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Biovision in Textile Wet Processing Industry- Technological Challenges

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ABSTRACT

Environmental consciousness is one of the major concerns for textile wet processing industry as the industry contributes much to industrial pollution problems facing the country. Such pollutants as such as lime, sodium sulfide, salt, solvents, synthetic pigments come mainly from desizing, scouring, bleaching and dyeing processes in textile wet processing. In order to overcome the hazards caused by the chemical effluents, use of enzymes as a viable alternative has been resorted to in preparatory dyeing operations such as desizing, scouring, and bleaching treatments. This review focuses on the use of microbial enzymes as an alternate technology to the conventional methods, and highlights the importance of these enzymes in minimizing the pollution load. Environmental pollution has been a major irritant to industrial development. Also in this paper we have discussed the advantages and limitations of bioprocessing techniques in the various textile wet processing such as desizing, scouring, bleaching, biopolishing, bio-singeing and bio-decoloration in the dyeing effluents for cellulosic and non-cellulosic materials.

Keywords: enzymes, dyeing, wet processing, environmental pollution

1. INTRODUCTION

In the conventional textile wet processing, the grey fabric has to undergo a series of chemical treatments before it turns into a finished fabric. This includes desizing, scouring, mercerization, bleaching and washing. For all these steps, the chemicals used are quite toxic. During fabric manufacture, the non-cellulosic and foreign constituents are removed partially or completely in the various pre and post operations; the extent of removal of these constituents decides the characteristics of the final textile fabric [1]. Besides chemical treatment, certain enzymatic treatments are also necessary to get optimum results. Chemical and chemical-based industries are the prime targets of the environmentalists for their crusade against pollution, and textile industry has also not been left out of the reckoning. The generation of pollution is significantly high in the preparatory and dyeing operations compared to the post dyeing operations. In fact, one third of the pollution caused by the textile industries results from the wastes generated during desizing operations. The wastes from the dyeing houses are let out into the drains which in turn empty into the main sewerage causing hazard to those who use this water.

Many dyeing houses have been forced to close down because of their noncompliance with the standards laid down. In a short span of time, Indian textile industry has faced serious challenges such as German ban on pentachlorophenate, certain azo dyes, formaldehyde, etc. on one hand, and court order for compliance with environmental regulations. The attention of dyeing units is focused towards revamping the processing methods, recovery systems, and effluent treatment techniques to make textile processing eco-friendly. Intensive efforts are being directed towards using a viable alternative technology for pre and post processes using enzymes. This could be one of the ways of solving the industrial pollution problems resulting from textile waste water effluents and sustainable planet.

2. BIOPROCESSING

Bioprocessing can simply be defined as the application of living organisms and their components to industrial products and processes. It is not an industry in itself, but an important technology that will have a large impact on many industrial sectors in the future. Bioprocessing is the application of biological organisms, systems or processes to manufacturing industries. Bioprocessing firms will rely mainly on inexpensive substrates for biosynthesis, processes that will function at low temperatures, and will consume little energy [2]. In Textile Processing, the enzymatic removal of starch sizes from woven fabrics has been in use for most of this century and the fermentation vat is probably the oldest known dyeing process. Bioprocessing a new impetus in the last few years has been the very rapid developments in genetic manipulation techniques which introduce the possibility of 'tailoring' organisms in order to optimize the production of established or novel metabolites of commercial importance and of transferring genetic material from one organism to another. Bioprocessing also offers the potential for new industrial processes that require less energy and are based on renewable raw materials [3]. Various applications which entail enzyme and colors broadly included fading of denim and non-denim, bioscouring, bio-polishing, silk degumming, carbonizing of wool, peroxide removal, washing of reactive dyes, etc.

2.1 BIOTECHNOLOGY IN TEXTILE PROCESSING

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

- Improvement of plant varieties used in production of textile fibers.
- Improvement of fibers derived from animals and health care of animals.
- Novel fibers from biopolymers and genetically modified microorganisms.
- Replacement of harsh and energy demanding chemical treatments by environment friendly routes to textile auxiliaries such as dyestuffs.
- Novel uses for enzymes in textile finishing.
- Development of low energy enzyme based detergents.
- New diagnostic tools for detection for adulteration and quality control of textiles.
- Waste management.

