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APPLICATION OF ENZYMES IN THE TEXTILE INDUSTRY : A REVIEW

PRIMENA NA ENZIMI VO TEKSTILNATA INDUSTRIJA : PREGLED

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Abstract

The use of enzymes in textile industry is one of the most rapidly growing field in industrial enzymology. The enzymes used in the textile field are amylases, catalase, and laccase which are used to removing the starch, degrading excess hydrogen peroxide, bleaching textiles and degrading lignin. The use of enzymes in the textile chemical processing is rapidly gaining globally recognition because of their non-toxic and eco-friendly characteristics with the increasinly important requirements for textile manufactures to reduce pollution in textile production. The application of cellulases for denim finishing and lactases for decolourization of textile effluents and textile bleaching are the most recent commercial advances. The use of enzyme technology is attractive because enzymes are highly specific and efficient, and work under mild conditions. Furthermore, the use of enzymes results in reduced process times, energy and water savings, improved product quality and potential process integration. The aim is to provide the textile technologist with an understanding of enzymes and their use with textile materials.

Key words: Enzymes, application, textile industries, eco-friendly characteristics.

Izvod

Upotrebata na enzimi vo tekstilnata industrija e edno od najbrzo rastečko podracje vo industriskata enzimologija. Enzimi koi se upotrebuvani vo tekstilnoto podračje se amilazi, katalazi, i lakazi za otstranuvanje na skrob, degradiranje na višokot vodoroden peroksid, belenje na tkaenini i degradiranje na ligninot. Upotrebata na enzimite vo tekstilnite hemiski procesi e brzo steknuvanje na globalno priznavanje zatoa što nivnata neotrovnost i ekološki karakteristiki se baranja od zgolemena važnost za tekstilnite fabriki da go namalat zagaduvanjeto vo tekstilnoto proizvodstvo. Primenata na celulazite vo završnicata na platnoto za farmerki i laktazite za obezbojuvanje na tekstilnite otpadni materii i tekstilno belenje se najskorešni komercijalni prednosti. Upotrebata na enzimnata tehnologija e atraktivna zatoa što enzimite se mnogu specifični i efikasni, i reagiraat pod blagi uslovi. Osven toa, upotrebata na enzimite rezultira vo namaleni procesni vreminja, zašteda na energija i voda, zgolemuvanje na proizvodniot kvalitet i potencijal na proizvodna integracija. Celta e da se obezbedi tekstilniot tehnolog so znaenje za enzimite i nivnata upotreba so tekstilnite materiali.

Ključne riječi: Enzimi, primena, tekstilni industrii, ekoloski karakteristiki.

Introduction

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 and highly specific biocatalysts. 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. 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. There is a large number of microorganisms which produce a variety of enzymes (Boyer, 1971; Fersht, 2007). Microorganisms producing enzymes of textile important are listed Table 1.
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 play key role in such alternative processes. Use of enzymes in textile started as long as a centure ago.
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. At present, applications of pectinases, lipases, proteases, catalases, xylanases etc., are used in textile processing. 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. (Cavaco-Paulo and Gubitz, 2003; Chelikani et al., 2004; Barrett et al., 2003; Sharma, 1993; Nalankilli, 1998; Shenai, 1990).

Enzymes, classification, action and properties

Enzymes are biocatalyst, and by their mere presence, and without being consumed in the process, enzymes can speed up chemical processes that would otherwise run very slowly. After the reaction is complete, the enzyme is released again, ready to start another reaction. Usually most enzymes are used only once and discarded after their catalytic action.
Enzymes are very specigic in comparison to inorganic catalysts such as acids, bases, metals and metal oxides. Enzyme can break down particular compounds. The molecule that an enzyme acts on is known as its substrate, which is converted into a product or products. For each type of reaction in a cell there is a different enzyme and they are classified into six broad categories namely hydrolytic, oxidising and reducing, synthesising, transferring, lytic and isomerising. The essential characteristic of enzymes is catalytic function. Consequently, the original attempt to classify enzymes was done according to function. The International Commission on Enzymes (EC) was established in 1956 by the International Union of Biochemistry (IUB), in consultation with the International Union of Pure and Applied Chemistry (IUPAC), to put some order to the hundreds of enzymes that had been discovered by that point and establish a standardized

terminology that could be used to systematically name newwly discovered enzymes. The EC classification system is divided into six categories of basic function:

- EC1 Oxidoreductases: catalyze oxidation/reduction reactions.
- EC2 Transferases: transfer a functional group.
- EC3 Hydrolases: catalyze the hydrolysis of various bonds.
- EC4 Lyases: cleave various bonds by means other than hydrolysis and oxidation.
- EC5 Isomerases: catalyze isomerization changes within a single molecule.
- EC6 Ligases: join two molecules with covalent bonds.

