

Revolution of Biotechnology in Finishing Sector of Textile

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ABSTRACT:

This paper aims to provide the latest information on developments & applications of biotechnology in finish sector of textile. Textile finishing is one of the main sectors of textile which have always been focused in terms of advancements due to its versatility, high & functional value addition aspects. Bio-technology is replacing all harsh chemicals from wet processing of textile, therefore, term "Revolution" is used which seems much true & sustainable in near future.

Key words: bio-Catalyst, Enzymes, Biotechnology, Laccase

INTRODUCTION

Contrary to its name, biotechnology is not a single technology. Rather it is a group of technologies that share two (common) characteristics -- working with living cells and their molecules and having a wide range of practice uses that can improve our lives. Biotechnology can be broadly defined as "using organisms or their products for commercial purposes." As such, (traditional) biotechnology has been practiced since the beginning of recorded history. (It has been used to :) bake bread; brew alcoholic beverages, and breed food crops or domestic animals (2). But recent developments in molecular biology have given biotechnology new meaning, new prominence, and new potential. It is (modern) biotechnology that has captured the attention of the public. Modern biotechnology can have a dramatic effect on the world economy and society (3). One example of modern biotechnology is genetic engineering. Genetic engineering is the process of transferring individual genes between organisms or modifying the genes in an organism to remove or add a desired trait or characteristic. This paper deals with the application of modern biotechnology in textile industries.

Unique genetic engineering methods to create new and useful fiber modifying enzymes. Most of our enzyme products are made with genetically engineered organisms. This gives our customers the best economy and functionality possible. American industry spends billions of dollars annually on technology systems to manage waste and capture pollution emissions. Industrial biotechnology--the use of genetically enhanced microorganisms (GEMs) and enzymes--offers a new cost-effective way to prevent the creation of pollution in the first place. Among the report's findings * Biotechnology process changes in the textile finishing sector can reduce water usage by about 17% to 18%. Textile mills may potentially reduce water consumption by as much as 30% to 50% through the use of biotechnology. (Washington report on biotechnology 2004)

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... The need is to provide the textile technologist with an understanding of enzymes and their use with textile materials.

ENZYMES:

Enzymes are generally 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.

BIO CATALYST:

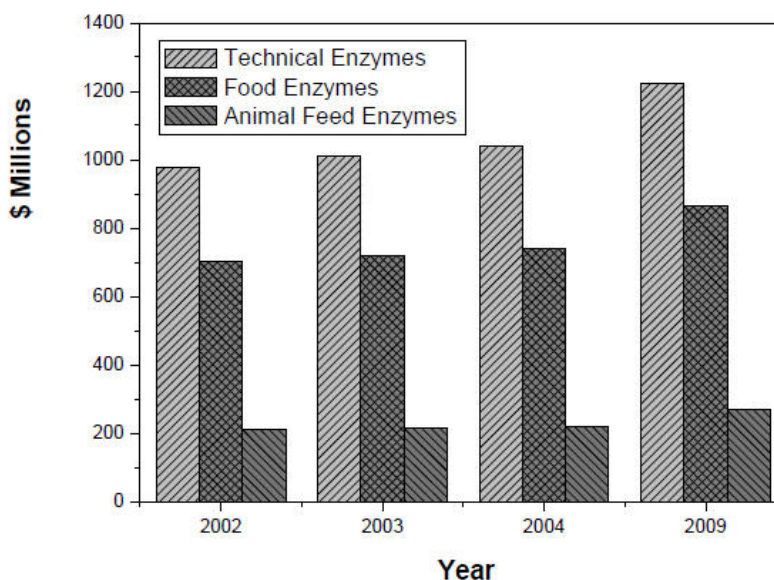
Enzymes are biocatalysts, and by their mere presence, and without being consumed in the process, enzymes can speed up chemical processes that would otherwise run very slowly. After the reaction is complete, the enzyme is released again, ready to start another reaction. Most of the biocatalyst has limited 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.