2.2 ENZYMES IN BIOPROCESSING

Today, enzymes have become an integral part of the textile processing. Though enzyme in desizing application was established decades ago, only in recent years the application has widened with new products introduced. With the increase in awareness and regulation about environment concerns, enzymes are the obvious choice because enzymes are biodegradable and they work under mild conditions saving the precious energy [4]. Enzymes being biocatalysts and very specific are used in small amounts and have a direct consequence of lesser packing material used, the transportation impact is lower. In an overall consideration enzymes are the wonder products.

2.2.1 SALIENT FEATURES OF ENZYME APPLICATION IN TEXTILE PROCESS ARE

- Extremely specific nature of reactions involved, with practically no side effects.
- Low energy requirements, mild conditions of use, safe to handle, non- corrosive in their applications.
- On account of lesser quantities of chemicals used in process as well as ease of biodegradability of enzymes results in reduced loads on ETP plants.
- Enzymes under unfavorable conditions of pH or temperatures chemically remain in same form but their physical configuration may get altered i.e. they get "denatured" and lose their activity. For this reason live steam must never be injected in a bath containing enzymes and any addition of chemicals to the enzymes bath must be done in pre-diluted form.
- Compatibility with ionic surfactants is limited and must be checked before use. Nonionic wetting agents with appropriate cloud points must be selected for high working efficiency as well as for uniformity of end results.
- High sensitivity to pH, heavy metal contaminations and also to effective temperature range.
- Intense cautions are required in use.

3. ENZYMES

Enzymes are biological catalysts. A catalyst is any substance which makes a chemical reaction goes faster, without itself being changed. A catalyst can be used over and over again in a chemical reaction: it does not get used up. Enzymes are very much the same except that they can be easily denatured by some means. All enzymes are made of protein; that is why they are sensitive to heat, pH and heavy metal ions. Unlike ordinary catalysts, they are specific to one chemical reaction. An ordinary catalyst may be used for several different chemical reactions, but an enzyme only works for one specific reaction [5]. Enzymes must have the correct shape to do their job. Enzymes change their shape if the temperature or pH changes, so they have to have the right conditions. Conventional chemical processes are generally severe and fiber damage may occur. However, enzymes are characterized by their ability to operate under mild conditions. As a result processes may take place without additional harm to the fiber. Enzymes are also readily biodegradable and therefore potentially harmless and environmentally friendly. Enzymes are proteins with highly specialized catalytic functions, produced by all living organisms.

3.2 MECHANISM OF ENZYME ACTION - LOCK & KEY THEORY

In the absence of enzymes, chemical reactions occur only when molecules collide while in proper alignment with each other. Because molecules are bumping into each other randomly, chemical reactions are essentially due to chance events. This sometimes results in reactions that occur very slowly, or reactions that do not occur at all. Enzymes act like tiny molecular machines to ensure that molecules come into contact with each other and react. Like a key fitting into a lock, chemical molecules fit into pocket-like structures located on an enzyme. These pockets hold the molecules in a position that will allow them to react with each other, ensuring that they are close enough together and aligned properly for a reaction to occur. In this way, enzymes speed up reactions. The enzymes are not changed themselves by the reaction. When the reaction is complete, enzymes release the product(s) and are ready to bring together more molecules and catalyze more reactions [6]. Enzymes have active centers, which are the points where substrate molecule can join. Just as a particular key fits into a lock, a particular substrate molecule fits into the active site of the enzyme. The substrate forms a complex with the enzyme. Later the substrate molecule is converted into the product and the enzyme itself is regenerated which is shown in Figure 1.

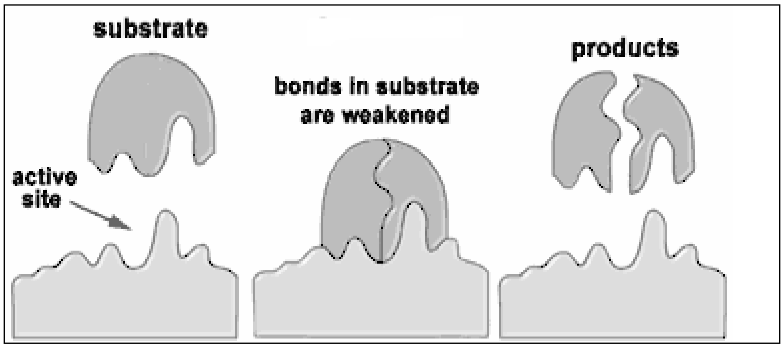

FIGURE 1. LOCK & KEY MODEL OF ENZYME SPECIFICITY

3.3 ENZYME SOURCES

Commercial sources of enzymes are obtained from three primary sources, i.e., animal tissue, plants and microbes. 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).

