A Revolutionary Enzymatic Process for Textile Industries

Professor D.Jothi

Abstract

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. However, there is little known about potential enzyme usage in other textile areas. 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. Now the use of biocatalyst has become state of the art in the textile industry. The production processes in cotton processing industry not only consume large amount of energy and water but also produce substantial waste products. According to a study, existing processing industries use strong and excess of alkalis/acids, extreme temperature, and large volume of water. Industrial overheads include not only the cost of the chemical and energy, but also the cost of wastewater treatment. Effluents generated from these processing houses exert pollution load in terms of BOD (biochemical oxygen demand), COD (chemical oxygen demand), dissolved solids, high pH, residual chlorinated organic, residues of oxidizing agents, traces of alkalis or acids etc. One possible way of attending this problem is to adopt bio-processing techniques. In view of the same, a comparative study has been conducted by the author to observe the performance of different parameters associated with effective processing of both enzymatic and existing alkaline methods on cotton fabric, keeping an environment friendly route in processing and process economics in mind.

1 Introduction

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 increasingly important requirements for textile manufacturers to reduce pollution in textile production. Enzymes sources, activity, specificity, reaction, mechanism and thermodynamics, function of textile processing with enzymes, major enzymatic applications in textile wet processing and promising areas of enzyme applications in textile processing are discussed. The aim is to provide the textile technologist with an understanding of enzymes and their use with textile materials.

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1.1 Enzymes are Proteins

Enzymes are general y 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. Individual protein chains may sometimes group together to form a protein complex. Enzymes are biocatalysts, 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. Most of the biocatalyst have limited stability and over a period of time they lose their activity and are not stable again. Usually most enzymes are used only once and discarded after their catalytic action.

1.2 Nomenclature

The International Union of Biochemistry and Molecular Biology have developed a nomenclature for enzymes, the EC numbers where each enzyme is described by a sequence of four numbers preceded by "EC". The first number broadly classifies the enzyme based on its mechanism.

The top-level classification is

EC 1 Oxidoreductases: catalyze oxidation/reduction reactions.

EC 2 Transferases: transfer a functional group.

EC 3 Hydrolases: catalyze the hydrolysis of various bonds.

EC 4 Lyases: cleave various bonds by means other than hydrolysis and oxidation.

EC 5 Isomerases: catalyze isomerization changes within a single molecule.

EC 6 Ligases: join two molecules with covalent bonds.

At present, more than 2,000 enzymes have been isolated and characterized. Among them about 50 microbial enzymes have industrial applications.There is a large number of microorganisms which produce a variety of enzymes. Microorganisms producing enzymes of textile important are listed Table 1.

Table-1	
Micro organisms	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
Basidiomycetes	α- amylase
Aspergillus sp	Pectinase, lipase

1.3 Activity

The activities of enzymes are determined by their three-dimensional structure. Most enzymes can be denatured, which disrupt the three-dimensional structure of the protein. Denaturation may be reversible or irreversible depending on the enzyme.

There are two proposed models of enzyme substrate complex formation.

1.4 Lock – Key Mechanism

In 1894 Emil Fischer provided the lock-and-key model assuming that the active site is a perfect fit for a specific substrate and that once the substrate binds to the enzyme no further modification is necessary. It is a simplistic model.

1.5. Induced fit Model or Koshaland Model

.In 1958 Daniel Koshland suggested a modification to the lock and key model. Instead of flexible structures, the active site is continually reshaped by interactions with the substrate as the substrate interacts with the enzyme. As a result, the substrate does not simply bind to a rigid active site; the amino acid side chains which make up the active site are molded into the precise positions that enable the enzyme to perform its catalytic function. In some cases, such as glycosidases, the substrate molecule also changes shape slightly as it enters the active site. The active site continues to change until the substrate is completely bound, at which point the final shape and charge is determined. The product is usually unstable in the active site due to steric hindrances that force it to be released and return the enzyme to its initial unbound state.

