Green Revolution in Textile Processing by using Laccases

By:
Ambadas N. Garje

Green Revolution in Textile Processing by using Laccases

By: Ambadas N. Garje

Textile and Engineering Institute, Ichalkaranji

Abstract

The environmental and industrial safety condition increased the potential for the use of enzymes in textile processing to ensure eco-friendly production. Laccase enzymes formulation has been used in textile processing like different processes such as bio-bleaching, dyeing, rove scouring, dyeing, finishing, neps removal, printing, wash-off treatment, dye synthesis & effluent treatment. The discharge printing by using laccases helps to avoid the hazardous reducing chemicals like sulphoxylic acid derivatives and tin salts, in particular stannous chloride. The bio-bleaching is helps the decolorising textile material by using laccase enzyme which don't increasing effluent load. Laccases are also use for washing off process which decreasing use of synthetic detergent. Laccase enzymes does not affecting fiber polymer which means less fabric damages found after processing. Laccase enzymes development further more step in eco-friendly processing.

KEYWORDS: Enzyme, Eco friendly, Laccase, Discharge printing, Bio-washing, Bio-Technology, Bio- scouring, Dye synthesis, Denim washing,

Introduction

Enzymes are a Greek word 'Enzymos' meaning 'in the cell' or 'from the cell'. They are the protein substances made up of more than 250 amino acids. Based on specificity they are grouped. The concept of treating fabrics with enzymes to improves their surface properties was first developed in Japan in 1989. The treatment has assumed more important due present concern of clean and eco-friendly environment under the following group:

- Oxidoreductases- oxidation, reduction reaction
- Transference- transfer of functional group
- Hydrolases- hydrolysis reaction
- Lyases- addition to double bond or its reverse
- Isomerses- isomerisation
- Ligases- formation of bonds with ATP clevags

Enzymes have bright future in wet processing of textile industry. Enzymes do not produce toxic effluent as they can easily deactivated disposal off.

The silent features of enzymes application in textile processing:-

1. Extremely specific nature of reaction involved, with practically no side effect.
2. low energy requirement , mild condition of use safe to handle , non-corrosive in their applications
3. On account of lesser quantities of chemical used in process as well as ease of biodegradability of enzymes result in reduced loads on ETP plants.
4. Enzymes under unfavorable condition of pH or temperature, chemically remain in same form but their physical configuration may get altered i.e. they get “denature” and lose their activity. for this reason live steam must never be injected in a bath containing enzyme bath must done in pre-diluted form
5. Compatibility with ionic surfactant is limited and must be checked before use. Nonionic wetting agents with appropriate cloud point must be selected for high working efficiency as well as for uniformity of end result
6. High sensitivity to pH, heavy metal contamination and also to effective temperature rang. Intense cautions are required in use

Laccases Enzyme

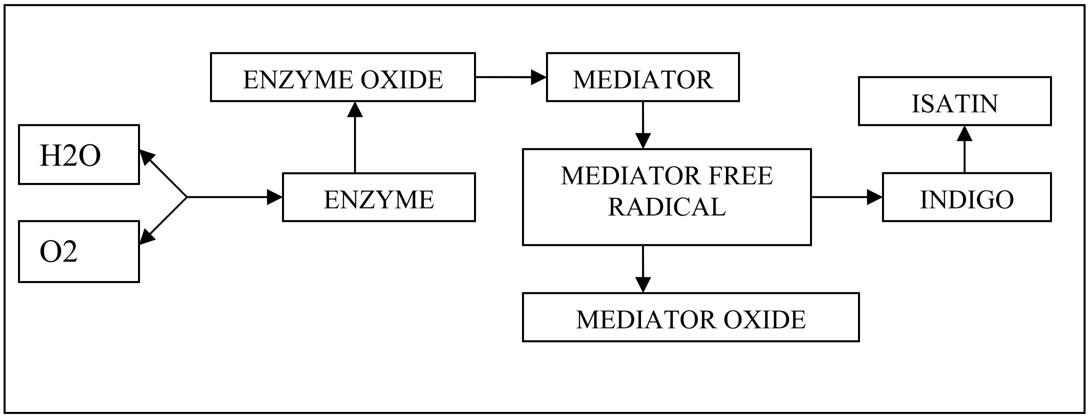
Laccases is the newest enzyme class to be introduced into the denim finishing area. The first commercial product was introduced in 1996. This product exhibited good performance, but handling characteristic were not ideal. A fully-formulated solid laccases has been commercially available for the denim market since1999.