3.4 ADVANTAGES

- ❖ Lower discharge of chemicals and wastewater and decreased handling of hazardous chemicals for textile workers.
- ❖ Improved fabric quality.
- ❖ Traditionally, to get the look and feel of stonewashed jeans, pumice stones were used. However, thanks to the introduction of cellulase enzymes, the jeans industry can reduce and even eliminate the use of stones. Of course, a big driver for the jeans industry is fashion. Enzymes give the manufacturer a newer, easier set of tools to create new looks. Although many consumers do not want their jeans to look or feel new, they usually do not want them to look worn-out or torn. The pumice stones used to "stonewash" the denim clothes can also over abrade or damage the garment. By using enzymes, the manufacturer can give consumers the look they want, without damaging the garment.
- ❖ Less mining, reduced waste, less energy, less clogging of municipal pipes with stones and stone dust,

fewer worn out machines and pipes attributed to stones and stone dust.

- ❖ More fashion choices longer garment life/wear due to lower damage of original fabric.
- ❖ Reduced chemical load, reduced water consumption, lower energy consumption.

3.5 TYPES OF ENZYMES

Enzymes are responsible for many essential biochemical reactions in microorganisms, plants, animals, and human beings. Enzymes are essential for all metabolic processes, but are not alive. Although like all other proteins, enzymes are composed of amino acids, they differ in function in that they have the unique ability to facilitate biochemical reactions without undergoing change themselves. This catalytic capability is what makes enzymes unique [7]. 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. Major types of enzymes used in the textile wet processing industries are given in Table 1.

TABLE 1. TYPES OF ENZYMES USED IN TEXTILE INDUSTRY

S. No.	Type of enzyme	Application
1	Amylases	To decompose starches in sizing preparations
2	Catalases	Act on Hydrogen Peroxide to decompose it into water and oxygen
3	Protease, lipases and pectinase	When combined, act on Proteins, Pectins and natural waxes to effect scouring
4	Laccases	Decompose indigo molecules for wash-down effect on denim
5	Cellulases	Break down Cellulosic chains to remove protruding fibers by degradation & create wash-down effect by surface etching on Denims etc.

3.5.1 AMALYSES

Amylases are hydrolase class of enzymes, which hydrolyze 1-4 α glucosidic linkage of amylase and amylopectin of starch to convert them into soluble dextrins. The following types find major application in textiles:

- **(a) Thermostable amylases:** Amylases which catalyze starch hydrolysis in the temperature range of 70-110°C and at pH 6.0-6.8.
- **(b) Conventional amylases:** Amylases which catalyze starch hydrolysis in the temperature range of 50-70°C and at pH 6.0-6.8.
- **(c) Low temperature amylases:** Majority of fungal amylases which catalyze starch hydrolysis in the temperature range of 30-70°C and at pH 6.0-6.8.

3.5.2 CELLULASES

Cellulases are hydrolase class of enzymes which cleavage 1-4β glucosidic linkage of cellobiose chain or cellulose. The commercially available cellulases are a mixture of enzymes viz., Endogluconases, Exogluconases and Cellobiases, Endogluconases are subclass of cellulase enzymes which randomly attack the cellulose enzymes and hyudrolyze the 1-4 β glucosidic linkage of cellobiose chain [8]. Exoglucanases of cello-biohydrolases are again subclass of cellulose enzyme which hydrolyses 1-4 β glucosidic linkage of cellulose to release cellotiose from the cellulose chain and Cellobiases are enzymes which hydrolyse cellobiose into soluble glucose units. All these three enzymes act synergistically on cellulose to hydrolyse them. Among the different classes of commercially available cellulases, following types find major application in textiles.

