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ROLE OF BIOTECHNOLOGY IN TEXTILE INDUSTRY: A REVIEW

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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. Biotechnology in textiles is one of the revolutionary ways to advance the textile field. Biotechnology 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. Due to the ever-growing costs for water and energy worldwide investigations are carried out to substitute conventional chemical textile processes by environment-friendly and economically attractive bioprocessesusing enzymes.This work represents a reviewofrole of biotechnology in textile processing. The aim is to provide the textile technologist with an understanding of enzymes and their use with textile materials.

Key words: Enzymes, Textile Processing, Textile Fibres, Eco-Friendly Characteristics.

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1.Introduction:

Biotechnology is the application of living organisms and their components to industrial products and processes. The rapid developments in the field of genetic engineering have given a new impetus to biotechnology. Biotechnology also offers the potential for new industrial processes that require less energy and are based on renewable raw materials. Defining the scope of biotechnology is not easy because it overlaps with so many industries, such as, the chemical industry or food industry being the majors, but biotechnology has found many applications in textile industry also, especially in genetic engineering, textile processing and effluent management. Caused of the evergrowing costs for energy and polluted waste water, enzymatic technologies will stay in the focus of science and technique, and their relevance will increase significantly in the future. Enzymes, biological catalysts with high selectivities, have been used in the foodindustry for hundreds of years, and play an important role in many other industries(washing agents, textile manufacturing, pharmaceuticals, pulp and paper). Currently,enzymes are becoming increasingly important in sustainable technology and greenchemistry. Modern wet processing industries are followed the enzymes in the preparatory process instead of using harmful chemical because enzyme are more convenient, effective and environment friendly. Especiallyintextilemanufacturing the use of enzymes has a long tradition.The first microbial amylases were used in the 1950s for the removal of starch sizes, which today is routinely used by the industry [Ciechanska and Kazimierezak 2006; Marcher et al. 1993]. *Amylases* are enzymes which hydrolyse starch molecules to give diverse products, including dextrins and smaller polymers composed of glucose units [Gupta et al. 2003]. Moreover, *cellulases, pectinases, hemicellulases, lipases* and *catalases* are used indifferent cotton pre-treatment and finishing processes [Meyer-Stork 2002].Other natural fibers are alsotreated with enzymes. Examples are the enzymatic degumming of silk with *sericinases*[Gulrajani1992], the felt-free-finishing of wool with *proteases* [Fornelli 1994] or the softening of jute with *cellulases* and *xylanases* [Kundu et al. 1991].The application ofenzymes has many advantages compared to conventional, non-enzymatic processes.The use of enzyme technology is attractive because enzymes are highly specific and efficient, and work under mild conditions. Moreover, enzymesarebiologicallydegradableandcanbehandledwithoutrisk[Uhlig 1991; Ruttloff 1994]. These are just a few applications of biotechnology to enunciate, however many such potentials are yet to be explored.

2.Literature Review:

2.1Enzymes

Enzymesarebiocatalysts thatacceleratetherateofchemicalreactions[Cavaco-Paulo and Gübitz 2003]. The reaction happens with lower activation energy which is reached byforming an intermediate enzyme – substrate.In the reaction itself the enzymes are not usedup, they do not become a part of the final product of the reaction, but only change thechemical bonds of other compounds. 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.

All known enzymes are proteins. Generallytheyareactive at mild temperatures. Above certain temperature the enzyme isdenaturated. Enzymes have a characteristic pH at which their activity is maximal. Otherimportantfactorsthat influence the effect of enzymaticprocesses are the concentration of enzyme, the time of treatment, additives like surfactantsand chelators and mechanical stress[Tavčer 2011].

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 newly 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.

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].

