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Enzymes in Fabric Preparation: How much are we Successful?

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Abstract

The role of cotton, wool and silk fibres in apparel segment of the textile industry has been robust in all these years. Cotton fibre has a dominant role in the apparel segment even though many alternative, regenerated cellulosics fibres are available. Besides cellulose, cotton fibre contains many constituents are systematically eliminated in the fabric preparation process to facilitate dyeing and finishing. Preparatory processes assume the centre stage, in entire process sequence of fabrics due to high water, chemicals, energy requirements. Enzymes provide sustainable solutions, in operations that require more amounts of energy, at relatively low energy levels with meagre amount of auxiliaries. Reviews and reports have been frequently published to demonstrate the advantages of enzyme based processes in comparison with chemical treatments. Both bacterial and fungal sources suffice requirement of various enzymes used in textile applications.

Keywords: Cotton; Wool; Silk; Fibres; Apparel; Dyeing; Finishing

Amylase assisted desizing of textile materials is carried out in equipment such as jigger, jets, pad-batch and pad-stream ranges, employing different levels of mechanical agitations. Hydrolysis of starch by α-amylase, into oligosaccharides and soluble dextrins, is sufficient for removing starch from textile materials during desizing and, mixed cultures have advantage, in comparison to purified α amylases. Common waxes do not inactivate amylases but prevent quick wetting, penetration of enzymes and desizing besides viscosity of starch, amount of size applied, fabric construction and method of washing-off.

Cuticular lipids, of cotton, are complex mixtures of aliphatic and aromatic components; most of them are derivatives of n-acyl alkanes with chain length of C_{20} to C_{40} and melting point between 64 to 214°C. Lipases increase lipid removal from all morphological locations on the cotton fibres including lumen and fibre surfaces. However, it has never been exploited commercially for scouring. Proteins that occur (~ 1.3%) in the lumen and primary wall of the cotton fibres, are the residual, dead protoplasm from biosynthesis, composed of several proteins and peptides, rather than a single protein. Most of the nitrogen containing compounds of cotton can be removed by a mild alkaline scouring boil and a very low residue remains in scoured and bleached cotton. Denaturation of proteins by ageing, heating and oxidation makes them less accessible to enzymatic degradation. However, since the protein contents are high among the noncellulosics in cotton fibre, potential of proteolytic enzymes as scouring agents for raw cotton cannot be underestimated. Though protease in scouring offers a range of advantages, the limitation in terms of autoproteolysis of enzymes in the crude cultures remains, still, unaddressed.

Large parts of galacturonan residues of pectin are esterified with methyl groups at the C_2 and C_3 position to a varying degree up to 85%, usually in a random fashion, with blocks of polygalacturonic acid being completely methyl esterified. Pectins form either ionic or covalent interactions with different classes of proteins located in the cell wall, middle lamella and, charged homogalacturonan forms ionic interactions with proteins, forming an insoluble protopectin. Pectinases, a generic name for the family of enzymes, catalyse hydrolysis/depolymerisation of the glycosidic bonds in the pectin polymers, are classified according to their preferential substrate specificity. Pecinase scouring suffers due to incomplete removal of wax and little or no effect on mote removal. Addition of chelating agent and higher levels of mechanical agitations during scouring are recommended for enhanced scouring action. However, alkaline scouring of cotton appears to have a strong place among the processors.

In bleaching, oxidative chemical pretreatments are effective in degradaing colourants and other impurities, though such methods often lead to oxidative degradation of the substrates also. Unwithstanding the complexities associated with the hypochlorite or chlorite processes, attempts have been made to utilize various enzymes that belong to the class of oxidoreductases, in bleaching. Glucose oxidases generate hydrogen peroxide and gluconic acid from glucose in the presence of oxygen. However, no bleaching process, using enzymatically produced peroxide is industrially practiced till now, perhaps due to the difficulty in production of glucose oxidase enzyme itself or the ready availability of hydrogen peroxide.

In addition to the developments in exploiting the potential of individual enzymes in fabric preparation, different combinations of pectinases with protease, hemicellulase, cellulase and lipase have been attempted, which are not efficient in scouring process when used alone. Integrated desizing and scouring using α-amylase and polygalacturonate lyase process in single or two steps have been attempted by many researchers.

Combinations of pectinase or cellulase with hemicellulases like arabinases or, pectinases with hemicellulase activities have also been recommended for scouring to destroy lignocellulosic structure of the seed coat fragments, produce soluble forms of lignin. Alkaliphile amylases with sodium hydroxide and hydrogen peroxide have been attempted for a combined desizing-scouring-bleaching process. However, the combined desizing and bleaching using glucose oxidase often results in non-uniform wetting properties, though wicking and average drop absorbency show similar values as that of commercial processes.

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Researchers have also advocated the combinations of three or four different enzymes including amylase, pectinase, protease, cellulase, glucose oxidase and various hemicellulases in fabric preparation to improve the absorbency of the samples. Presence of xylanase and pectinase in commercial cellulase preparations facilitates the removal of seed coats up to 70 – 85%, while protease and lipase together with pectate lyase remove slashing lubricants from the fabrics. Strong agitation levels in the enzyme based preparatory processes results in higher weight loss values as high as 13.9%, and various combinations of enzymes show CIE whiteness index up to 68-70.

Needless to say that the conventional chemical treatments using acids, alkali and alkaline bleach solutions in cotton fabric preparation offers better results compared to enzyme assisted treatments, however, degradation of fibres appears to be inevitable in such processes. Conventional chemicals, in the single stage preparatory processes, often necessitate high concentrations of alkali, bleaching agents to remove motes and to obtain acceptable levels of whiteness. On the contrary, enzymes based treatments offer lower degradation of fabric properties due to substrate specific nature of the enzymes and less energy requirement besides environmental benevolent nature. Small processors equipped with the limited range of machinery, expect an appropriate technology to combine the unit processes into a single stage with the available range of machines, i.e. winch, soft over flow and jigger. Though such limitations are addressed in enzyme assisted fabric preparation, to a larger, extent it suffers from lack of acceptance perhaps due to the mindset of the processors. On the contrary, biopolishing of cotton fabrics using cellulases enjoys ready acceptance of the industry and, the day is not far when processors also would also welcome the enzymes in their stores for fabric preparation.