(a) Acid Cellulases

Acid cellulases are class of enzymes that act at pH 3.8-5.8 (optimum 4.5-6) and in the temperature range of 30-60°C. The low temperature range of 30-60°C and conventional acid cellulases act in the temperature range of 45-60°C.

(b) Neutral Cellulases

Cellulase enzymes which act at pH 6.0-7.0 and in the temperature range of 40-55°C are termed as neutral Cellulases.

3.5.3 PECTINASES

Pectinases are a mixture of enzymes, which along with other such as cellulose, are widely used in the fruit juice industry. Enzymes in this pectinase group include polygalacturonases, pectin methyl esterase and pectin lyases. These pectinase enzymes act in different ways on the pecans, which are found in the primary cell walls of cotton and jute. Pectins are large polysaccharide molecules, made up of chains of galacturonic acid residues.

3.5.4 PROTEASES

Proteases are Hydrolase class of enzymes, classified based on the source from which it is extracted, optimum temperature of activity. Proteases precisely act on peptide bonds formed by specific amino acids to hydrolyze them. Commercial proteases are available, which can work in different range of pH and temperature. Trypsin (pancreatic), Papain based and alkaline proteases find industrial applications in textiles.

3.5.5 PEROXIDASES

Peroxidases or Catalases are Oxidoreductase class of enzymes. The peroxidase enzyme catalyzes the decomposition of hydrogen peroxide in to water and molecular oxygen as illustrate.

$$\mathbf{2H_2O_2 \rightarrow 2H_2O + O_2}$$

Catalase is a heam-containing enzyme. Thus, in addition to the protein part of the molecule the enzyme contains a non-protein part, which is a derivative of heam and includes the metal iron. Peroxidases effectively degrade the hydrogen peroxide at varied pH between 3 to 9 and temperature range 30 - 80 °C.

3.5.6 LACCASE

Laccases are Oxidoreductase class of enzymes, belonging to bluoxidase- copper metalloenzymes. Laccases are generally active at pH 3-5 and in the optimal temperature range of 30-50°C. They oxidize using molecular oxygen as electron acceptor from the substrate. Their special property of oxidation of indigo pigments is made use of in textile industries.

4. DIFFERENT APPLICATIONS BIOPROCESSING IN TEXTILE INDUSTRY

4.1 BIO-SINGEING

This mode of finishing has been specifically developed to achieve clearer pile on terry towel goods. A treatment with an enzyme, which is a powerful cellulase composition, gives clearer look to the pile, improves absorbency and softness. Earlier, desizing was carried out by steeping the fabric with mineral acid, which affected the cellulose as well as the color. Use of enzymes here led to reaction with the starch only and thus they assumed considerable significance. Explaining the action of enzymes, the food consumed by human body was digested due to secretion of the enzyme. At the enzyme-substrate complex level, the concentration of the reactants became large and accelerated the reaction while reducing the activation energy barrier. Thus, the reaction which took place at higher temperature and severe conditions could be carried out at relatively lower temperatures and milder conditions [9].

4.2 BIO-DESIZING

Before the fabric can be dyed, the applied sizing agent and the natural non-cellulosic materials present in the cotton must be removed. 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 [10]. 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 are being developed (cellulase, hemicellulase, pectinase and lipase), which offer the potential to totally replace the use of other chemicals in textile preparation processes. Complete removal of starch-containing size without fiber damage is best obtained by using enzymatic desizing agents. Formerly amylase derived from mold, pancreas or malt where used in desizing. Today liquid bacterial amylase preparations dominate. The enzymatic desizing process can be divided into three stages; **(a) Impregnation**: Enzyme solution is absorbed by the fabric. This stage involves thorough wetting of fabric with enzyme solution at a temperature of 70°C or higher with a liquid pick up of 1 liter per kg fabric. Under these conditions there is sufficient enzyme stability (temperature, pH, calcium ion level govern the stability). During this stage gelatinization of the size (starch) is to the highest possible extent, **(b) Incubation**: The enzyme breaks down the size. Long incubation time allows a low enzyme concentration, **(c) After-wash**: The breakdown products from the size are removed from the fabric. The desizing process is not finished until the size breakdown products have been removed from the fabric. This is best obtained by a subsequent detergent wash (with NaOH) at the highest possible temperature.