Enzymes differ from chemical catalysts in several important ways

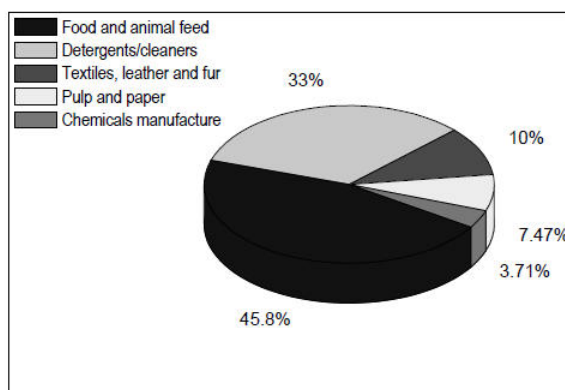
1. Enzyme-catalyzed reactions are at least several orders of magnitude faster than chemically-catalyzed reactions. When compared to the corresponding uncatalysed reactions, enzymes typically enhance the rates by 10^6 to 10^{13} times.
2. Enzymes have far greater reaction specificity than chemically-catalysed reactions and they rarely form byproducts.
3. Enzymes catalyse reactions under comparatively mild reaction conditions, such as temperatures below 100°C , atmospheric pressure and pH around neutral. Conversely, high temperatures and pressures and extremes of pH are often necessary in chemical catalysis.

ENZYMES MARKET:

The industrial enzyme market is divided into three application segments: technical enzymes, food enzymes and animal feed enzymes. The following chart shows the global enzyme markets by application sectors, through 2009.



The major enzymes in this category are enzymes for processing cotton and cellulosic textiles, followed by enzymes for processing leather and fur. The enzyme market for the treatment of silk and wool is minor



BIO-POLISHING & HANDLE MODIFIER

Bio-polishing is the controlled hydrolysis of cellulose fiber to modify the fabric in way that reduce the pilling tendency and increased the softness of the finishing fabric. The bio-polishing is usually applied under acidic condition (ph 4.5-5.5) at 50 C and just after the bleaching process and before dyeing. The process can be applied after dyeing but due that is unacceptable to the dye house this is not preferred.

Enzyme use for Bio-polishing of cellulosic fibers:

Bio-polishing is a biological process in which the cellulase acts on the surface of the fabric. The enzyme molecule is more than a thousand times larger than a water molecule and is therefore too large to penetrate the interior of a cotton fiber. Thus only cellulosic fiber are affected near the surface. In the reaction, small fibrils protruding from the cotton fiber surface are weakened. They then easily break off from the surface, making it much smoother than before. The smoothing effect has several benefits: The fiber will have a lesser predisposition towards forming pills and will consequently have a clearer surface structure containing less fuzz. These changes in the fabric's appearance are long lasting because the Cellulase treatment actually modifies the fiber itself, rather than just a coating on the surface. Since it is a cellulase, it will function on all cotton substrates such as viscose, flax and ramie, as well as parts of mixed fibers and yarns. Mega Pacific Technology has developed a wide variety of bio-polishing enzymes that can function as both stonewash enzymes and bio-polishing enzymes in various strengths of concentrations. We also developed various bio-polishing enzymes which maintain good color retention with minimal color loss. Cotton and other natural and man-made cellulosic fibres can be improved by an enzymatic treatment called Bio-Polishing. The main advantage of Bio-Polishing is the prevention of pilling. Cellulases hydrolyse the microfibrils (hairs or fuzz) protruding from the surface of yarn because they are most susceptible to enzymatic attack. This weakens the microfibrils, which tend to break off from the main body of the fibre and leave a smoother yarn surface. A ball of fuzz is called a 'pill' in the textile trade. These pills can present a serious quality problem since they result in an unattractive, knotty fabric appearance. After Bio-Polishing, the fabric shows a much lower pilling tendency. Other benefits of removing fuzz are a softer, smoother feel and superior colour brightness. Unlike conventional softeners, which tend to be washed out and often result in a greasy feel, the softness-enhancing effects of Bio-Polishing are washproof and non-greasy. AETL's **Sebrite series** is much effective to impart pill proof biopolishing on woven and knit cotton fabric and garments. Sebrite also gives high color retention.