Each enzyme is described by a sequence of four numbers preceded by "EC". The first number broadly classifies the enzyme based on its mechanism.

Enzymes can work at atmospheric pressure and in mild conditions with respect to temperature and acidity (pH). Most enzymes function optimally at a temperature of 30ºC-70ºC and at pH values, which are near the neutral point (pH 7). Enzyme processes are potentially energy saving and save investing in special equipment resistant to heat, pressure or corrosion. Due to their efficiency, specific action, the mild conditions in which they work and their high biodegradability, enzymes are very well suited for a wide range of industrial applications.

Enzymes work only on renewable raw materials. Fruit, cereals, milk, fats, cotton, leather and wood are some typical candidates for enzymatic conversion in industry. Enzymes are used in the textile industry because they accelerate reactions, act only on specific substrates, operate under mild conditions, are safe and easy to control, can replace harsh chemicals and enzymes are biologically degradable i.e. biodegradable (Uhlig, 1991; Ruttloff, 1994).

Properties of enzymes used in textiles

1. **Enzyme accelerates the reaction**
   - An enzyme accelerates the rate of particular reaction by lowering the activation energy of reaction
   - The enzyme remains intact at the end of reaction by acting as catalyst
2. **Enzymes operate under milder condition**
   - Each enzyme have optimum temperature and optimum pH i.e. activity of enzyme at that pH and temperature is on the peak
   - For most of the enzyme activity degrades on the both sides of optimum condition
3. **Alternative for polluting chemicals**
   - Enzymes can be used as best alternative to toxic, hazardous, pollution making chemicals
   - Also some pollutant chemicals are even carcinogenic. When we use enzymes there is no pollution
4. **Enzyme acts only on specific substrate**
   - Most enzymes have high degree of specificity and will catalyse the reaction with one or few substrates
   - One particular enzyme will only catalyse a specific type of reaction. Enzymes used in desizing do not affect cellulose hence there is no loss of strength of cotton
5. **Enzyme are easy to control**
   - Enzymes are easy to control because their activity depends upon optimum condition
6. **Enzymes are biodegradable**
   - At the end of reaction in which enzymes used we can simly drain the remaining solution because enzymes are biodegradable and do not produce toxic waste on degradation hence there is no pollution

Enzyme applications in textile preparatory process

Especially in textile manufacturing the use of enzymes has a long tradition. Enzymes used in textile and their effects are shown in Table 2. The current application in the textile industry involves mainly hydrolases and now to some extent is oxidoreductase. The Tables 3 and 4 exemplify such textile applications. The enzymatic desizing of cotton with α-amylases is state-of-the-art since many decades (Marcher et al., 1993). Moreover, cellulases, pectinases, hemicellulases, lipases and catalases are used in different cotton pre-treatment and finishing processes (Meyer-Stork, 2002). Other natural fibers are also treated with enzymes. Examples are the enzymatic degumming of silk with sericinases (Gulrajani, 1992), the felt-free-finishing of wool with proteases (Fornelli, 1994) or the softening of jute with cellulases and xylanases (Kundu et al., 1991). In future, also synthetic fibers such as polyester (Yoon et al., 2002) or polyacrylonitrile (Tauber et al., 2001) will be modified by an enzymatic treatment. 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 (Uhlig, 1991; Ruttloff, 1994). Besides cellulose cotton contains in the so-ccalled primary wall natural compounds such as pectins, hemicelluloses, proteins, waxes and lignin, which can impair the finishing results. In 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-amylasees. This inspecific alkaline scouring process has a high energy, water and alkali consumption and can also cause a damage of the cellulosic material (N.N., 2002).