2.2 Production of enzymes

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]. Screening approaches are being performed to rapidly identify enzymes with potential industrial application (Korfet al.2005). For this purpose, different expression hosts (*Escherichia coli, Bacillus sp., Saccharomyces cerevisiae, Pichiapastoris*, filamentous fungi) have been developed to express heterologous proteins.*E. coli* remains one of the most attractive. Compared with other established and emerging expression systems, *E. coli,* offers several advantages including its ability to grow rapidly and at high density on inexpensive carbon sources, and the availability of an increasingly large number of cloning vectors and mutant host strains (Baneyx 1999).

The enzymes are inducible, i.e., produced only when needed, and they contribute to the natural carbon cycle. 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 [Cao et al. 1992; Kapoor et al. 2001]. Agro-industrial residues such as wheat bran, rice bran, sugarcane bagasse, corncobs, and apple pomace are generally considered the best substrates for processes [Blandino et al. 2002; Maldonado and Saad 1998; Pandey et al. 1999].

For practical applications, immobilization of microorganisms on solid materials offers several advantages, including repeated usage of enzyme, ease of product separation and improvement of enzyme stability [Kapoor et al. 2001].

2.3Role of biotechnology in textile industry

In pure scientific terms biotechnology is defined as "application of biological organisms, systems and processes to manufacturing and processing industries". The history of identifying enzymes is over 100 years old, while that of using purified enzymes commercially is 60 years old. Among 2000 enzymes reported so far around 150 are found to be of great importance for various industrial processes, which involve applied microbiology and biochemistry. The term BIOTECHNOLOGY is used to refer to the textiles that are based on enzymes. In this paper our attempt is to overview the application of biotechnology in different fields of textile.

Modern wet processing industries are followed the enzymes in the preparatory process instead of using harmful chemical because enzyme are more convenient, effective and environment friendly. The application of enzymes has many advantages compared to conventional, non-enzymatic processes. Especially in textile manufacturing the use of enzymes has a long tradition. Enzymes for cellulosic textilesand their effects are shown in Table 1. The principal enzymes applied in textile industry are hydrolases and oxidoreductases. The group of hydrolases includes*amylases, cellulases, proteases, pectinases and lipases/esterases*, but their innovative applications are increasing and spreading rapidly into all areas of textile processing.

Table 1. Enzymes for cellulosic textiles

Type	Effect
Amylases	Desizing (to decompose starches applied in sizing)
Catalases	Act on H_2O_2 to decompose it into water & oxygen
Protease, lipases and pectinase	When combined, act on proteins, pectins and natural waxes to effect scouring
Laccases	Decomposes indigo molecules for wash-down effect on denim
Cellulases	Break down cellulosic chains to remove protruding fibres by degrading and create wash-down effect by surface etching on denims etc.

The enzymatic desizing of cotton with α-*amylases* is state-of-the-art since many decades (Marcher et al. 1993). The amylose is bioconverted to 100% by the α-*amylase* into glucose whereas the amylopectin is converted to 50% into glucose and maltose. Bio desizing is preferred due to their high efficiency and specific action. *Amylases* bring about complete removal of the size without any harmful effects on the fabric besides eco friendly behavior. Moreover, *cellulases, pectinases, hemicellulases, lipases* and *catalases* are used in different cotton pre-treatment and finishing processes (Meyer-Stork, 2002).

*Cellulases*havebeen employed to enzymatically remove fibrils and fuzz fibres, and have also successfully been introduced to the cotton textile industry. Further applications have been found for these enzyme to produce the aged look of denim and other garments. The potential of proteolytic enzymes was assessed for the removal of wool fibre scales, resulting in improved anti-felting behavior. *Esterases* have been successfully studied for the partial hydrolysis of synthetic fibre surfaces, improving their hydrophilicity and aiding further finishing steps.

Oxidoreductases have also been used as powerful tools in various textile processing steps. *Catalases* have been used to remove H_2O_2 after bleaching, reducing water consumption.

