Enzymes in Textile Wet Processing

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The environment issues associated with textile processing are not new. A large number of chemical of diverse nature involved in process may be present as such or converted in to gone other chemical in processing and this effluent pure definite environment treat. Enzymes assisted textile processes are envisaged as environmentally benign alternatives.

What are Enzymes?

Enzymes are present in living organism and are themselves not living organism. Structurally they resemble protein of varying complexity based on chain of amino acid linked by peptide linkage. Each enzymes is different from other enzyme and the dept is due to –

- Particular amino acid present
- The order in which amino acid are linked
- The presence of absence of metal ion
- The conformation of structure as a whole.

Enzymes for textiles use can be classified as follows-

- **Amylases**

  It convert amylose or amylopectin polymeric commonly referred to as starch into water soluble shorter chain sugars. It is isolated from bacteria, fungi, pancreases and malt.

- **Lipases**

  Cotton waxes consists of various hydrocarbons, fatty alcohol and acids, and their respective esters. These fats and waxes are the major reason for the hydrophobic nature of unscoured cotton fiber. Lipases hydrolyses fat and oils into alcohol & organic acid.

- **Pectinase**

Pectinic compound as found in raw cotton mainly consist of neutral and acidic heteropolysaccharides with different molecular weight and degrees of esterification.

Pectinases capable of hydrolyzing pectinic substances are generally enzyme complexes containing esterases and depolymerases with random or terminal activities.

- **Cellulase**

Cellulases enhance the effect of pectinase to a certain extent and add softness to the cotton fabric .They often accompany pectinases in small amount. If used for scouring, cellulases hydrolyze cotton cellulose, lifting off non cellulosic impurities in the course of reaction.

- **Proteases**

it catalyses splitting protein molecules and component amino acid in extreme may break protein down into laundry detergents.Its largest application in laundry detergents ,where they help removing protein based stains from clothing

Enzymatic Mechanism

Enzymes are biological catalyst. These materials consist of complex, three dimensional proteins that are composed of the polypeptide chain. In an enzyme, the amino acid chain are coiled in such a way that the hydrophobic portion are oriented inwards allowing maximum hydrogen bonding intra molecularly and with water or other molecules, they are thus essentially soluble in water.

As mentioned earlier that enzymes have quite specific 3 dimensional shapes and are absorbed onto the surface of some substrate in lock & key fashion. At the active site of on enzyme hydrolysis of substrate is accelerated product of decomposing are formed and enzymes is released to be reabsorbed onto a different location on the substrate

Most of the enzymes have specific requirement of temperature and Ph for their specific action. They may be termed as surface catalyst also. The production of enzymes is from bacterial or fungal species in large fermentation vessel.

These proteins only accelerate reaction enzymes can't cause reaction, to occur that ordinarily would not occur.

Enzymatic Desizing:-

Amylase enzymes are commercially available with flexible pH and temperature ranges, with some products even being thermo stable. A whole amylase complex usually contains various types of exo-and endo-enzymes, glucoamylases and debranching enzymes with different modes of action. Starches can not be recycled. The end-products of the enzymatic desizing process are various types of sugars and dextrin's which are nontoxic, however, negatively impact the BOD of the wastewater.

The desizing process may be divided into three stages: impregnation, incubation and after wash. The fabric may be pre-washed to remove non-starch water-soluble additives and to facilitate the binding of amylase to the starch molecules. Thorough wetting and heating to gelatins the starch facilitates the contact between the enzyme and its substrate. Impregnation should be carried out at temperatures above 70^0C in a buffered solution containing calcium. Alternatively, the fabric may be soaked with the enzyme solution at the optimum temperature before a longer incubation (at a lower temperature) is carried out. The incubation stage may take 2-16 hours, depending upon the stability and the activity of the enzyme at eh processing temperature and p^H, the nature of the size and of the fabric.

The efficiency of size removal is determined using the iodine coloure test to measure residual starch. A dilute solution of iodine in water gives as deep blue-black colour presence of starch. If starch is absent the solution reveals a pale yellow-brown colour. The test is very sensitive: traces of starch are readily detected.

The fabric is then washed with hot water, synthetic detergent and sodium hydroxide to remove the hydrolysis products. After a through rinsing and neutralization of any remaining alkali with acetic acid, the fabric is ready for the following stages of scouring and bleaching.

Desizing may be improved with a combination of amylase and lipase treatment. A mixed enzyme treatment was found to improve the removal of starch and triacylglycerol, give less risk of dye defects and a higher whiteness after scouring and bleaching, give a higher uptake of dye, to have a softening effect on the fabric.

For example :-

a) Desizyme-L(X,2X) :- It is Psychrophilic Bacillus alpha amylase.

   low temperature desizing enzyme to be used in textile processing.

b) Desizyme-M (X,2X) :-It is a Mesophilic Bacillus alpha amylase

   medium range temperature,desizing enzyme to be used in textile processing.

c) Desizyme- H (X,2X) :- It is Thermophilic Bacillus alpha amylase high temperature desizing enzyme to be used in textile processing.