For cotton fabrics, the use of **Bio-Polishing** is optional for upgrading the fabric. However, Bio-Polishing is almost essential for the new polynosic fibre lyocell (the leading make is known by the trade name Tencel®). Lyocell is made from wood pulp and is characterised by a tendency to fibrillate easily when wet. In simple terms, fibrils on the surface of the fibre peel up. If they are not removed, finished garments made with lyocell will end up covered in pills. This is the reason why lyocell fabric is treated with cellulases during finishing. Cellulases also enhance the attractive, silky appearance of lyocell. Lyocell was invented in 1991 by Courtaulds Fibres (now Acordis, part of Akzo Nobel) and at the time was the first new man-made fibre for 30 years. **Addcool** series is best suitable for biopolishing of lyocell as it works at pH 5.5 – 6.0 and temperature 30 – 45 OC, causing less damage to fabric and high quality finishes.

Advantages of bio polishing:

- Removes the protruding fibers from the surface
- No Pilling
- Provides a smooth and clean look
- Impart a soft feel to the fabric.
- Environmental friendly process



APPLICATION TECHNIQUES:

Novozyme’s latest product, cellusoft SR, is an easy-to-use cellulase specially developed to improve Bio-polishing in the textile industry.

Cellusoft CR gave the possibility of applying Bio-polishing before or after dyeing. Due to its broad ph profile(5-8), you can work under different process condition to achieve similar Bio-polishing effects. Additionally, you can combine Bio-polishing process with other process such as bleaching clean-up and bio-scouring for cost optimization.

BENEFITS:

Cellusoft CR gave the typical benefits offered by classic acid cellulose’s for the Bio- polishing process and also has several advantages over other cellulases on the market.

- Good color retention and less cross-staining.
- Can be applied in final sopping baths.
- No need to adjust ph.
- Can be used just as effectively before dyeing
- Maintain higher tensile strength.
- Good Bio-polishing repeatability due to robustness.
- More forgiving in the event of ph variance.
- Negative effect of core alkali minimized.
- Can combined with other enzyme process like Bio-scouring, bleach clean-up, desizing (towelng).
- Less weight loss .
- Less lint formation.

USAGE:

The Bio-polishing process ensures that loose fiber on the fabric is dislodged for optimum result. It is therefore important that equipment with high agitation is used to remove the loose fiber from the fabric. Suitable equipment includes jet dyeing machine as well as aqueous fabric tumbler.

PRODUCT	TEMP	PH	DOSAGE	APPLICATION		
				CONTINEOUS	PAD-BATCH	EXHAUST.JET, WINCH
Cellu soft R	40-55	5-8	0.5-2.0%	NR	NR	++

NR- not recommended

++- very good

+/-- suitable in certain circumstances

APPLICATION PROCESS TYPE

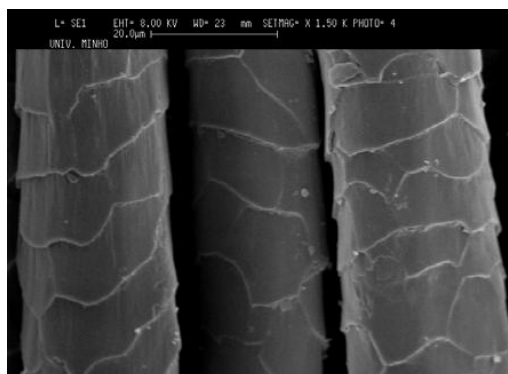
Bio-polishing can be applied at various stages of processing and at different liquor ratio. the most common practice is to apply Bio-polishing before or after dyeing

BIOPOLISHING AND HANDLE MODIFICATION OF WOOL :

Wool:

Wool is a complex natural fiber composed mainly of proteins (97%) and lipids (1%). One of the intrinsic properties of wool, that is peculiar to wool only, is its tendency to felting and shrinkage. Under certain conditions, such as moisture, heat and mechanical agitation, wool shrinks, basically due to its morphological and scale structure. There are two kinds of shrinkage of wool relaxation shrinkage and felting shrinkage. Relaxation shrinkage describes the shrinkage which appears during production when fabrics are subjected to more or less strong mechanical tensions in warp or in weft direction. In finished garments these tensions can still be present either completely or partially. Felting shrinkage describes the shrinkage of garments due to the felting of wool fibres.