The commercial laccase formula contains laccase an enzyme mediator, buffer and a non ionic surfactant. Pure laccase was obtained from this formulation and its activity determined. The first laccase studied was originated from *Rhus vernicifera* tree and many other laccases are being discovered and studied from various plant and microbial sources. The ability of laccases to catalyse the oxidation of phenolic and non-phenolic compound has gained much attention over the year in many industrial and environmental field; particular commercial interest is the wide range of synthetic dye sand natural coloring matter.

The laccase enzymes are known from microbial and plant origin. The microbial laccase enzyme may be derived from bacteria or fungi (including filamentous fungi and yeasts) and suitable examples include a laccase derivable from a strain of Aspergillus, Neurospora, e.g. N. crassa, Podospora, Botrytis, Collybia, Fomes, Lentinus, Pleurotus, Trametes (previously called Polyporus), e.g. T. villosa and T. versicolor, Rhizoctonia, e.g. R. solani, Coprinus, e.g. C. plicatilis and C. cinereus, Psatyrella, Myceliophthora, e.g. M. thermophila, Schytalidium, Phlebia, e.g., P. radita (WO 92/01046), or Coriolus, e.g. C.hirsutus (JP 2-238885).

The range of dyes which can be decolorized by using laccase may be additionally applying defined mediator. *“Mediators are low molecular weigh compounds that are easily oxidised by laccases producing very reactive radicals which attack more complex substrate before return to its original state.”*

Determination of Laccase Activity (LACU): Laccase activity is determined from the oxidation of syringaldazin under aerobic conditions. The violet color produced is photometered at 530 nm. The analytical conditions are 19 µM syringaldazin, 23.2 mM acetate buffer, pH 5.5, 30° C, 1 min. reaction time.



Mechanism Concerned with Decolorisaton

Bio-bleaching By Using Laccases

Both conventional and enzymatic scouring processes do not affect natural colorant in the natural fiber to a major extent, and bleaching is essential for a good level of whiteness, especially for material to be dyed in lighter shades. Currently, the most common industrial bleaching agent is hydrogen peroxide, which is applied at pH 10.5-11 and temperature close to the boil. Hydrogen peroxide itself decomposes into environmentally being compound (water and oxygen), however the condition during bleaching possible radical reaction of the bleaching compound with the fiber. These reactions can lead to a decrease in the degree polymerization and eventually to a drop in tensile strength, specialty in presence of particular metal ions which act as activators for hydrogen peroxide. Additionally, alkaline conditions negatively influence the effluent treatment and the temperature needed for the cost.

Laccases /mediator system have been used explored. First, laccases/mediator systems have been used successfully for bleaching of natural fiber material. The major drawback of this bleaching system is identification of suitable mediator compound. Currently available mediator raise question about efficiency and toxicity.

Removal of Neps and Seed Coat Fragment

With conventional alkaline scouring bleaching, seed coat fragments are removed. However, undyable neps remain a problem. Neps generally consist of flat immature fiber. Laccases from different sources were incorporated into the bioscouring process as well as after bleaching and the treatment was increased with this treatment, it is possible to break up seed coat fragments and reduces number drastically.

Rove scouring

Flax processing into yarn essentially still follows traditional methodologies. Laccase is an alternative to the chemical scouring of rove. One of the studies shows that the effects of several enzymes under slightly alkaline pH conditions. They found that the treatment with laccase plus mediator performed better than the chemical one. Also showed that laccase enzyme could be used for roving treatment to improve yarn regularity. The advantage of the use of laccase in rove scouring is that the process is performed under mild reaction conditions resulting, thus, in an ecologically friendly process.

Discharge printing

The theory of discharge printing involves the degradation by chemical reagent of the chromophore system of the dyestuff applied to the textile material. There are mainly two type of discharging agent, namely two type of discharging agent namely oxidizing and reducing agents. The most important discharging agent in textile printing today are reducing agent. The letter comprises sulphoxylic acid derivatives and tin salts, in particular stannous chloride. The reaction takes place during the steaming fixation step and the quality of product depends, to great extent on the temperature and moisture content of the fixation room; any error will cause destruction of the cellulose material.

Enzymatic Discharge Printing of Dyed Textiles The instant invention is a method for enzymatic discharge printing of a dyed fabric. Specifically, dye on the surface of a dyed fabric is decolored in selected areas to create a printed surface. The method of the invention may also be used in the air brushing of dyed fabrics, particularly of indigo-dyed denim fabrics. However, the method of the invention can be used with non-denim fabrics as well.

