ENZYME SCOURING OF COTTON FABRICS: A REVIEW

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Abstract:

Textile processing is a growing industry that traditionally has used a lot of water, energy and harsh chemicals. Due to the ever-growing costs for water and energy worldwide investigations are carriedout to substitute conventional chemical textile processes by environment-friendly andeconomically attractive bioprocesses using enzymes.Enzymes are used in a broad range of processes in the textileindustry: scouring, bleachclean-up, desizing, denim abrasion andpolishing. The conventional scouring process involving the harsh environment is slowly being replaced with environment-friendly approach using enzymes.Enzymes are specific and fast in actionand small amountsof enzyme often savelarge amounts of raw materials, chemicals, energy and water.This work represents a review of enzyme scouring of cotton fabrics. This enzymes remove the non cellulosic impurities present in the fabric. Such a process would enhance the absorbency of the fabric without appreciable strength loss and also would help in the proper dyeing and finishing of the fabric. The efficiency of the bioscoured cotton fabric was compared with that of the conventionally scoured fabric.The described enzymatic procedure isaccompanied by a significant lower demand of energy, water, chemicals, time andtherefore costs. So it has advantages as well in terms of ecology as in economy.

Key words: Enzymes, Biotechnology, Enzyme Scouring, Eco-Friendly Characteristics,Water and Energy Saving.

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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. The chemicals used for all these steps are quite toxic. In the various pre and post operations during fabric manufacture, the non-cellulosic and foreign constituents are removed partially or completely [Churi et al. 2004].

The use of enzymes in the textile industry is an example of white industrial biotechnology, whichallows the development of environmentally friendlytechnologies in fibre processing and strategies toimprove the final product quality. The consumptionof energy and raw-materials, as well as increasedawareness of environmental concerns related to theuse and disposal of chemicals into landfills, water orrelease into the air during chemical processing oftextiles are the principal reasons for the applicationof enzymes in finishing of textile materials [O'Neill et al. 1999].

The cotton fibre is a single biological cell with a multilayer structure. These layers are structurally and chemically different, and contain approximately 10% by weight of non-cellulosic substances such as lipids, waxes, pectic substances, organic acids, proteins/nitrogenous substances, non-cellulosic polysaccharides, and other unidentified compounds included within the outer layer of the fibre [Karmakar 1999; Li and Hardin 1997; Li and Hardin 1998; Lin and Hsieh 2001]. These non-cellulosic materials create a physical hydrophobic barrier which protects the fibre from the environment throughout development; they provide lubrication during textile processing, and affect the enhancement of the fabric's wettability and absorbency [Etters 1999; Hartzell and Durrant 2000].

The common industrial removal of these impurities is conventionally carried out by treating the fabric with sodium hydroxide. Although alkaline scouring is effective and the cost of sodium hydroxide is low, the process is costly because it consumes large quantities of energy, water, and auxiliary agents. The potential for the environmental contamination and depletion of natural resources is also serious. The strict pH and temperature requirements for alkaline scouring are damaging to many fibres. The treatment is generally at a high temperature 80-100 $^{\circ}$C, employing strongly alkaline solutions of the scouring agent, e.g. pH 13-14. Due to the non-specific nature of chemical processes not only are the impurities but the cellulose itself is attacked, leading to damages in strength or other desirable fabric properties. The softness of the cellulosic fabric is a function of residual natural cotton waxes. Furthermore, the conventional scouring process can cause environmental problems due to the highly alkaline effluent from these processes [Buschle-Diller et al. 2001; Hartzell and Hsieh 1998; Hartzell and Durrant 2000].

Textile processing is a growing industry that traditionally has used a lot of water, energy and harsh chemicals that result in waste streams causing high environmental burdens.

The scouring stage prepares the fabric for the optimal response in bleaching. An inadequately scoured fabric will need a higher level of bleach chemical in the subsequent bleaching stages.