Enzymatic Desizing

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 (30-60ºC) and optimum pH is 5,5-6,5 (Cavaco-Paulo and Gübitz, 2003).

Enzymatic Scouring (Bioscouring)

Scouring is removal of non-cellulosic material present on the surface of the cotton. In generally cellulase and pectinase are combined and used for Bioscouring. In this pectinase destroy the cotton cuticle structure by digesting the pectin and removing the connection between the cuticle and the body of cotton fibre whereas cellulase can destroy cuticle structure by digesting the primary wall cellulose immediately under the cuticle of cotton. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of enzymatic scouring process are 20-45 % as compared to alkaline scouring (100 %). Total Dissolved Solid (TDS) of enzymatic scouring process is 20-50% as compared to alkaline scouring (100%). Handle is very soft in enzymatic scouring compared to harsh feel in alkaline scouring process. Enzymatic scouring makes it possible to effectively scour fabric without negatively affecting the fabric or the environment. It also minimises health risks ence operators are not exposed to aggressive chemicals (Pawar et al., 2002).

Enzymatic Bleaching

The purpose of cotton bleaching is to decolourise natural pigments and to confer a pure white appearance to the fibres. Mainly flavonoids are responsible for the colour of cotton (Hedin et al., 1992; Ardon et al., 1996). The most common industrial bleaching agent is hydrogen peroxide.

Conventional preparation of cotton requires high amounts of alkaline chemicals and conse quently, 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 polymerisation and, thus, to severe damage. Therefore, replacement of hydrogen peroxide by an enzymatic bleaching system would not only lead to better product quality due to less fibre damage but also to substantial savings on washing water needed for the removal of hydrogen peroxide. An alternative to this process is to use a combination of suitable enzyme systems. Amyloglucosidases, pectinases, and glucose oxidases are selected that are compatible concerning their active pH and temperature range.

Tzanov et al. (2003) reported for the first time 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) showed that a laccase from a newly isolated strain of *T. hirsuta* was responsible for whiteness improvement of cotton most likely due to oxidation of flavonoids. More recently, Basto et al. (2006) proposed a combined ultrasound-laccase treatment for cotton bleaching. They found that the supply of low ultrasound energy(7W) enhanced the bleaching efficiency of laccase on cotton fabrics. Natural fabrics such as cotton are normally bleached with hydrogen peroxide before dyeing. Catalase enzyme is used to break down hydrogen peroxide bleaching liquor into water molecules and less reactive gaseous oxygen. Compared with the traditional clean-up methods, the enzymatic process results in cleaner waste water or reduced water consumption, a reduction of energy and time.

Biopolishing

Biopolishing is a finishing process that improves fabric quality by mainly reducing fuzziness and pilling property of cellulosic fibre. The objective of the process is elimination of micro fibrils of cotton through the action of cellulase enzyme (Stewart, 2005; Cavaco-Paulo, 1998; Cavaco-Paulo et al., 1996; Lenting and Warmoeskerken, 2001). The main characteristics imparted to the fabric during biopolishing treament are as follow:

- 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.

Enzymatic treatment to denim

Denim is heavy grade cotton. In this dye is mainly adsorbed on the surface of the fibre. That is why fading can be achieved without considerable loss of strength. In traditional process sodium hypochlorite or potassium permanganate was used called as pumice stones(Pedersen and Schneider, 1998). Disadvantage of these method are as follows:

- Pumice stones cause large amount of back-staining.
- Pumice stones are required in very large amount.
- They cause considerable wear and tear of machine.

These disadvantages lead to give rise the process of use of enzymes. Cellulase enzyme is used in denim washing. Cellulase works by loosening the indigo dye on the denim in a process know as "Bio-Stonewashing". A small dose of enzyme can replace several kilograms of pumice stones. The use of less pumice stones results in less damage to garment, machine and less pumice dust in the laundry environment.

More recently, some authors showed that laccase was an effective agent for stone-washing effects of denim fabric with and without using a mediator (Campos et al., 2001; Pazarloglu et al., 2005).

Conclusion

These are just a few applications of Biotechnology, however many such potentials are yet to be explored. Biotechnology finds finds wide application in textiles and it will prove to be a boon to the ever-changing conditions of the ecology as well as economy.

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.