In one of the studies, medium weight desized, bleached and mercerized cotton fabric was dyed with different reactive dyes. The viscosity of the paste was maintained by sodium alginate, which was used as thickening agent. Denilite IIS (a commercial product based on laccases enzymes) supplied by Novo Nordisk

Fabric used for discharge printing

The method of the invention may be used with a variety of fabrics, including a cellulosic fabric, a mixture of cellulosic fibres, or a mixture of cellulosic fibres and synthetic fibres. Suitable fabrics include cotton, cotton denim, polyester, spandex, silk, wool, cellulosic fibers, or a mixture there of.

Washing off process

Washing off reactive dyeing is an expensive treatment in term of water, energy time and chemicals. The efficiency of washing of unfixed reactive dyestuff and fastness requirement. This problem has been solved by used of laccases, enzyme which oxidizes the organic substance. They are specific in action in that they act on unfixed dyes only.

The use of laccases it is conclude that about 20-30% saving in process time is possible with 10-15% in the total cost.

Anti-shrink treatment for wool

A process conventionally used for wool shrink-proofing is chlorination. This process degrades the exo-cuticle of the wool, forming cysteic acid residues and protein losses. This process has been replaced by proteinases treatment due to their high specificity and much lower environmental impact. However, proteinase treatment leads to protein degradation, resulting in deterioration of fiber strength and limited shrink resistance. A patent application about the use of laccase from *T. versicolor* plus a mediator to increase the shrink resistance of wool was published (Yoon 1998). Also, Lantto et al. (2004) found that wool fibers can be activated with laccase if a suitable mediator is present. Therefore, the use of laccase for anti-shrink treatment of wool seems very attractive.

Denim finishing

In the textile finishing industry, enzymatic degradation of indigo could have a potential both in stone-wash process and for the treatment of dyeing effluents. Several steps are involved in the manufacture of denim garments between dyeing and the final stone-washing where excessive amounts of indigo are removed from the fabrics and discharged with the wastewater. The traditional technology of producing a stone-washed look in denim fabric involves the wash of the fabrics in the presence of pumice to generate the desired erosion of the fabrics. Subsequently, the fabrics are partially bleached by a treatment with sodium hypochlorite, followed by neutralisation and a rinsing step all causing substantial environmental pollution (Pedersen and Schneider 1998). In 1996, Novozyme (Novo Nordisk, Denmark) launched a new industrial application of laccase enzyme in denim finishing: DeniLite TM, the first industrial laccase and the first bleaching enzyme acting with the help of a mediator molecule. In 1999, USA launched DeniLite IITM based on a new type of laccase with higher activity than that of DeniliteI TM. Also, in 2001, the company Zytex (Zytex Pvt. Ltd., Mumbai, India) developed a formulation based on LMS capable of degrading indigo in a very specific way. The trade name of the product is Zylite. Campos et al. (2001) reported the degradation of indigo both in effluents and on fabrics using purified laccases from *Trametes hirsuta* and *Sclerotium rolfsii* in combination with redox-mediators and reported that bleaching of fabrics by the laccases correlated with the release of indigo degradation products. More recently, Pazarlogliu et al. (2005) showed that a phenol-induced laccase from *Trametes versicolor* was an effective agent for stonewashing effects of denim fabric without using a mediator. Moreover, they found that *T. versicolor* laccase without a mediator was more effective than commercial laccase (obtained from recombinant *Aspergillus niger*, Novo Nordisk, Denmark) with a mediator.

Advantage Of Laccases Enzyme Over Conventional Process

- Non AOX generation
- Authentic wash resulting in an excellent look
- It would not attack on fiber polymer
- Interesting effect were obtained on bleaching denim
- Reduces environmental burden by reducing waste water treatment
- Requires less washing which reduces processing time and save water
- Whiteness indices of the treated good of 62-63 could be achieved ,which are very closer to those of conventionally scoured & bleached cotton sample (WI=72)
- Absorbency and mechanical properties of the good excellent & minimum damage
- Less energy required
- No any hazardous chemical liberate
- No any back staining on fabric
- Residues are easily biodegradable

Future Prospect on Laccases Enzymatic Treatment

- The major drawback of this bleaching system though is that suitable mediator, compound have to be identified. Currently available mediator raise question about efficiency about efficiency and toxicity, mediator seem necessary for electron transfer to support the action of the fairly non-specific laccase. They are consumed during the reaction and as such not considered true catalyst.
- The initial cost of the enzymatic processing are very high
- The more time consuming required for processing.
- The lack of commercialized product availability.