Chlorination is a commonly used process to modify the scales of wool fibres with the purpose of providing resistance to felting and shrinkage. There have been many attempts to replace this chlorine process by an environmental friendly enzymatic process that would similarly degrade the scales (Nolte *et al.* 1996; Heine and Höcker 1995; Silva and Cavaco-Paulo2003; Cortez *et al.* 2004). However, despite proteases are large molecules, their attack is not only limited to the scales, causing unacceptable weight and strength loss to the fibres. It is believed that if the proteases are chemically modified in order to increase their molecular weight, their attack would be restricted only to the surface of the fibres, thus removing the cuticle.

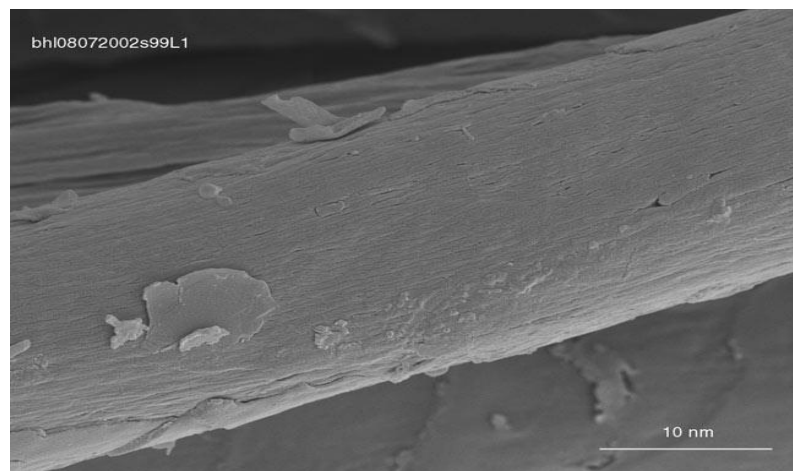


Enzyme used for finishing of wool:

Protease enzyme are used for wool bio polishing .Protease enzyme breaks down proteins. It conducts proteolysis, that is, begins protein catabolism by hydrolysis of the peptide bonds that link amino acids together in the polypeptide chain forming the protein. Proteases work best in acidic conditions. Proteases, also known as proteinases or proteolytic enzymes occur naturally in all organisms and belong to 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. As a result of the combined effect of surfactants and enzymes, stubborn stains can be removed from fibres.

In 1995 enzymes were also introduced for the **Bio-Polishing of wool**. Wool is made of protein and so this treatment features a protease that modifies the woolfibres. 'Facing up' is the trade term for the ruffling up of the surface of wool garments by abrasive action during dyeing. Enzymatic treatment reduces facing up, which significantly improves the pilling performance of garments and increases softness. **Proteases or Sebrité WDE of AETL** are also used to treat silk. Threads of raw silk must be degummed to remove sericin, a proteinaceous substance that covers the silk fibre. Traditionally, degumming is performed in an alkaline solution containing soap. This is a harsh treatment because the fibre itself, the fibrin, is also attacked. However, the use of proteolytic enzymes is a better method because they remove the sericin without attacking the fibrin. Tests with

high concentrations of enzymes show that there is no fibre damage and the silk threads are stronger than with traditional treatments



On this fiber of bio-polished wool, the scales are smoothed by the enzyme treatment and shrinkage is prevented. Another aspect of the bio-polishing treatment is the enzyme removes projecting fiber ends from the yarn or fabric surface, thereby contributing to the "itch-free" quality. Credit: Jan Cardamone, USDA/ARS

Fireproof Wool Clothing Offers Protection Against Fire Related Injuries

Earlier army had created the "biopolished" wool that is both machine-washable and itch-free. Now, " working with visiting scientist Anand Kanchagar, Cardamone improved the flame retardancy of the biopolished wool by treating it with a heat-resistant polymer that is stable, easy to process and highly tolerant of extreme temperatures. Early tests have shown that the burning behavior of the polymer-treated ARS wool compares to a 50/50 blend of wool with Nomex, the fabric currently used in protective firefighting gear."

