasti tekstila su amilaze, katalaze i lakaze koji se koriste za uklanjanje skroba, degradacija višak vodonik peroksida, izbeljivanje tekstila i degradacije lignina. Primena celulaze za teksas dorade i lakaze za izbeljivanje tekstilnih efluentima i tekstilno beljenje su najnovije komercijalne dostignuća.

Kljucne reči: industrijski enzimi, tekstilna obrada, ekološke karakteristike, zdrava životna sredina.

1. INTRODUCTION

Enzymes are biological catalysts. There are optimum temperatures and Ph values at which their activity is greatest. Enzymes are proteins, and usually denatured above about 45ºC. That are folded into complex shapes that allow smaller molecules to fit into them. The place where these substrate molecules fit is called the active site. If the shape of the enzyme changes, its active site may no longer work. We say the enzyme has been denatured. They can be denatured by high temperatures or extremes of pH. As the temperature increases, so does the rate of reaction. But very high temperatures denature enzymes. Changes in pH alter an enzyme's shape. Different enzymes work best at different pH values.

Enzymes were discovered in the second half of the nineteenthh century, and since then have been extensively used in several industrial processes. Enzymes are generally globular proteins and like other proteins consist of long linear chains of amino acids that fold to produce a three-dimensional product. Each unique amino acid sequence produces a specific structure, which has unique properties. Enzymes are extremely efficient in increasing the reaction rate of biochemical processes that otherwise proceed very slowly, or in some cases, not at all.

Enzymes are categorized according to the compounds they act upon. Some of the most common include: proteases which break down proteins, cellulases which break down cellulose, lipases which split fats (lipids) into glycerol and fatty acids, and amylases which break down starch into simple sugars.

Commercial sources of enzymes are obtained from three primary sources, i.e., animal tissue, plants and microbies. These naturally occurring enzymes are quite often not readily available in sufficient quantities for food applications or industrial use. However, by isolating microbial strains that produce the desired enzyme and optimizing the conditions for growth, commercial quantities can be obtained. This technique, well known for more than 3,000 years, is called fermentation. Today, this fermentation process is carried out in a contained vessel. Once fermentation is completed, the microorganisms are destroyed, the enzymes are isolated, and further processed for commercial use.

Enzyme manufacturers produce enzymes in accordance with all applicable governmental regulations, including the appropriate federal agencies (e.g., Food and Drug Administration, United States Department of Agriculture, Environmental Protection Agency, etc.). Regardless of the source, enzymes intended for food use are produced in strict adherence to FDA's current Good Manufacturing Practices (cGMP) and meet compositional and purity requirements as defined in the Food Chemicals Codex (a compendium of food ingredient specifications developed in cooperation with the FDA).

There is a large number of microorganisms which produce a variety of enzymes [1]. Most of the industrial enzymes are produced by a relatively few microbial hosts like Aspergillus and Trichoderma fungi, Streptomyces fungi imperfecti and Bacillus bacteria. Yeasts are not good produces of extracellular enzymes and are rarely used for this purpose.

Microorganisms that produce enzymes from textile importance are listed in Table 1.
Several methos, such as submerged fermentation (SmF), solid-state fermentation (SSF) and whole cell immobilization have been successfully used for enzyme production from various microorganisms.

Table 1. - Microorganisms that produse enzymes from textile importance

Microorganisms	Enzymes
Bacteria	
Bacillus subtilis	Amylase
B. coagulans	α-amylase
B. licheniformis	α-amylase, protease
2. Fungi	
A. niger	Amylases, protease, pectinase, glucose oxidase
A. oryzae	Amylases, lipase, protease
Candela lipolytica	Lipase
P. notatum	Glucose oxidase
Rhizopus sp.	Lipase
Trichoderma reesei	Cellulase
A. niger	Amylases, protease, pectinase, glucose oxidase
A. oryzae	Amylases, lipase, protease
Candela lipolytica	Lipase
P. notatum	Glucose oxidase

2. INDUSTRIAL ENZYMES AND THE ENVIRONMENT

Due to constantly increasing level of pollutants governments of many countries imposing stricter limitations on release of pollutants. Therefore there is ever increasing demand for clean processes i.e. processes which either cause no pollution or less pollution. Textile industry particularly the chemical processing sector always has a major share in the global pollution. Enzymes can often replace chemicals or processes that present safety on environmental issues.

Enzymes play key role in such alternative processes. Use of enzymes in textile started as long as a centure ago. For example, enzymes can:

- Replace acids in the starch processing industry and alkalis or oxidizing agents in fabric desizing;
- Reduce the use of sulfide in tanneries;
- Replace pumice stones for "stonewashing" jeans;
- Allow for more complete digestion of animal feed leading to less animal waste;
- Remove stains from fabrics. Clothes can be washed at lower temperatures, thus saving energy;
- Enzymes can be used instead of chlorine bleach for removing stains on cloth;
- The use of enzymes also allows the level of surfactants to be reduced and permits the cleaning of clothes in the absence of phosphates.

Alternative eco-friendly desizing agents are available in the market in the form of enzymes. Today enzymes have become an integral part of the textile processing. There are two well-established enzyme applications in the textile industry. Firstly, in the preparatory finishing area amylases are commonly used for desizing process and secondly, in the finishing area cellulases are used for softening, bio-stoning and reducing of pilling propensity for cotton goods. Enzyme desizing is the most widely practiced method of desizing starch. In the textile industry amylases are used to remove starch-based size for improved and uniform wet processing. Amylase is a hydrolytic enzyme which catalyses the breakdown of dietary starch to short chain sugars, dextrin and maltose. The advantage of these enzymes is that they are specific for starch, removing it without damaging to the support fabric. An amylase enzyme can be used for desizing processes at low-temperature (30-60 ºC) and optimum pH is 5,5-6,5 [2]. There are various applications which entail enzymes included fading of denim and non-denim, bio-scouring, bio-polishing, wool finishing, peroxide removal, decolourization of dyestuff, etc. [2-12].