4.3 BIO-SCOURING

Cotton could be treated with bioscouring enzyme although the techno-economical parameters were not conductive. But, it had a bright future due to rigorous effluent treatment since disposal of both caustic soda and soda ash was causing environmental concern. The enzymes helped removal of waxes, pectins, sizes and other impurities on the surface of the fabric. Combination of pectinase and lipase gave best results, but cost of the latter was a deterrent. Advantages of bioscouring were lower BOD, COD, TDS, and the alkaline media of water, extent of cotton weight loss, which was a boon to the knitting industry, lower alteration of cotton morphology i.e.

less damage since it was specific to pectin and waxes and not cellulose besides increased softness. The lone disadvantage was that the cotton motes were not removed, which warranted peroxide bleaching. In a heterogeneous reaction like cotton scouring, the kinetics of enzymatic reaction is influenced by rate of diffusion of bulky reactants into cotton fiber. In cotton the major portion of impurities is located in its primary wall and cuticle of the fiber. This is favorable for the action of macro – molecules used in bio-scouring enzymes [11]. Factors influencing scouring are the nature of the substrate, the kind of enzyme used, the enzyme activity, the use of surfactants and mechanical impact. It was observed that, during pectinase scouring, much less wax was removed compared with the alkaline scouring. If the treatment was combined with surfactant treatment, results equivalent to alkaline scouring could be achieved. A water treatment at 100°C is reported to increase the effectiveness of the subsequent scouring of cotton fabric with a combination of pectinase, protease and lipase, results equivalent to alkaline scouring could be achieved. Traditionally this is achieved through a series of chemical treatments and subsequent rinsing in water. This treatment generates large amounts of salts, acids and alkali and requires huge amounts of water.

Bio-scouring systems

The bio-scouring process is built on ▪ Protease, ▪ Pectinase & ▪ Lipase enzymes that act on proteins, pectin's & Natural waxes to effect scouring of cotton.

Advantages of bio-scouring:

- Milder conditions of processing, low consumption of utilities, excellent absorbency in goods.
- No oxy-cellulose formation and less strength loss because of absence of heavy alkali in bath.
- Uniform removal of waxes results in better levelness in dyeing.
- Highly suitable for scouring of blends like silk, wool, viscose, modal, lyocel, and Lycra etc.
- Low TDS in discharge.
- Fabric is softer and fluffier than conventional scouring, ideal for terry towel/knitted goods.

4.4 INTEGRATED BIO-DESIZING AND BIO-SCOURING

The integrated Bio-desizing and Bio-scouring system uses an empirically developed enzyme formulation, based on amylase, pectinase, protease and lipase that act synergistically, resulting in desizing and scouring of cotton goods, under mild conditions.

4.5 BIO-BLEACHING

It was applicable for all kinds of colors and a single enzyme could be used in the textile industry. Biobleaching had been adapted for denim. Indigo specific lipases were used to bleach indigo. Earlier denim was bleached with chlorine to get lighter denim or wash down effect. Lipase combination was used successfully and if this could be extended to other colors, this would become an important enzyme in future. The advantages were environment friendly application, non-AOX generation and cellulose was not affected. A bio-bleaching or lipase treatment on denim gave an authentic wash resulting in an excellent look, which was better than a neutral wash and a grey cast, which was used in bleaching. Amylase and lipase were used for desizing and cellulase for aberration. Lactase was introduced for bleaching of indigo [12].

4.6 PEROXIDE KILLERS

It ensured shade quality particularly with reactive dyes, reduced the complexity of treatment after peroxide bleaching and conserved water. In case of reactive dyeing, after bleaching it was vital that the peroxide residues must be cleared out of the system and as such there were no fool proof ways of such clearance, which entailed several rinsing operations or reduction treatments. Empirically, it was difficult to know how much quantity of reducing agent was required to react with the peroxide left in the bath. In the event either of them happened to be excess, it might affect the dyeing. Therefore, after bleaching, the bath should be neutralized with peroxide killers like peroxidase or catalase followed dyeing with reactive dyes. They did not affect reactive dyes and only react with the peroxide. These catalysts were fastest acting type as 1 molecule of catalyst destroyed 5 million molecules of peroxide or 700 times its own weight of peroxide.