Conclusion

The environment and industrial safety condition have increased the potential for the environmental friendly chemicals in textile processing to ensure eco-friendly production. Enzymes seem to be one of the promising chemicals which has opened the doors of eco-friendly processing. Further development in the application of enzymes in textile will open new avenues for making the process environmental friendly thereby saving our precious PLANET. The sensitivity and the specificity aspect are to be dealt with much depth and new generation multifunctional enzymes are to be developed which will be rugged and versatile. Hopefully the Bio-technology will surely lay the foundation of eco-friendly processing by totally replacing the hazardous chemicals and will pass the test of difficult time.

References

1. Ecofriendly discharge printing on cotton fabrics using laccase enzyme; I Abd El-Thalouth, F Kantouch, S H Nassar, H M El-Hennawi & M Adel Youssef;Indian Journal of Fibre & Textile Research Vol. 33, March 2008, pp. 52-57

2. Decolorization of reactive dyes by laccase immobilized in alginate/gelatin blent with PEG.;Wang P, Fan X, Cui L, Wang Q, Zhou A.;Key Laboratory of Eco-textiles, Ministry of Education, Jiangnan University, Wuxi 214122, China. wxwping@163.com
3. Decolorization of Textile Dyes by Microbial Laccase; UCHIDA HIROYUKI(Fukui Univ., Fac. of Eng.) FUKUDA TETSUYA(Fukui Univ., Fac. of Eng.) TAKASHIMA YOSHIKO(Fukui Univ., Fac. of Eng.) UWAJIMA TAKAYUKI(Fukui Univ., Fac. of Eng.); Bulletin of the Fiber and Textile Research Foundation
4. Study of dye decolorization in an immobilized laccase enzyme-reactor using online spectroscopy; Andreas Kandelbauer [1], Oliver Maute [2], Rudolf W. Kessler [2], Angelika Erlacher [1], Georg
5. Enzyme based pretreatment for cotton goods; R.Y. Churi &S.M. Khadilkar ; Colourage,july2001
6. Impact of bio- technology on the textile industry; Rakesh Doshi;Asian Textile journal, Jan 2002
7. Role of enzymes in textile processing industry; O L Shanmugasundaram & S Kumaravel; Asian Dyer;NOV-DEC2005
8. Enzymes in wet processing; Dr.Nikhil Verma& Dr. Anita Nishkam; The Indian Textile JournalFeb2003/37
9. Application of biotechnology in textile; M Muthu manickem and J Ganesh Prasad; Asian Dyer,oct2006/67
10. Recent research on biotechnology in textile ; Dr.Danny E Akin &Ian R Hardin; colourage, Annual2004/55
11. Chemistry of the textile industry; edited by C. M. Carr
12. Biotransformation enzymes for the degradation of textile dyes,Sushama S. Gomare and Sanjay P. Govindwar, Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology.
13. Katja Koschorreck, Rolf D Schmid and Vlada B Urlacher*, Improving the functional expression of a Bacillus licheniformis laccase by random and site-directed mutagenesis, BMC Biotechnology 2009, 9:12 doi:10.1186/1472-6750-9-12
14. Sushama S. Gomare and Sanjay P. Govindwar, Biotransformation enzymes for the degradation of textile dyes, Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology.
15. Mee-Young Yoon, Finishing with Enzymes, International Dyer, December2005

16. Elisabetta Aracri a, Amanda Fillat a, José F. Colom a, Ana Gutiérrez b, José C. del Río b, Ángel T. Martínez c,Teresa Vidal a,*, Enzymatic grafting of simple phenols on flax and sisal pulp fibres using laccases, http://www.elsevier.com/locate/biortech
17. Susana Rodríguez Couto* and José Luis Toca-Herrera*, Lacasses in the textile industry, Biotechnology and Molecular Biology Review Vol. 1 (4), pp. 115-120, December 2006

18. Susana Rodríguez Couto* and José Luis Toca-Herrera*, Industrial and biotechnological applications of laccases: A review, Biotechnology Advances 24 (2006) 500–513.
19. Anna-Liisa Auterinen, The use of enzymes in textile wet processing results in time, energy and water savings; as well as improved product quality, MAY/JUNE 2006 TextileWorld.com

This paper was presented at Veermata Jijabai Technological Institute (VJTI), Mumbai in the VASTRA 2011 in a two day event held on Feb 18th & 19th, 2011