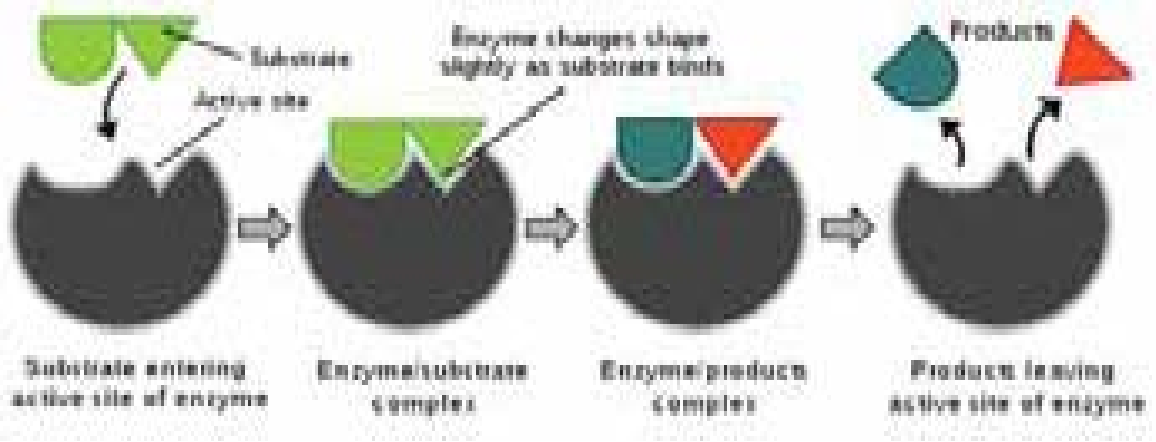

Fig 1: Induced Fit Model

1.6 Enzymatic Reaction

Victor Henri elaborated enzyme reactions in two stages. In the first, the substrate binds reversibly to the enzyme, forming the enzyme-substrate complex. This is sometimes called the Michaelis complex. The enzyme then catalyzes the chemical step in the reaction and releases the product.

1.7 Enzymes can act in several ways, all of which lower ΔG‡:

- Lowering the activation energy by creating an environment in which the transition state is stabilized.

- Lowering the energy of the transition state, but without distorting the substrate, by creating an environment with the opposite charge distribution to that of the transition state.

- Providing an alternative pathway. For example, temporarily reacting with the substrate to form an intermediate ES complex, this is not possible without enzyme.

- Reducing the reaction by bringing substrates together in the correct orientation to react.

- Reactions speed up with increase in temperatures. However, the enzyme's shape deteriorates on overheating and only when the temperature comes back to normal does the enzyme regain its shape. Some enzymes like hermolabile enzymes work best at low temperatures.

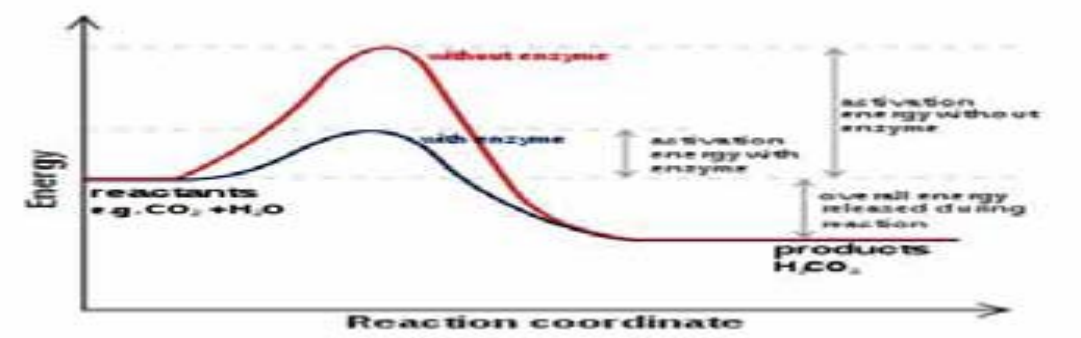

Fig-2 Enzyme Reaction Coordinates

Enzymes like all catalysts do not alter the position of the chemical equilibrium of the reaction. They do not alter the equilibrium itself, but only the speed at which it is reached. Usually, in the presence of an enzyme, the reaction runs in the same direction as it would without the enzyme, just more quickly. However, in the absence of the enzyme, other possible uncatalyzed, spontaneous reactions might lead to different products, because in those conditions this different product is formed faster.

2. Objectives

- To replace hazard chemicals in textile chemical processing by organic natural products
- To minimize energy ,water and cost
- To establish pollution free textile processing

2.0 Experimental Procedure

2.1 Materials

Knitted fabric samples were collected from Yirgaleum Addis Textile Factory ,PLC,Addis Ababa. Enzymes were supplied from Harini Bio Tech Chemical Manufacturing, Addis Ababa, Fabric sample with following construction particulars was subjected to scouring and dyeing in winch:

2.3 Methods

2.2 Sample Details

Fabric - 100% cotton

Type: single Jersy

GSM: 180

Details Of Enzymes

- Bio Scouring ,Type :Lipase extracted from Aloe Deberana Plant
- Dye-fixing ,Type :catalase extracted from Aloe Deberana Plant
- Bio softener ,Type Spanion extracted from Aloe Deberana Plant
- organic acid to replace Acetic acid,Type :Lipase+ xylanase+ acid component from Ethiopian natural resources.

Conventional process for Dark Colors

Scouring

Scouring was carried out by using material: liquor ratio of 1:10. The scouring bath is prepared with 3% of caustic soda (38°Be), 4% of hydrogen peroxide, 0.4% of peroxide stabiliser, 0.2% softener ,acetic acid 1.5 gpl and 1% of wetting agent.

The sample was worked out for 4 ends at 95°C and pH of 10. After scouring, 2 ends' hot wash and 2 ends cold wash is given.

Dyeing

Dyeing is carried out by using material: liquor ratio of 1:10. The bath is prepared with 0.50% Corozal yellow HE4G, 0.25% Corozal Orange HEG, 60g/1 Glauber's salt, and 15 g/I Soda ash. Dyeing is carried at 80°C temperature and at a pH of 10. After dyeing, soaping is carried out using 2 g/I neutral detergent at a temperature 60°C followed by cold washing and drying.