4.7 ENZYMES EFFECT ON COLOR

Hydrolases and oxireductases constituted important class of enzymes which dealt with color in textile application. Due to effect of enzyme and physical aberration of cellulose, the exposed areas became white as well as indigo dyed. This kind of effect on denim was called salt and pepper effect. The more contrast, better was the denim wash. Some of the denims had blue or greyer cast because they were woven with one up or two down and one of the yarn was colored while the other wasn't. Thus, the effect was created with the combination of the hydrolysis of 1-4 glucose linkage in cellulose and the abrasion e.g. turbulence of friction of metal to metal or fiber to fiber led to denim appearance. Combination of enzyme, sand blasting and bleach evolved a fashion recently. Sand blasting was enzyme treatments which subject the denim fabric to sand at high pressure with consequent exposure of white area while blowing off surface color followed by a treatment of the fabric again with enzyme, leading to a salt and pepper effect and bleached to reduce the color value. Furthermore, after sand blasting, treatment with enzyme followed by over dyeing of the abraded areas produced typical effects on denim [13].

4.8 BIO-POLISHING

It was perceived that bio-polishing and fading or bio-polishing and wash down were two different operations. But both of them basically employed the same action. They degraded the cellulose due to abrasion or friction between fiber to fiber or fiber to metal resulting in removal first from cellulose and then surface bleeding. Bio-polishing before dyeing could increase depth apparently due to clarity of shade. Bio-polishing or cellulase enzyme treatment of lyocel type of regenerated cellulose could produce peach like effect. Bio-polishing give cleaner appearance to the garment besides wash down effect. If it was sulphur or pigment dyed goods or ring dyed fabric, wash down effect as well as cleaning of fabric surface could be obtained. The result surface hair was removed, reduced pilling, better print registration and color brightness. Size of cellulase enzyme was about 8nm as also the size of cellulose monomer, which was in similar region [14]. Bio-polishing, a technique first adopted by the Danish Firm, Novo Nordisk for the finishing treatment of cellulosic fabrics with cellulase enzymes. The main objectives of the bio-polishing is to upgrade the quality of the fabric by removing the protruded fibers from the surface and modification of the surface structure of the fiber, thereby making it soft and smooth. In conventional process protruded fibers are removed by singing process and smoothness imparted by chemical treatment. The conventional methods are temporary, fibers return on the surface of the fabric and chemicals are removed after few washing and fuzz is formed [15, 17]. The fuzz on the surface spoils the fabric appearance and generates customer's dissatisfaction whereas biopolishing is permanent and it not only keeps the fabric in good condition after repeated washing but also enhances feel, color, drapability etc consequently products become more attractive to the customer and fetch better prices.

The bio-polishing treatment offers the following advantages:

- Improved pilling resistance.
- A clearer, lint and fuzz-free surface structure.
- Improved drape ability and softness.
- The effects are durable.
- Slight improvement in absorbency.
- Fashionable effects on fabric like distressed look of denim.

Examples of some cellulases are Aspergillus Niger, Trichoderma longibrachiatum, Fusarium solani and Trichoderma viride. The enzymes are bimolecular of about 20 amino acids with molecular weight ranging from 12,000 to 1,50,000 and therefore they are too large to penetrate the interior of a cellulosic fiber. Hence, only 1,4 β-glucosidic bonds at the surface of cellulose fiber are affected. This results in removal of surface hairs which are responsible for improvement in the hand and feel of the fabric due to surface etching. Biopolishing or bio finishing can be performed continuously and in batch form but the treatment conditions are more easily controlled in batch processes for which winches, jiggers, jet or over flow machines are suitable. In principle, biofinishing can be carried out along with any other stage of textile finishing, with dyeing for example provided that both processes are subject to identical conditions. However, it is best carried out after bleaching and before dyeing. The conditions for bio polishing are as follows:

4.9 BIO-CARBONIZING

Polyester / cellulosic blends after dyeing and/ or printing are occasionally treated with strong solution of sulphuric acid to dissolve cellulosic component. The resultant goods are soft and have a peculiar fluffy feel. This process is risky due to highly corrosive acid that is also difficult to treat in an ET plant. The process developed at UNO, has none of the above drawbacks. It offers a safe and eco-friendly to the obnoxious practice of using sulphuric acid. The goods are treated with cellulose enzyme based formulation to achieve dissolution of cellulosic fibers. In the bio-carbonizing process the goods are treated with a cellulose enzyme based formulation "chemizyme UZ" to achieve dissolution of cellulosic component. The goods are padded in a warm solution of this product and batched on a roll under normal conditions and are washed off after 12-16 hours. This process offers an eco friendly option to the obnoxious use of strong acids.