Before the fabric can be dyed, the applied sizing agent and the natural non-cellulosic materials present in the cotton must be removed. Conventionally the scouring process carried out by treating the fabric with caustic soda and sodium hydroxide at 70 °C to 90 °C. The use of traditional strongly alkaline process can have a detrimental effect on fabric weight (g/m^2) and on the environment. Enzymatic scouring makes it possible to effectively scour fabric without negatively affecting the fabric or the environment. Hydrolysis by enzymes such as *pectinases* promotes efficient interruption of the matrix to achieve good water absorbance without the negative side effect of cellulose destruction. This process is called bioscouring. It breaks down the pectin in the cotton and thus assists in the removal of waxes, oils and other impurities. The optimum temperature is 50-65 °C and pH between 7,5-9,0 [Losonczi et al. 2004; Rajendran et al. 2011; Sawada et al. 1998; Tzanov et al. 2001; Yachmenev et al. 2001]. The fabric gives better wetting and penetration properties, making subsequent bleach process easy and resultantly giving much better dye uptake.

With the increasingly important requirement for textile industries to reduce pollution in textile production, the use of enzymes in the chemical processing of fibres and textiles is rapidly gaining wider recognition because of their non-toxic and eco-friendly characteristics. Enzymes were discovered in the second half of the nineteenth centure, and since are routinely used in many environmentally friendly and economic industrial sectors. There is increasing demand to replace some traditional chemical processes with biotechnological processes involving microorganisms and enzymes such as *pectinases, xylanases, cellulases, laccases* and *ligninases*[Bajpai 1999; Beg et al. 2000; Bruhlmann et al. 2000].

A wide range of studies have been undertaken to understand the effects of enzymes in cotton bioscouring. These previous works include either only the use of one kind of enzyme, or a combination of *proteases, pectinases, lipases* and *cellulases.* The effect of different *proteases* on bioscouring was investigated by using fabrics boiled in water at 100°C [Hsieh and Cram 1999].This study was expanded by the direct scouring of cotton fabrics with *proteases*. It was concluded that the wettability results obtained after both studies were quite similar, furthermore, the researchers concluded that similar wettability properties could be achieved by using a lower amount of energy when compared to the use of pre-treated fabrics at 100°C water [Lin and Hsieh 2001]. Some of the researchers have reported that *pectinase* treatment alone results in adequate wettability[Traore and Buschle-Diller 2000; Buchert and Pere 2000;Hartzell and Hsieh 1998]. Yachmenev and his co-workers (2001) obtained better absorbency and whiteness after the treatment with alkaline *pectinase* than with acidic *pectinase*. Hartzell and Durrant (2000) studied the effect of agitation in *pectinase* scouring, and concluded that agitation during scouring improves the fabric absorbency. Li and Hardin (1998) studied the effects of *pectinase* and *cellulase* treatment on cuticle properties, and the correlation between absorbency and the cuticle image of bioscoured fabric was explained. These researchers also studied the effects of surfactants, agitation, and enzyme selection, and concluded that the effects of surfactants and agitation depend on the enzyme structure and the characteristics of cotton fibre.

The bio-scouring process results in textiles being softer than those scoured in the conventional sodium hydroxide process [Nierstrasz and Warmoeskerken 2003].

Not only do enzymes make good economic senseby saving energy, water and chemicals or by improving quality, they alsogive valuable environmental benefits.Enzymatic processing enables the textile industry to reduce production costs, to reduce the environmental impact of the overall process and to improve the quality and functionality of the final products.

2.Literature Review:

2.1Structure of cotton:

Cotton, the seed hair of plants of the genus *Gossypium*, is the purest form ofcellulose readily available in nature. It has many desirable fibre propertiesmaking it an important fibre for textile applications.Cotton is the most important of the raw materials for the textile industry. The cotton fibre is a single biological cell with a multilayer structure The layers in the cell structure are,from the outside of the fiber to the inside,cuticle, primary wall, secondarywall, and lumen. These layers are differentstructurally and chemically [Boylston and Hebert 1995; Jeffries et al.1992].The primary and secondary walls havedifferent degrees of crystallinity, aswell as different molecular chain orientations.The cuticle, composed of wax,proteins, and pectins, is 2.5% of thefiber weight and is amorphous. Theprimary wall is 2.5% of the fiberweight, has a crystallinity index of30%, and is composed of cellulose.The secondary wall is 91.5% of the fiberweight, has a crystallinity index of70%, and is composed of cellulose.The lumen is composed of protoplasmicresidues [Li and Hardin 1997]. Cotton fibres have a fibrillar structure.The whole cotton fibre contains 88 to96.5% of cellulose, the rest are noncellulosicpolysaccharides constituting up to 10% of the total fibre weight[Hartzell and Hsieh1998; Buchert and Pere 2000]. The primary wall in mature fibres is only 0.5-1 μm thick and contains about 50% of cellulose. Noncellulosic constituents consist of pectins, fats and waxes, proteins and natural colorants. The secondary wall, containing about 92-95% cellulose, is built of concentric layers with alternatic shaped twists. The layers consist of densely packed elementary fibrils, organized into microfibrils and macrofibrils. They are held together by strong hydrogen bonds. The lumen forms the centre of the fibres. Cotton is composed almost entirely of the polysaccharide cellulose.Cotton cellulose consists of crystalline fibrils varying in complexity and lengthand connected by less organized amorphous regions with an average ratio ofabout two-thirds crystalline and one-third non-crystalline material, depending onthe method of determination [Morton and Hearle 1997].The chemical composition of cellulose is simple, consisting of anhydroglucoseunits joined by β-1,4-glucosidic bonds to form linear polymeric chains. The chain length, or degree of polymerisation (DP), of a cotton cellulosemolecule represents the number of anhydroglucose units connected together toform the chain molecule. DP of cotton may be as high as 14 000, but it can beeasily reduced to 1000–2000 by different purification treatments with alkali[Nevell 1995]. According to Battista (1950), the crystalline regions probablyhave a DP of 200 to 300. Correspondingly, the molecular weight (MW) of cottonusually lies in the range of 50,000–by 1,500,000 depending onthe source of the cellulose [Sundquist 1983].The individual chains adhere to each other alongtheir lengths by hydrogen bonding and Van der Waals forces. The physicalproperties of the cotton fibre as a textile material, as well as its chemicalbehaviour and reactivity, are determined by arrangements of the cellulosemolecules with respect to each other and to the fibre axis.

The primary wall is about 1 μm thick and comprises only about 1 % of the total thickness of cotton fibre. The major portion of the noncellulosic constituents of cotton fibre is present in or near the primary wall. Noncellulosic impurities, such as fats, waxes, proteins, pectins, natural colorants, minerals and water-soluble compounds found to a large extent in the cellulose matrix of the primary wall and to a lesser extent in the secondary wall strongly limit the water absorbency and whiteness of the cotton fiber [Yamamoto et al. 2001]. Pectin is located mostly in the primary wall of the fibre. It is composed of a high proportion of D-galacturonic acid residues, joined together by α(1→4)-linkages. The carboxylic acid groups of some of the galacturonic acid residues are partly esterified with methanol. Pectic molecule can be called a block-copolymer with alternating the esterified and the non-esterified blocks. In the primary cell wall pectin is covalently linked to cellulose or in other plants to hemicellulose, or that is strongly hydrogen-bonded to other components. Pectin is like a powerful biological glue. The mostly water-insoluble pectin salts serve to bind the waxes and proteins together to form the fiber`s protective barrier.

The general state ofknowledge of the chemical compositionof a mature cotton fiber is presentedin Table 1.

Table 1- Typical Values for the Composition of a Mature Dry Cotton Fiber (Tripp et al.1951)

Composition of a Fiber				Composition of theCuticle %
Constituent	Typical %	Low %	High %	
Cellulose	94.0	88.0	96.0	
Protein (N-6.25)	1.3	1.1	1.9	30.4
Pectic substances	0.9	0.7	1.2	19.6
Wax	0.6	0.4 1	1.0	17.4
Mineral matters	1.2	0.7	1.6	6.5
Maleic, citric, and other organic acids	0.8	0.5	1.0	?
Total sugars	0.3			?