The application of enzymes has many advantages compared to conventional, non-enzymatic processes. Moreover, enzymes are biologically degradable and can be handled without risk [13, 14]. Especially in textile manufacturing the use of enzymes has a long tradition. Enzymes used in textile and their effects are shown in Table 2.

Table 2. - Enzymes used in textile and their effects

Enzyme	Effect
Amylase	Desizing
Cellulases and Hemicellulases	Biostoning of jeans Desizing of CMC Stylish effect on cellulose fibres
Pectinase	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

3. TEXTILE PROCESSING AND THE ENVIRONMENT

Textile processing has benefited greatly on both environmental and product quality aspects through the use of enzymes. The fabric should be free from natural and added impurities before it goes colouration. Some of the chemicals that are used at different stages preparatory process like caustic soda, soda ash, hydrogen peroxide, hydrochloric acid, detergent and auxiliaries can be harmful to the environment. Cotton fibres and cotton/synthetic fibre blends are sized, i.e. they are coated with a strengthening, adhesive like material (usually starch in native or modified form or a starch based material) to prevent damage during the weaving process. The size must be removed (desizing) before a fabric can be bleached and dyed, since it affects the uniformity of wet processing.

The application of enzymes has many advantages compared to conventional, non-enzymatic processes. Enzymes can be used in catalytic concentrations at low temperatures and at pH-values near to neutral. On the other hand, in the textile industry large amounts of water, energy and auxiliary chemicals are consumed. Especially waste water from the desizing process causes environmental problems [15]. The sizing process is necessary to prevent abrasion, fluffiness and cutting of warp during the weaving process, meanwhile the sizing agent (mainly starch) has negative impact in following treatments, specially dyeing. Therefore, after completion of weaving, sizing agent must be removed.

In conventional desizing of cotton fabric, a large amount of hot water, surfactants and the other chemical have to be consumed. To minimize the consumption of water, chemical, energy and also environmental pollution, enzymatic desizing of cotton by amylases has been developed [16]. Enzymatic desizing was the first use of enzymes in the chemical pretreatment of textiles. Biotechnology as an ecological advantageous and moreover economical beneficial technology plays an increasingly important role in the industrial wet textile pretreatment and the finishing processes. Due to ever-growing costs of energy and concerning of environmental pollution, enzymatic technologies will stay in the focus of science and technique. While conventional wet textile processes are characterized by long residence time, high concentration of chemicals, alkaline or acidic pH and high temperature, biotechnology is a flexible and reliable tool that presents a promising technology for fulfilling the expected future requirements [17, 18].

Various types of desizing methods are available. If the size is water soluble, an alkali wash with detergents may be used. Oxidative chemicals such as persulphate and alkali or bromide and alkali may also be used at high pH and temperature. Before the discovery of amylase enzymes, the only alternative to remove the starch based sizing was extended treatment with caustic soda at high temperature.

The chemical treatment was not totally effective in removing the starch (which leads to imperfections in dyeing) and also results in a degradation of the cotton fiber resulting in destruction of the natural, soft feel, or hand, of the cotton. The use of amylases to remove starch-based sizing agents has decreased the use of harsh chemicals in the textile industry, resulting in a lower discharge of waste chemicals to the environment, improved the safety of working conditions for textile workers and has raised the quality of the fabric. New enzymatic processes which are developed (cellulase, hemicellulase, pectinase and lipase) offer the potential to totally replace the use of other chemicals in textile preparation processes.

4. ENVIRONMENTAL AND ECONOMIC BENEFITS

- Lower discharge of chemicals and wastewater and decreased handling of hazardous chemicals for textile workers;
- Increased biodegradability of effluent;
- Less handling of aggressive chemicals;
- Avoidance of chemical fiber damage;
- Improved fabric quality.

5. CONCLUSION

Pollution free processes are gaining ground all over the world. In this scenario, enzymes emerging as the best alternative to the polluting textle processing methods. Enzymes are not only beneficial from ecological point of view but they are also saving lot of money by reducing water and energy consumption which ultimately reduce the cost of production. It seems that in the future it will be possible to do every process using enzymes.

Biotechnology offers a wide range of alternative environmentally-friendly processes for the textile industry to complement or improve the conventional technologies. The use of various enzyme 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 was identified as a key sector where opportunities available from adapting biotechnology are high but current awareness of biotechnology is low. In textile processing the enzyme can be successfully used for preparatory process like desizing, scouring and bleaching. These enzymatic processes are gives the similar results as that of conventional methods. Though these enzymatic processes we can reduce the water consumption, power energy, pollution, time, and increasing quality. These are just a few applications of Biotechnology, however many such potentials are yet to be explored.

The textile industry can greatly benefit from the expanded use of these enzymes as highly specific and efficient, non-toxic, environmenatally friendly compounds, work under mild conditions (pH, temperature) with low water consumption that results in reduced the use of harsh chemicals in the textile industry, process times, energy and water savings and improved product quality.

Advances in enzymology, molecular biology and screening techniques provide possibilities for the development of new enzyme-based processes for a more environmentally friendly approach in textile industry. It seems that in the future it will be possible to do every process using enzymes.

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