4.10 DEGUMMING OF SILK

Silk is made up of two types of proteins like fibrin and ceresin. In the case of enzymatic treatment, a ceresin specific protein was used to degum the silk without causing damage, impart softness and increase dye uptake of about 30%. If silk was degummed by alkaline treatment, there was damage to fibrin and heavy weight loss.

4.11 TEXTILE AUXILIARIES

Textile auxiliaries such as dyes could be produced by fermentation or from plants in the future (before invention of synthetic dyes in the nineteenth century many of the colors used to dye textiles came from plants e.g. wood, indigo and madder). Many microorganisms produce pigments during their growth, which are substantive as indicated by the permanent staining that is often associated with mildew growth on textiles and plastics. It is not unusual for some species to produce up to 30% of their dry weight as pigment. Several for these microbial pigments have been shown to be benzoquinone, naphthoquinone, anthraquinone, perinaphthenone and benzo fluoranthene quinone derivatives, resembling in some instances the important group of vat dyes. Microorganisms would therefore seem to offer great potential for the direct production of novel textile dyes of dye intermediates by controlled fermentation techniques replacing chemical syntheses, which have inherent waste disposal problems (e.g. toxic heavy metal compounds). The production and evaluation of microbial pigments as textile colorants is currently being investigated. Another biotechnological route for producing pigments for use in the food, cosmetics of textile industries is from plant cell culture. One of the major success stories of plant biotechnology so far has been the commercial production since 1983 in Japan of the red pigment shikonin, which has been incorporated into new range of cosmetics. Traditionally, shikonin was extracted from the roots of five year old plants of the species *Lithosperum erythrorhiz* where it makes up about 1 to 2 per cent of the dry weight of the root,. Din tissue culture, pigment, yields of about 15 per cent of the dry weight of the roof cells has been achieved.

4.12 ENZYMATIC DECOLORIZATION

In textile dyeing as well as other industrial applications, large amounts of dyestuffs are used. As a characteristic of the textile processing industry, a wide range of structurally diverse dyes can be used in a single factory, and therefore effluents from the industry are extremely variable in composition. This underlines the need for a largely unspecific process for treating textile waste water. It is known that 90% of reactive dyes entering activated sludge sewage treatment plants will through unchanged and be discharged in to rivers. High COD and BOD, suspended solids and intense color due to the extensive use of dyes characterize wastewater from textile industry, especially process houses. This type of water must be treated before discharging it into the environment. The water must be decolorized; harmful chemicals must be converted into harmless chemicals. Biological treatments have been used to reduce the COD of textile effluents. Physical and chemical treatments are effective for color removal but use more energy and chemicals than biological processes [2, 10]. They also concentrate the pollution into solid or liquid side streams that require additional treatments or disposal, on the contrary biological processes completely mineralize pollutants and are cheaper. Instead of using the chemical treatments, various biological methods can be used to treat the water from the textile industry. These methods include, biosorption, use of enzymes, aerobic and anaerobic treatments etc. Only biotechnological solutions can offer complete destruction of the dyestuff, with a co-reduction in BOD and COD. In addition, the biotechnological approach makes efficient use of the limited development space available in many traditional dye house sites. The synthetic dyes are designed in such a way that they become resistant to microbial degradation under the aerobic conditions. Also the water solubility and the high molecular weight inhibit the permeation through biological cell membranes. Anaerobic processes convert the organic contaminants principally occupy less space; treat wastes containing up to 30,000 mg/l of COD, have lower running costs and produce less sludge. Azo dyes are susceptible to anaerobic biodegradation but reduction of azo compounds can result in odor problems. Biological systems, such as biofilters and bioscrubbers, are now available for the removal of odor and other volatile compounds. The dyes can be removed by biosorption on apple pomace and wheat straw. The experimental results showed that 1 gm of apple pomace and 1 gm of wheat straw, with a particle size of 600 μm, where suitable adsorbents for the removal of dyes from effluents. Apple pomace had a greater capacity to absorb the reactive dyes, compared to wheat straw.