Bioscouring

Noncellulosic impurities, such as fats, waxes, proteins, pectin's, natural colorants, minerals and water-soluble compounds, are found to a large extent in the primary wall and to a lesser extent in the secondary wall and strongly limit the water absorbency and whiteness of the cotton fiber. Quantity and composition varies with growing conditions, climatic factors and cotton variety.

Additionally naps consisting of immature cotton and enclosed seed fragments, present a serious problem as they are basically undyeable. Conventional scouring is performed with 3-6% aqueous sodium hydroxide solution at the boil. Although very effective, the process requires huge amounts of rinse water once the process is complete. Excessive usage of water and water contamination are expensive and unacceptable.

The process of enzymatic scouring is based on the idea of specifically targeting the non-cellulosic impurities with appropriate enzymes. For example, pectinases could be used for the decomposition of pectinic substances, proteases for proteins, lipases for fats. Parts of the natural pigments are associated with the non-cellulosic compounds and will be lifted off the fiber during bioscouring. An additional asset of this process is that besides being less energy intensive and more environmentally friendly, enzymes used for bioscouring do not affect the cellulose backbone, thus drastically limit fiber damage.

For example:-

Scourzyme is a mixture of various enzymes preparative produced from selected strain of ***Bacillus spp.*** enzymes to be used in textile processing

Biobleaching

Natural pigments usually remain in the cotton fiber after scouring, and bleaching is necessary for a good level of whiteness. The most common industrial bleaching agent is hydrogen peroxide, which is applied at p^H 10.5-11 and temperature close to the boil. Hydrogen peroxide itself decomposes into environmentally benign compounds (water and oxygen), however the conditions during bleaching pose a serious problem due to possible radical reactions of the bleaching compounds with the fiber. These reactions can lead to a decrease in the degree of polymerization and eventually to a drop in tensile strength, especially in presence of particular metal ions which act as activators for hydrogen peroxide.

In the bleaching process, while enzymes are not used to replace bleach, the application of enzyme technology has facilitated the use of an alternative, less toxic, peroxide bleaching to replace the chlorine bleaching. After the bleaching process, residual hydrogen peroxide can be removed by the addition of catalase. Its use saves a large number of rinses and reducing agents (used formerly to remove hydrogen peroxide or chlorine based bleaches, before the next stage of dyeing), thus saving water, time and energy.

The use of catalase enzymes to break down residual hydrogen peroxide after, for example, a pre-bleach of cotton that is to be dyed a pale or medium shade. Reactive dyes are especially sensitive to peroxides and currently require extended rinsing and/or use of chemical scavengers. Several commercial enzyme products are already on the market for this purpose.

For Example:-

Peroxzyme is a catalase enzymes from fungal ***Aspergillus spp.*** specially used for removal of residual hydrogen peroxide from textile material and process liquor prior to dyeing.

Proteases

Proteolytic enzymes or proteases catalyze the hydrolysis of certain peptide bonds in protein molecules.

Probably the largest application of proteases is in laundry detergents, where they help removing protein based stains from clothing. In textile industry proteases may also be used to remove the stiff and dull gum layer of sericine from the raw silk fiber to achieve improved luster and softness. Protease treatments can modify the surface of wool and silk fiber to provide new and unique finishes.

For Example:-

Woolzyme is protease enzymes from Bacillus species used for finishing of wool

Cellulases

Cellulose is used to modify the surface and properties of cellulosic fibers and fabrics in order to achieve a desire hand or surface effect.

The most widely used application of cellulases is the replacement of pumice stones in the “stone-washing” process to produce the aged appearance of denim garments. Cellulases are also used to improve the appearance of cellulosic fabrics by removing fuzz fiber and pills from the surface, reducing pilling propensity, or delivering softening benefits. There is also an increasing use of cellulases n domestic washing products.

For example:-

Bioace Plus (Rocksoft) :-It is a liquid cellulase enzyme that can effectively be used for biofinishing of cellulosic fabrics. It performs best at a pH of 4.5 – 5.0 and a temperature of 45oC – 60oC (113oF – 140oF). it is designed for use in biofinishing of all cellulosic fabrics.

Biopolishing of cotton fabrics

‘Biopolishing’ is an enzyme treatment designed to improve fabric quality. The most widely used application of cellulases (neutral p^{H} cellulases is the replacement of pumice stones in the “stone-washing” process to produce the aged appearance of denim garments. Using cellulases in replacement of pumice stones prevents damage by abrasion to washing machines and the garments, eliminates the need for disposal of the used stones ad improves the quality of the waste water. The load of garments may also be increased by as much as 50% since stones are no longer added. Depending on the finishing effect required, a mixture of cellulases and pumice may be used.