Synthetic materials can stick on to the wound, whereas wool turns to ash. This makes it an ideal choice for the troops and firefighters. Biopolished wool aims to make the attire much safer. Currently they are collaborating with interested companies to enhance its virtues



The advantages bio polishing of wool :

- Smooth & harsh free
- Handle modified become soft

- Preventing felting of wool fibers
- More comfortable

DENIM FINISHING:

Denim bleach effect :

Tradition chemical process: Denim Bleach is a process that can be used to decolorize indigo from denim. In this process a strong oxidative bleaching agent such as sodium hypochlorite or KMnO_4 is added during the washing with or without stone addition. Discoloration produced is usually more apparent depending on strength of the bleach liquor quantity, temperature and treatment time. It is preferable to have strong bleach with short treatment time. Care should be taken for the bleached goods so that they should be adequately antichlored or after washed with peroxide to minimize yellowing. Materials should be carefully sorted before processing for color uniformity.



LIMITATIONS:

Process is difficult to control i.e. difficult to reach the same level of bleaching in repeated runs. When desired level of bleaching reached the time span available to stop the bleaching is very narrow. Due to harshness of chemical, it may cause damage to cellulose resulting in severe strength losses and/or breaks or pinholes at the seam, pocket, etc.

- Harmful to human health and causes corrosion to stainless steel.
- Required antichlor treatment.
- Problem of yellowing is very frequent due to residual chlorine.
- Chlorinated organic substances occur as abundant products in bleaching, and
- Pass into the effluent where they cause severe environmental pollution

ENZYMATIC BLEACHING EFFECT ON DENIM :

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

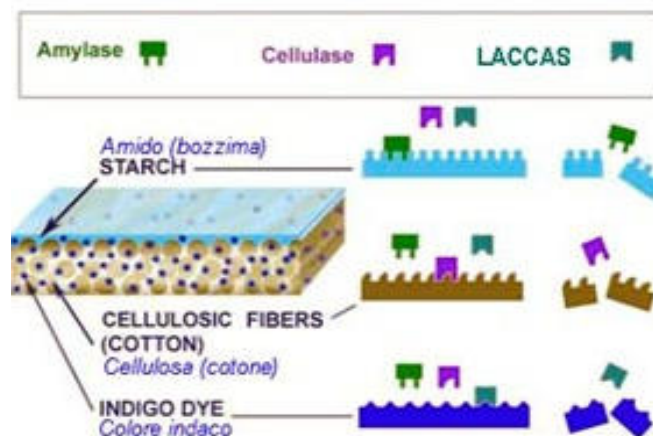
Denim clothing continues to reinvent itself through various fabrications, finishes, and embellishments that enhance its consumer appeal. Its continued and rising popularity has opened new worlds of possibility for its

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.

New Laccase enzyme based bleaching technique only affects the indigo and natural raw white of weft yarn is retained, giving the woven fabric a darker shade, which is not implicitly achieved with hypochlorite bleaching. The product is so specialised on indigo that it does not attack any other dyes. Laccases open up the door to bleach Lycra containing denim without losing the strength of the fabric. In case of hypochlorite bleaching Lycra containing product affects adversely by losing the tear and tensile strength. Finally the process is based on enzyme so no risk of environmental pollution and harmful effluent discharge. This is a new tool in denim processing that will enable the denim finisher to create a number of new fashions and look – distinctly different from the finish of traditionally bleached denim.



Benefits

Den Bleach is an extremely versatile tool for denim finishing as it can be used in a number of applications. As Den Bleach acts directly on the dyestuff, it enables denim finishing with minimum strength loss. This process offers a number of unique features and advantages over other decolonization technologies, ranging from safety in handling to superior garment quality and process control.

- Denim finishing with minimum strength loss
- Grey shade change, creation of new looks, new fashions and new finishes
- Clean-up of back staining and improved garment contrast
- Reproducible performance and ease of use
- Stone-free processing. Enhanced denim abrasion, allowing a very fast process.
- Ideal for processing light weight chambray fabrics and stretch garments
- Creation of super-abraded finishes with minimum strength loss
- Safe handling and operation

Usage

Application / process type

DeniLite II S is used when the following are sought :

- Creation of new looks. Fashions and finishes
- Enhanced denim abrasion, allowing a very fast process
- Denim finishing with optimum fabric strength retention
- An easily controllable and reproducible dye decolonization process

Recommended process condition are:

Liquor/garment ratio.....4:1-20:1 (optimum 5:1- 10:1)

Treatment time..... 10-30 min

pH..... 4.0- 5.5

Temperature..... 60-70 C (140-158 F)

After wash..... Rinse (preferably hot with soap)

The enzyme treatment should be completed with a thorough detergent wash-off. For

Complete inactivation, run for 15 minutes with 1-2 g/l sodium carbonate (pH.10) at 80 c(176F).