The use of various enzymes in the early stages of development but their innovative applications are increasing and spreading rapidly into all areas of textile processing. Enzyme producing companies constantly improve their products for more flexible application conditions and a more wide-spread use. The textile industry can gratly benefit from the expanded use of these enzymes as non-toxic, environmentally friendly compounds if their effects on the textile substrate and the basic mechanisms involved are better understood.

As with all chemicals and products, enzymes too have their own merits and limitations. They show specific action without undesirable effects on other components and normally operate under mild temperature and pressure conditions, but at the same time are sensitive to temperature, pH, humidity and contaminants. They often shorten the process cycle reducing time, water consumption and wastewater generation. The main hindrance in using enzymes is their high cost. 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 this enzymatic processes we can reduce the water consumption, power energy, pollution, time, and increasing quality.

Enzymes are emerging in a big way in the field of textile wet processing.If their cost can be managed, enzymes can be put to use in a much bigger way for textile processing applications.

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Table captions

Table 1. Microorganisms produsing enzymes of textile important

Table 2. Enzymes used in textile and their effects

Table 3. Application of hydrolase enzyme in fabric preparation

Table 4. Application of oxidoreductase in fabric preparation

Table 1. Microorganisms produsing enzymes of textile important

Microorganisms	Enzymes
1. 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
T. viride	Cellulase
Ascomycetes	α-amylase
Basidomycetes	α-amylase
Aspergillus sp.	Pectinase, lipase

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

Table 3. Application of hydrolase enzyme in fabric preparation

Enzyme Name	Substrate	Textile Application
Amylase	Starch	Starch desizing
Cellulase	Cellulose	• Stone wash-Bio-polishing (Bio-singeing) • Bio finishing for handle modification • Carbonization of wool
Pectinase	Pectin	Bio scour replacing caustic
Catalase	Peroxides	In situ peroxide decomposition without any rinse in bleach bath
Lipase	Fats and oils	Improve hydrophilicity of PET in Place of alkaline hydrolysis

Table 4. Application of oxidoreductase in fabric preparation

Enzyme Name	Substrate	Textile Application
Laccase	Colour Chromophore and pigments	• Discoloration of coloured effluent chromophore • Bio-bleaching of lignin containing and pigments fibres like kenaf and jute • Bio-bleaching of indigo in denim for various effects
Peroxidase	Colour Chromophore and pigments	Bio-bleaching of wood pulp
Glucose	Pigments	In situ generation of H_2O_2 and bio-bleaching of cotton

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Народна и универзитетска библиотека
Републике Српске, Бања Лука

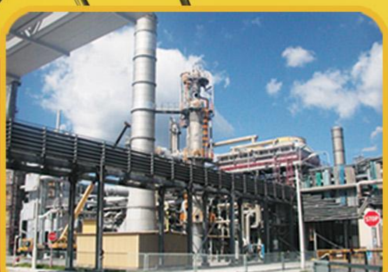
66.02-9(082)(0.034.2)
54(082)(0.034.2)
502/504(082)(0.034.2)

МЕЂУНАРОДНИ конгрес "Инжењерство, екологија и материјали у процесној индустрији" (2 ; 2011 ; Јахорина)
Knjiga radova [Електронски извор] = Proceedings / II međunarodni kongres "Inženjerstvo, ekoligija i materijali u procesnoj industriji" = 2nd International Congress "Engineering, Ecology and Materials in the Processing Indusrty", Jahorina, 09.03-11.03.2011. Bosnia and Herzegovina ; [organizator] Univerzitet u Istočnom Sarajevu, Tehnološki fakultet Zvornik = [organized by] University of East Sarajevo, Faculty of Technology Zvornik ; [urednici Miomir Pavlović, Aleksandar Došić, Dragana Kešelj]. - Zvornik : Tehnološki fakultet, 2011 (Zvornik : Eurografika). - 1 elektronski optički disk (CD-ROM) : tekst, ilustr. ; 12 cm

Nasl. sa naslovnog ekrana. - Tekst ćir. i lat. - Tiraž 300. - Bibliografija uz sve radove.

ISBN 978-99955-81-01-5
1. Технолошки факултет (Зворник)

COBISS.BH-ID 1891608



ISBN 978-99955-81-01-5

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