The major areas of applications of biotechnology in textile industry are:

- Advancing in plant biotechnology
- Bio-polishing
- Biotechnology for bastfibre
- Biotechnology in protein fibers
- Biotechnology in textile wet processing
- Biotechnology in garment processing
- Biotechnology in waste water treatment

2.3.1 Advancing in plant biotechnology

Advancing in plant biotechnology resulting in crop improvement by making entire gene pool for utilization.By biotechnology the characteristics of cotton get improved, which results in better quality of yarn and fabric.

2.3.2 Bio-polishing

Bio-polish treatment is imparted to any fiber or fabric to improve its smoothness and shine on the fabric's surface by removing fiber-yarn ends projecting from it. The process can be applied to everything from loose fibers to yarn, fabric, or completed garments. Bio-polishing treatment can be applied for wool and lyocell.

2.3.3 Biotechnology for bastfibre

Retting is generally a microbial process in which stem pectins are degraded there by freeingfibre bundles from the epidermis/cuticle.The practice of water retting which produces high quality fibre has been abandoned in western countries. Commercial enzyme mixtures such as flaxzym and ultrazym are effective in separating fiber bundles from the epidermis/cuticle layer. The linen fabric was treated with purified enzymes acting on pectin, xylan and glukomannan.

2.3.4 Biotechnology in protein fibers

Genetic engineering methods are being investigated with their potential to produce new kind of textile fibers. They are those systems that can produce monomeric protein molecules in solution from appropriately engineered genes. Milk fibers and spider web fibers are some of the fibers produced genetically.

Extraction of new keratin-degrading enzyme suitable for use in shrink-proofing treatment for wool was isolated from mold. This enzyme acts preferentially on the cuticle that is responsible for felt shrinkage, it gives woolen fabric an excellent resistance to shrinkage without weakening the fiber or damaging the hand.

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. Enzyme degumming involves proteollytic degradation of sericin using a specific protease, which does not attack fibroin.

A number enzymatic treatments have been developed to improve the comfort and appearance of wool.

2.3.5 Biotechnology in textile wet processing

In textile industry enzymes are used mainly in the finishing of fabrics and garments (bio-singeing, bio-desizing, bio-scouring, bio-stoning, bio-bleaching and etc.)

2.3.5.1 Bio-singeing

Fabrics containing cellulosic fibers often show fuzzy surface due to chafing during wet processing. A smooth and clear finish can be achieved by bio-singeing.

2.3.5.2 Bio-desizing

Duringtheweavingprocessthewarp (chain) threadsareexposedtoconsiderablemechanicalstrain. Inordertopreventbreaking, theyareusuallyreinforcedbycoating (sizing) with a gelatinoussubstance (size).Sizingistheprocesswheresizeisappliedtowarpyarnsforweaving.Thepurposeofsizeistoprotectt heyarnfromtheabrasiveactionoftheloom. The size must be removed (desizing) before a fabric can be bleached and dyed, since it affects the uniformity of wet processing.Desizingistheprocessofremovingthesizematerialfromthewarpyarnsinwovenfabrics.Sizi ngagentsareselectedonthebasisoftypeoffabric,environmentalfriendliness, easeofremoval, costconsiderations, effluenttreatment, etc.Desizing, irrespectiveofwhatthedesizingagentis,involvesimpregnationofthefabricwiththedesizingagent,allo wingthedesizingagenttodegradeorsolubilisethesizematerial, andfinallytowashoutthedegradationproducts. Various types of desizing methods are available. Alternativeeco-friendlydesizingagentsareavailableinthemarketintheformofenzymes. *Amylases* are used to remove starch. Enzymedesizingisthemostwidelypracticedmethodofdesizingstarch.*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 [Cavaco-Paulo and Gübitz, 2003].