Hot Washing followed by cold wash

Dye –fixing process: M:l ratio 1:10 ,Dye-fixing agent 3%-Time :20 min Temp-90ºC

Washing

Softening Process: M:l ratio 1:10 ,Synthetic softener 3%-Time :20 min Temp-90ºC

Enzymatic Process

Scouring

Enzymatic scouring is done by using material: liquor ratio of 1:10. Scouring bath was prepared with 3.5% bio Scour Enzyme Sample is scoured at 70°C and at a pH of 7, followed by 2 ends' hot wash and 2ends cold wash.

Dyeing

Similar to conventional process.

Dye-fixing: In the same bath without draining water

Softener: In the same bath without draining water at 90 C for 20 min.

3.0 Test results

Evaluation

3.1 Determination of weight loss %

Let us take GSM of the unprocessed fabric as Wi' Then, after processing, the fabric is dried and GSM of processed fabric is taken as W2. Weight loss can easily calculated by using formula :

Weight loss % = (W1-W2)/W1 X 100

3.2 Determination of wash fastness

Source: IS 687-1979

Apparatus: Launder-o-meter (Capacity of each container: 500 ml and the rotor speed is 40±2 revolutions/minute.)

3.3 Determination Of Colour Fastness To Rubbing

Source: IS 766-1956

Apparatus: Crock-o-meter

Principle: It prescribes the method of determination of colour fastness of the specimen to rubbing off and staining other material.

3.4 Determination Of Color Fastness To Light

Source: IS 2454-1985

Apparatus: Xenon tester/Fade-o-meter

Weight loss% of traditional, enzymatic and Conventional process is indicated in Table 2.

Higher weight loss in traditional method may be due to severity of treatment, which results in greater removal of natural and added impurities. There is also the possibility of degradation of cellulose because of harsher alkaline treatment. Enzymatic processing shows lower weight loss and this may be due to controlled treatment.

Particulars	Conventional Process	Enzymatic process
Weight loss in %	6.4	4.04
Wash Fastness	¾	4/5
Rubbing fastness		
Dry	4	4/5
Wet	3/4	4/5
Light fastness	3/4	4/5

Table 2: Comparative Evaluation of Conventional and Enzymatic Process

Chemicals	Consumption by %	Consumption by Quantity	Unit cost in USD	Total cost in USD
Per-oxide	4	168 liters	1.50	252.0
Caustic	3	126 Kg	0.80	100.8
Stabilizer	o.4	16.8 Kg	1.40	23.52
softener	0.2	8.4	3.0	25.2
Acetic Acid	1.5	50.4 liters	1.8	90.72
Soap	1	40 liters	0.9	36.0
Energy cost	20		1.0	20.0
Water	0.10	2800 liters		14.0
			Total cost	**542.44**
			Cost/1 KG	**0.13**

Table 3: Economic Advantages of Enzymatic Process (Pre-treatment Process only considered)

Fabric Weight 4000 Kg
Costing Details of Conventional Process

Chemicals	Consumption by %	Consumption by Quantity	Unit cost in USD	Total cost in birr
t Bio scouring	3.5%	140 kg	1.3	182.0
Energy cost	15		1.0	15.0
water	0.10	1600		6.8
			Total cost	**203.8**
			Cost/1 Kg	**0.05**

Table 4: Costing Details of Enzymatic Bio Tech Process

SINO	Process	Cost/Kg USD	
1	Conventional Process	0.13	
2	Enzymatic process	0. 05	
	Net cost saving	**0.08**	

Table 5: Cost difference between Conventional and Enzymatic Pre-treatment Process

Economics for each process was calculated considering all the details like chemicals, auxiliaries, water, electricity and labor costs, and tabulated in Table3, 4&5. It is observed that cost of processing fabric in traditional method is around 0.13USD /Kg, whereas costs of one stage enzymatic processed fabric was 0.05/Kg USD respectively. The net cost saving in enzymatic process is 0.08 USD /Kg.

Summary

Cotton fabrics processed with enzymes have shown better color fastness properties are observed. In the subjective assessment, enzymatic processes have registered better hand feeling than traditional method. Significant saving of water due to lower water consumption scouring method of enzymatic processes exert less effluent load on environment. Economics also do favor enzymatic process. Considering better durability, fastness, feel of the fabric, and environment friendly processing, enzymatic process may be preferred for the betterment of World Textile Industries.

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About the Author

Durairaj Jothi obtained his Master in Textile Technology from PSG.Tech, India. He has around three decades of working experience in R&D, quality assurance and teaching. He is presently working as HOD/Textile Chemistry Department of SSM.College of Engineering, B.Komarapalayam, India. He has published technical papers in reputed national/international journals. He has received two Utility Model certificate from Ethiopian Science &Technology for his innovation on enzymatic industrial process for Leather &Textile .