4.13 FINISHING OF COTTON KNITS

Cellulase enzyme treatments increasingly find applications in cotton hosiery sector to enhance aesthetic feel as well as surface clarity. Ultrazyme Super is an enzyme –based formulation, well suited for use in winches or high turbulence soft flow machines. Adequate caution must be exercised to deactivate residual enzyme by elevating temperatures to around 80-85°C, otherwise the reaction would continue to take place resulting in loss of physical strength of goods.

4.14 BIO-DENIM WASHING

Another use of cellulase enzyme is in the fading of denims. Denims are manufactured from indigo dyed warp yarns. The dyes are mainly absorbed on the surface of the fiber, a phenomenon technically termed as ring dyeing. The fiber surface etching with cellulase enzymes results in exposure of the undyed core of the fibers which gives a faded look to the denim. The dye removal is further facilitated by the mechanical abrasion. Earlier the effect was obtained by washing denim with pumice stones. Pumice stones are soft, light and porous in nature. About 1-2 Kg pumice stones per pair of jeans were used to get the desired worn out look. Though stone washing gives the desired result but it has got several disadvantages. The major problem with stone washing is that lot of sludge gets deposited in the effluent tank due to the wear of the pumice. The sludge has to be separated from effluent water and disposed off. The use of stones was, therefore, replaced by cellulase enzymes. When indigo dye is released to the wash liquor during washing, the solution turns dark blue. Indigo dye has two amino groups which are capable of getting protonated in an acidic media. Due to protonation, the dyestuff gains an overall positive charge on the contrary; cellulose maintains its negative charges in an acidic media [15-16]. Positive and negative charges attract one another in solution. Therefore, in acidic pH the affinity of indigo for cotton increases. Some of this indigo redeposit on the whiter parts of the denim fabric which spoils the color contrast of the stone wash effect. This phenomenon is known as "back staining". Back –staining problem is more evident with acid cellulases. The use of neutral cellulases is recommended to control the back staining problem because of their better control in decoloration effect and resistance to back staining. Some auxiliary chemicals help in controlling the back staining effect e.g. Sandoclear IDS Liq is claimed to be very efficient in removing back-staining. Treatment with proteases during rinsing or at the end of the cellulase washing step results in significant reduction of back staining and improved contrast. The use of enzyme for denim washing has the following advantages over pumice stone washing.

- Superior garment quality
- Increased load handling (30 – 35%)
- Environment friendly processing
- Less damage to seams, edges and badges
- Extra softener not required
- Less equipment wear
- Easy handling of floors and sewers
- No handling of pumice/ ceramic stones

5. CONCLUSIONS

Biotechnology is a multidisciplinary field, which has been considered in several National Development Programs as one of the strategic areas and as source of considerable amount of new products with high impact in textile industries. Enzymes are a sustainable alternative to the use of harsh chemicals in industry. Because enzymes work under moderate conditions, such as warm temperatures and neutral pH, they reduce energy consumption by eliminating the need to maintain extreme environments, as required by many chemically catalyzed reactions. Reducing energy consumption leads to decreased greenhouse gas emissions by power stations. Enzymes also reduce water consumption and chemical waste production during manufacturing processes. Because enzymes react specifically and minimize the production of by-products, they offer minimal risk to humans, wildlife, and the environment. Enzymes are both economically and environmentally feasible because they are safely inactivated and create little or no waste; rather than being discarded, end-product enzymatic material may be treated and used as fertilizer for farmers' crops. Bioprocessing done with enzymes on organic cotton fabrics will produce 100% eco-friendly garments and apparel, which is very advantageous for the health of the consumers and the environment. Bioprocessing with its pervasive field of application surely going to conquer the world of textiles and will make it to rich the pinnacle of its performance. There are few to enunciate, however many such potentials are yet to explore. Bio-processing in textiles provides to be a boon to the ever changing conditions of the ecology as well as economy.

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