2.3.5.3 Bio-scouring

Scouring is removal of non-cellulosic material present on the surface of the cotton. Raw cotton contains about 90 % of cellulose and various noncellulosics such as waxes, pectins, proteins, fats, lignin-containinig impurities and colouring matter. The goal of the cotton preparatory process is the remove the hydrophobic and noncellulosic components and produce highly absorbent fibres that can be dyed and finished uniformly. The mild reaction conditions offered by enzymatic treatment provide an environmentally friendly alternative.Thestartingstudiesofenzymetreatmentforscouringthatis, cleaningofcottonfibres, werecarriedoutbyGermanresearchers[Schachtetal. 1995; Rößner 1995], andtheyincluded*pectinases*, *proteases*and*lipases*thatactuponimpuritiesand*cellulases*whichhydrolysethecellulosechain. Manyotherresearchersfollowedintheirpath. Theyestablishedthat*cellulases*and*pectinases*arethemosteffectiveones, *lipases*lesswith*proteases*beingtheleasteffective. *Pectinases*, *cellulases*, *proteases* and *lipases* have been investigated most commonly and compared to alkaline scouring.Favourableeffectsofscouringhavebeenobtainedwiththeenzymes*pectinases*[Etters 1999; HartzellandHsieh 1998; LiandHardin1998; Csiszar et al. 2001;AnisandEren 2002; Buchertetal. 2000], thatcatalysethehydrolysisofpectinsubstances. Threemaintypesofenzymesareusedtobreakdownpectinsubstances[Jayani 2005]: *pectinesterases*, *polygalacturonases*and*pectinlyases*.In generally *cellulase* and *pectinase* are combined and used for bio-scouring. But at present, the only commercial bioscouring enzyme products are based on *pectinases*. Bioscouring process provides many advantages, such as reduced water and wastewater costs, reduced treatment time and lower energy consumption because of lower treatment temperature (the optimal temperature is from 40 to 60 ºC) [Li and Hardin 1998]. Moreover, the weight loss in fabric is reduced, and fabric quality is improved with a superior hand and reduced strength loss [Pawar et al. 2002].

Inthestartingresearches, longertimesoftreatmentwerepointedoutasthemaindisadvantageoftheenzymescouring[Sawadaetal. 1998]. Bydevelopingnew*pectinases*,thetimesoftreatmenthaveshortened. Thus, thepresentformsof*pectinases*need 30 to 60minutesfortheirfunctioning[Alyetal. 2004; Hartzell-LawsonandDurant1998].

Pectinase, as the name suggests, hydrolysis pectins that are present in cotton as a non-cellulosic impurity. The best kinds of *pectinase* are those, which can function under slightly alkaline conditions even in the presence of chelating agents. Such enzymes are called "alkaline pectinases". Most conventional *pectinases* are usually inactive under these commercially useful conditions, their optimum activity lying in the slightly acidic region.

The bioscouring process results in textiles being softer than those scoured in the conventional sodium hydroxide process [Nierstrasz and Warmoeskerken 2003].

After the bioscouring the cotton fibres are darker than after alkaline scouring [PrešaandTavčer 2009; Tavčer 2008].

Bioscouring can also be used for mixtures of cotton and silk, wool and cashmere.

2.3.5.4 Bio-stoning

The stone-washed jeans-look is obtained by washing the indigo-dyed jeans with abrasive pumice (volcanic) stones. However, these stones wear out the fabric, damage the washing machines and break apart. A type of enzyme called a *cellulase* has been developed to replace the pumice stones. The cellulase enzymes are capable of breaking down the surface cellulose fibres of the jeans in a controlled manner without seriously damaging the fabric. Enzymes developed for the textile industry can improve production methods and fabric finishing.

2.3.6 Biotechnology in garment processing

Biopolishing may be carried out at any time during wet-processing, but is most conveniently performed after bleaching.Acidcellulase, whenusedinbiopolishing, offers a numberofbenefitssuchasimprovementinpillresistance, coolerfeel, brighterluminosityofcoloursandsoftness, andatthesametimethetreatmentresultsincertainadverseeffectslikelossinweightandstrength.