Safety, handling and storage

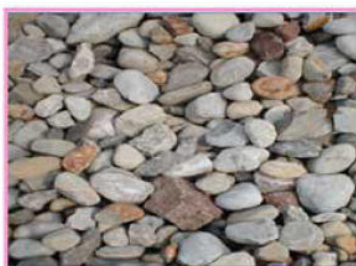
Safety, handling and storage guidelines are provided with all products.

BIO STONE WASH FINISH OF DENIM :

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.
- excessive damage to garment hems and seams.
- large amount of stone required for small batch.



So the 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 biostone wash 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.

APPLICATION TECHNIQUES

VALUMAX A 376

Valumax A 376 is a fully formulated, ready-to-use, neutral cellulose product with superior anti-back staining agent for denim abrasion.

BENEFITS:

Valumax A 376 is a high-per formation. Ready-to-use cellulose for the abrasion of denim(stone washing) .this produce allows new shades and finishing to be created and cost-effectively in an environmentally friendly way.

Valumax A 376 is recommended when the following are sought.

- High color contrast finish
- Low degree of indigo back staining
- Optimum strength retention
- High degree of reproducibility and reliability
- Maximized fabric strength retention
- Improved wash look or creation of new looks
- Easy handling
- Cost –effectiveness

PERFORMANCE:

Valumax A376 performs best under the following condition

	Ph	Temperature
Valumax A376	6.0-7.5	45-60 c

APPLICATION/PROCESS TYPE:

Valumax A376 is a fully formulated. Ready-to-use neutral cellulose product that needs no futer auxiliaries .it is formulated with anti-redeposit ion agent to ensure minimal bake staining and is buffered with a phosphate buffering system aimed at maintaining 6.0-7.5 during washing.

RECOMMENDED PROCESS CONDITION ARE:

Equipment----- wash extractor or barrel

Dosage ----- 1-2% o.w.o.g

Liquor/garment ratio----- 8:1-15:1

Temperature----- 45-60 C

Treatment time----- 45-90min

Ph----- 6.0-7.5

The enzyme treatment should be completed with thorough detergent wash off. for complete inactivation, run for 15min with 1-2g/l sodium carbonate(ph \geq 10) at 80C (176 F)

Valumax A 838

Valumax A 838 is a fully formulated, ready-to-use, neutral cellulose product with superior anti-backstaining for denim abrasion in cold-temperature washing.

Benefits

Valumax A 838 is a high-performance for denim abrasion, also known as stonewashing. New shades and finishes can be created easily and cost effectively in an environmentally friendly way with this unique enzyme solution.

Valumax A 838 offers the following benefits:

- High colour contrast finish
- Low degree of indigo back staining
- Optimum strength retention
- High degree of reproducibility and reliability
- Maximized fabric strength retention
- Improved wash look
- Creation of new looks
- Easy to handle
- Cost-effective

Performance

Valumax A 838 performs optimally under the following conditions:

	pH	temperature
Valumax A 838	6.5 – 7.5	25 – 35 C

Usage

Application / process type

Valumax A 838 is a fully formulated, ready-to-use enzyme solution for denim abrasion.

It is a stand-alone solution that does not have to be used with other products.

Valumax A 838 is formulated with anti-redepsoition agents to ensure minimal

Backstaning and has a phosphate buffering system that maintains the pH in the range 6 to 8 during washing.

Recommended process conditions are:

Valumax A 838 dosage..... 1-2% o.w.o.g.

Liquor/garment ratio..... 8:1-15:1
Treatment time.....60-90 min
Temperature.....25-35 C
pH.....6.5-7.5

It is recommended that the enzyme treatment be completed with a thorough detergent was-off. For complete inactivation, the wash cycle should run for 15 minutes with 1-2 g/l sodium carbonate (pH > 10) at 80C (176F).

Safety, handling and storage

Safety, handling and storage guidelines are provided with all products

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