Denim Finishing with Enzymes

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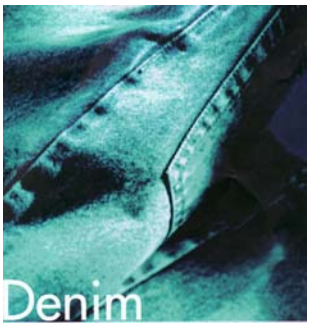

Today's incredible range of denim finishes owes a lot to biocatalysts, notably enzymes. Apparel designers, merchandisers and denim processors enjoy greater flexibility as result of new finishes made with the help of a range of enzymes. Various denim treatment applications like desizing, biostonewashing, and biobleaching currently use enzymes. The use of enzymes has resulted in improving the quality of fabric finishes, reducing processing time and saving on chemical and energy costs, thus reducing the environmental footprint. As designers strive to keep denim an important apparel fabric for years to come, enzyme makers will need to supply highly specialized products to enhance the styling and function of the denim fabric. A steady stream of biotechnological innovations will offer new opportunities for the textile industry in keeping denim fabric the evergreen favourite of generations.

Denim - The Universal Fashion Fabric

Denim - one of the world's oldest fabrics - is most commonly associated with jeans. Today, denim jeans are one of the most popular clothing items, which are loved by many people around the globe regardless of the gender, culture, climate conditions, seasons, and social occasions. The birth of denim jeans is credited to the Bavarian-born businessman, Levi Strauss, who made his way to the Gold Rush in San Francisco nearly 150 years ago. Since then, the denim fabric has run the gamut from a basic workwear fabric to a fashion trendsetter, and the original focus on durability and practicality has changed to fashion. The evolution of the denim market has led to the development of some unique and creative denim fabrics and opened new worlds of possibility for finishes.

Denim Finishing

Like denim itself, new finishes for the popular and versatile fabric can provide either functional utility (such as improved wear life, hand, drape, and colour retention), or fashionable flair. Typical denim wet finishing includes desizing to soften the fabric and stonewashing to remove colour and add contrast to the fabric. In olden days, such treatments were done using chemical and physical processes. With the advent of modern biotechnology, routes to cleaner technologies have become available, resulting in the replacement of these processes.

The use of biotechnology in textile processing has been known for more than 2000 years. The first application known is the vetting of bast fibres with the use of microorganisms. Other early examples include the removal of starch by soaking starch-sized cloth with water liquor containing. barley and the use of amylases in the same desizing process as early as 1912. However, since 1990, the use of enzyme technology in the textile industry has increased substantially, especially in the processing of natural fibres. Enzymes have become extremely popular in the industry because they are easy to use and applicable in many processes.

A major reason for embracing this technology is the fact that enzymes are highly specific in their action and as a consequence deliver a focused performance. Moreover, they have a reduced environmental impact. Other potential benefits of enzyme technology include cost reduction, reduced processing time, energy, and water savings, improve quality and potential process integration.

Desizing with Amylases

Warp yarns of denim fabric are sized with several compounds, such as starch, polyvinyl alcohol, polyvinyl acetate, polystyrene, polyacrylic acid, gelatin, oil, wax, and other polymers, either alone or in combination with each other, to provide abrasion resistance during the weaving process and stiffness and

stability during cut and sew operations. Proper desizing, to completely remove added sizing components, is essential to obtain even and consistent finishing results.

Enzymatic desizing using alpha amylase is the most popular method to remove starch and has been used in the textile industry for several decades. Alpha amylases break down starch into water-soluble sugars by cleaving internal 1,4 linkage. Although natural sizes of starch original can be easily removed by alpha amylases, variables such as enzyme type and concentration, process pH, temperature, time, mechanical action should be property controlled to achieve the best desizing results.

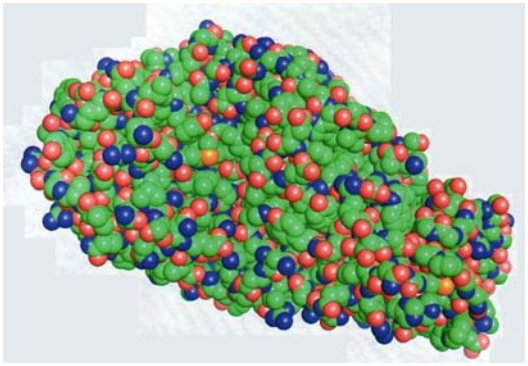

Figure 1: Three-dimensional model of microbial amylase which has been engineered for thermostability and pH activity profile

Alternatively, desizing can also be done by oxidative method, using hydrogen peroxide. The advantages enzymatic desizing ever other methods like treatment with acids, hot alkali or oxidizing agents include, high efficiency and specificity in action, no fibre damage, avoiding the use of hazardous chemicals, the ability to use a wide range of process conditions, including processing at room temperature, and complete biodegradability of the effluent.