Denim is the most preferred clothing of today's youth. Various items of denim like pants, shirts, skirts, jackets, belts and caps etc. are available in the market. To give distressed denim look many types of washing is done to denim fabric.One of such washing is known as Stonewash. In stonewashing the worn out look is given purposely. The fabric is washed along with pumice stones.Stonewashing the denim with pumice stones has some disadvantages. For instance stones could cause wear and tear of the fabric, also it creates the problem of environmental disposition of waste of the grit produced by the stones. High labor costs are to be beared as the pumice stones and its dust particles produced are to be physically removed from the pockets of the garments and machines by the labors. Denim is required to be washed several times in order to completely get rid of the stones. The process of stonewashing also harms the big expensive laundry machines.To minimize such drawbacks, stonewashing of denim is carried out with the aid of enzymes. The method of giving the denim a stonewash look by use of enzymes like *cellulase* is known as enzymatic stonewashing. Here *cellulases* are used to provide that distressed worn out look to the denim fabric.*Cellulase* is environment friendly in comparison to pumice stones. As jeans are made up of cellulosic fibers, the use of *cellulase* enzyme is successful in giving the stonewash look. This enzyme breaks down the surface cellulose fibers and removes them without causing harm to the jeans. Better finishing and look is achieved even with indigo dyed denim. Therefore, in terms of the environment, biotechnology offers the opportunity to develop cleaner and more energy-efficient processes, and clean up effluents.

2.3.7 Biotechnology in waste water treatment

Biotechnology can be used in new production processes that are themselves less polluting than the traditional processes. Waste treatment is probably the biggest industrial application of biotechnology. The textile industry include colour removal from effluent, toxic heavy metal compounds and etc.

Currently much research is being carried out to resolve these problems and biotechnology would appear to offer the most effective solutions.

3. Future Directions:

The continued development of new enzymes through modernbiotechnology may, for example, lead to enzyme products withimproved cleaning effects at low temperatures. This could allowwash temperatures to be reduced, saving energy in countrieswhere hot washes are still used. Today, white biotechnology is geared towards creating new materials and biobased fuels from agricultural waste and providing alternative biobased routes to chemical processes. These efforts could lead to the development of improved enzymes such as *amylases*, *hemicellulases*or*cellulases* that could be used in the textile industry. New enzymes with high specific activity, increased reaction speed, and tolerance to more extreme temperatures and pH could result in development of continuous processes for bioscouring or biofinishing of cellulosic fibres. Development of other processes in the future could also expand the use of enzymes on natural fibers into use on man-made fibers such as nylon and polyester.

Newandexcitingenzyme applications are likely to bring benefitsin other areas: less harm to the environment; greater efficiency;lower costs; lower energy consumption; and theenhancementof a product's properties.

Enzymes are now widely used to prepare the fabrics that your clothing, furniture and other household items are made of. Increasing demands to reduce pollution caused by the textile industry has fueled biotechnological advances that have replaced harsh chemicals with enzymes in many textile manufacturing processes. The use of enzymes not only make the process less toxic (by substituting enzymatic treatments for harmful chemical treatments) and eco-friendly, they reduce costs associated with the production process, and consumption of natural resources (water, electricity, fuels), while also improving the quality of the final textile product.

4. Conclusion:

Since the textile industries is the one of major water consumers, the problem faced by the textile industries is of effluent and waste disposal. Also listed chemicals and banned dyes are carcinogenic and highly toxic. 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 used in order to develop environmentally friendly alternatives to chemical processes in almost all steps of textile fibre processing. There are already some commercially successful applications, such as amylases for desizing, *cellulases* and *laccases* for denim finishing, and proteases incorporated in detergent formulations.

Enzyme producing companies constantly improve their products for more flexible application conditions and a more wide-spread use. Further research is required for the implementation of commercial enzyme based processes for the biomodification of synthetic and natural fibers. 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.

There is still considerable potential for new and improved enzyme applications in future textile processing. It seems that in the future it will be possible to do every process using enzymes.

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