Washing the garments with pumice stone removes the surface dye by abrasion, reducing fabric strength. A controlled treatment with cellulases, however, hydrolyses primarily the surface of the fiber but leaves its interior intact. This mode of action makes cellulases suitable for the "stone-washing" of garments dyed with indigo, since this dye stays on the surface of the fiber.

Biostoning and the closely related process of Biopolishing are perhaps attracting most current attention in the area of enzyme processing. They are also an excellent illustration of how different industry structure and market considerations can affect the uptake of enzyme technology.

Conventional stone washing uses abrasive pumice stones in a tumbling machine to abrade and remove particles of indigo dyestuff from the surfaces of denim yarns and fabric. Cellulase enzymes can also cut through cotton fibers and achieve much the same effect without the damaging abrasion of the stones on both garment and machine; moreover, there is no need for the time-consuming and expensive removal of stone particles from the garments after processing. Machine capacity can be improved by 30-50% due to reduce processing times, product variability is reduced and there is also less sludge deposited in the effluent.

Disadvantages can include degradation of the fabric and loss of strength as well as 'back staining' (discoloration of the white weft yarn, resulting in loss of contrast). A slight reddening of the original indigo shade can also occur. However, careful selection of neutral or alkaline cellulases able to function in the p^H range 6-8, albeit at higher cost and reduced activity compared with acid cellulases (p^H 4.5-5.5) can control these problems. Now, processors are learning to play more sophisticated tunes such as achieving a peach skin finish by use of a combination of stones and neutral Cellulase.

This treatment offers the following advantages:

- Improved pilling resistance;
- A clean, lint and fuzz-free surface structure;
- Improved drape ability and softness.

The effects are durable- the consumer will recognize the improvement in quality especially after repeated wear and laundering. Fuzz refers to fibers protruding fro the surface of the yarn and fabric. Pilling consists of fluffy agglomerations of loosened fuzz attached to the surface of the fabric. Pilling may occur during fabric processing, as well as during garment wearing and laundering.

Biopolishing of cellulosic fabrics, such as cotton and lyocell, involves treatment with a cellulase enzyme which weakens the ends of the fibers protruding from the fabric surface. Subsequent gentle mechanical action breaks off the weakened ends from the body of the fabric.

Biopolishing employs basically the same cellulase action to remove fine surface fuzz and fibrils from cotton and viscose fabrics. The polishing action thus achieved helps to eliminate pilling and provides better print definition, colour brightness, surface texture, drape ability and softness without any loss of absorbency.

A weight loss in the base fabric of some 3-5% is typical but reduction in fabric strength can be controlled to within 2-7% by terminating the treatment after about 30-40 minutes using a high temperature or low p^H 'enzyme stop'. Both batch and continuous processes can be employed as long as there is some degree of mechanical action to detach the weakened fibers. One area that still poses problems is that of tubular cotton finishing. Here the fiber residues tend to be trapped inside the fabric rather than washed away.

Biopolishing may be carried out at any time during wet-processing, but is most conveniently performed after bleaching. The advantage of carrying out Biopolishing at this stage is that the fabric is clean, hydrophilic and more accessible to the cellulases. Higher concentrations of enzyme would be required for grey fabric. If Biopolishing is done after dyeing there is a risk of color shade change. Also the dyestuff may reduce the performance of the enzyme, so that a higher concentration of enzyme would be required. Direct and reactive dyes are known to have an inhibition effect on cellulases.

Since Biopolishing removes the protruding fiber ends, a significant reduction in the pilling tendency is obtained. The effect is permanent since the protruding fibers which act as anchors for entanglement of other fibers and consequent development of pills are removed.

For example:-

Denabraide (Iogen): Used in denim processing to substitute or enhance the performance of pumice stones which fade and soften fabric.

Conclusion

From all the above data, it can easily be concluded that the global market for industrial enzyme is vast, but the current share of enzyme market in the area of textile is only about 10-13 %. It is expected that textile share of the market will significantly grow during the coming decades as new, environmentally sound, enzymatically based wet processing operations are expanded on a global basis .In view of ever-growing concern in international community for the environment, it is essential that all textile processes be critically examined for their environment impact and more research done in the field of enzyme activity to mitigate the impact.

Bibliography

1) Emerging opportunities for enzyme use in textiles :-J Nolan Etters (Colourage annual journal 1998)
2) The state of the art in Textile biotechnology :- J.Cegarra (Journal of society of Dyers and colourists)
3) Cellulase enzyme in Garment Washing :- V.A Nandsena (Textile bulletin-July-December 1996)
4) Industrial enzyme and their application:- John Wiley and Sons Inc
5) Environmentally Friendly Scouring Processes :- Moussa K Traore and Gisela Buchle-Diller (Textile Chemist and colourist &American Dyestuff Reporter)
6) Bioscouring of Cotton with Pectinase Enzyme :- K Sawada,S Tokino,M Ueda and X Y Yang(JSDC November, 1998)