Bio-Stonewashing with Cellulases

Stonewashing added a new dimension to denim garments in the late 1970s: the process enabled artificial ageing of denim garments which imparted a fashionably aged look. As the name 'stonewashing' implies, the blue jeans were washed with pumice stones to achieve a faded look. Due to the disadvantages of using pumice stones, such as machine damage, blocking of the drainage system, difficulty in removing pumice-stone residues and excessive damage to garment hems and seams, alternative methods for stonewashing were developed.

Cellulase enzymes were introduced in the 1980s as a denim-washing, aid to achieve a faded and abraded look similar to that provided by pumice stones. Cellulase works by loosening the indigo dye on the denim in a process know as 'biostonewashing'. A small dose of enzyme can replace several kilograms of pumice stones.

Biostonewashing has opened up new possibilities in denim finishing by increasing the variety of finishes available. For example, it is now possible to fade denim to a greater degree without running the risk of damaging the garment. Productivity can also be increased because laundry machines contain fewer stones or no stones and more garments. The use of less pumice stone results in less damage to garment and machine, and less pumice dust in the laundry environment.

A range of cellulases for denim finishing, each with its own unique properties, is available in the market. These can be used either alone or in combination with pumice stones in order to obtain a specific look. An ideal biostonewashing enzyme would possess high abrasive activity (the ability to remove indigo from denim) as well as low backstaining (the redeposition of indigo) with lower fabric strength loss.

Cellulases have been used for the past twenty years and it is estimated that approximately 80% of denim garments are processed in this way. Cellulases are enzymes that are specific for the hydrolysis of the beta-1, 4 glucose linkage of cellulose. The reaction mechanism of the naturally occurring cellulase enzymes on cellulose is very complicated and several different enzymes – endoglucanases, cellobiohydrolases and beta-glucosidases – are synergistically involved in the chain of reactions needed to break down cellulose into glucose. The first type of cellulases introduced to market was derived from the Trichoderma family, a fungus with the longest history of cellulase research.

The second phase in the, development of cellulase was the introduction of products based on another fungus called Humicola insolens. These cellulases soon became known as the neutral cellulases, as they could work in a more neutral pH environment. A special feature of the neutral cellulases is their ability to provide the stonewashed look with minimal indigo redeposition during the treatment. Thus the jeans and other denim garments would have a higher contrast between white and blue yarns, and the inside pockets as well as the leather labels would not be stained with indigo. However, the reaction time of this enzyme is slow and its use requires a longer processing time.

Since then, much progress has been made in the development of cellulase compositions, which are customized to achieve specific applications. Research and development activities have been focused on a new generation of cellulase enzymes whose composition has been altered through genetic engineering to provide higher abrasion contrast, reduced backstaining, improved fabric-strength retention and broadened operating pH and temperature ranges. The development of modern biotechnology brought new tools for scientists to create new, better cellulase products for textile applications. IndiAge® Super (Genencor International) are the examples of genetic engineered cellulase with improved features.

IndiAge Super, an engineered component enzyme, is the first cold cellulase in the market that works effectively at low temperatures and provides high contrast finish. The optimal temperature range of the enzyme is 40 to 45°C, which is significantly lower than that of other cellulases, thereby resulting in energy savings for processors. Also, the cold cellulase can be used to treat elastic denim fabric, which might be susceptible to fabric damage by conventional cellulase treatment at higher processing temperature.

Biobleaching with Laccase and Mediator

Laccase is the newest enzyme class to be introduced into denim finishing. Laccases are multi-copper oxidases that catalyze the oxidation of a wide range of phenols, including indigo, under simultaneous reduction of oxygen to water. Laccases alone are not effective in decolorizing indigo on denim and require a mediator, which mediates electron transfer from indigo to molecular oxygen. Since the laccase and mediator only degrade indigo, without affecting the weft yarns, the resulting finish exhibits unique wash-down of denim.

Conventional hypochlorite bleaching of denim is cheap, fast and efficient, but harsh to the environment and the denim. However, laccase and mediator bleach can be done under mild condition and is much simpler to control. Since the bleaching action is specific to phenol complexes, it is especially useful for stretch denim, without affecting its elasticity, unlike traditional hypochlorite bleach, which has a damaging effect on elastomeric yarn. The laccase and mediator can be alternatively used for abrasion enhancement by further brightening up the denim after cellulase treatment.

On the Horizon

Denim clothing continues to reinvent itself through various fabrications, finishes, and embellishments that enhance its consumer appeal. Its continued and rising popularity has opened new worlds of possibility for its uses, and denim is finding its way into home fashion, being used in upholstery, decorative pillows, comforters, window treatments, slipcovers for furniture or even the tabletop.

The majority of denim fabric finishing with enzymes is currently done in a batchwise process to achieve faded effects and soft feel. However, it might be possible to treat denim fabric in a continuous-process range in the future, if advances in biotechnology enable scientists to create extremely fast-acting and robust cellulases, and if machine manufacturers can build special continuous-range equipment with greater mechanical action. The birth of such an enzyme and process will further enable the textile industry to expand towards a much higher throughput and a more sustainable process by saving time, energy and water consumption.

As environmentally friendly processes consume less energy and raw materials and markedly reduce or even eliminate waste, the challenge to biotechnology is to provide tools that will enable to achieve these goals and thus ensure great industrial sustainability.