Cutin				8.7

Table 1shows that noncellulosicmaterials account for only a very smallamount of the fiber weight. These materialsare amorphous and are located inthe cuticle and the lumen. The cuticleforms a protective layer to shield thecotton from environmental attacks andwater penetration.Waxy materials aremainly responsible for the non-absorbentcharacteristics of raw cotton. Pectinsmay also have an influence, since85% of the carboxyl groups in the pectinsare methylated [Freytag and Donze1983].

Row cotton fibres have to go through several chemical processes to obtain propertiessuitable for use. With scouring, non-cellulose substances (wax, pectin, proteins,hemicelluloses…) that surround the fibre cellulose core are removed, and as a result, fibresbecome hydrophilic and suitable for bleaching, dyeing and other processing.

By removing pectin, it is easier to remove all otheruncellulosic substances. The processes of bioscouring that are in use today are based on thedecomposition of pectin by the enzymes called *pectinases*.

2.2 Enzymes:

Enzymes are biological catalysts that accelerate the rate of chemical reactions [Cavaco-Paulo &Gübitz 2003]. All enzymes are made of protein and they each have a very specific 3 dimensional shape. The shape is different for each enzyme and each enzyme only works on one substance or type of chemical reaction i.e. *amylase* speeds up the breakdown of starch into the sugar maltose. *Catalase*speed up the breakdown of hydrogen peroxide.The reason for this is that the substrate fits into a special region of the enzyme called the active site. When in the active site the enzyme can catalyse the reaction. The active site is a special shape and will therefore only allow molecules of a certain shape inside. The reaction happens with lower activation energy which is reached by forming an intermediate enzyme – substrate. Later the substrate molecule is converted into the product and the enzyme itself is regenerated.

Enzymes are high molecular weight proteins that are produced by living organisms. In the reaction itself the enzymes are not usedup, they do not become a part of the final product of the reaction, but only change thechemical bonds of other compounds. After the reaction is complete, the enzyme is released again, ready to start another reaction. Usually most enzymes are used only once and discarded after their catalytic action.They havemolecular weights ranging from 10,000 to 2,000,000.Some enzymes require small non-proteinmolecules, known as cofactors, in order to function as catalysts [Jenkins 2003].

Enzymes can work at atmospheric pressure and in mild conditions with respect to temperature and acidity (pH). Most enzymes function optimally at a temperature of 30ºC-70ºC and at pH values, which are near the neutral point (pH 7). Enzyme processes are potentially energy saving and save investing in special equipment resistant to heat, pressure or corrosion. Due to their efficiency, specific action, the mild conditions in which they work and their high biodegradability, enzymes are very well suited for a wide range of industrial applications.Enzymes are used in the textile industry because they accelerate reactions, act only on specific substrates, operate under mild conditions, are safe and easy to control, can replace harsh chemicals and are biodegradable [Uhlig 1991; Ruttloff 1994].

Commercial sources of enzymes are obtained from three primary sources, i.e., animal tissue, plants and microbies. These naturally occurring enzymes are quite often not readily available in sufficient quantities for food applications or industrial use. Commercial quantities can be obtained by isolating microbial strainsthat produce the desired enzyme and optimizing the conditions for growth. This technique, well known for more than 3,000 years, is called fermentation. Several methos, such as submerged fermentation (SmF), solid-state fermentation (SSF) and whole cell immobilization have been successfully used for enzyme production from various microorganisms [Cao et al. 1992; Kapoor et al. 2001].

For practical applications, immobilization of microorganisms on solid materials offers several advantages, including repeated usage of enzyme, ease of product separation and improvement of enzyme stability [Kapoor et al. 2001]. 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.Most of the industrial enzymes are produced by a relatively few microbial hostslike *Aspergillus* and *Trichoderma* fungi, *Streptomyces* fungi imperfecti and *Bacillus* bacteria. Yeasts are not good produces of extracellular enzymes and are rarely used for this purpose. There is a large number of microorganisms which produce a variety of enzymes [Boyer 1971; Fersht 2007]. Microorganisms producing enzymes of textile important are listed Table 2.

Table 2 - Microorganisms producing enzymes of textile important

Microorganisms	**Enzymes**
1. Bacteria	
Bacillus subtilis	*Amylase*
B. coagulans	*α-amylase*
B. licheniformis	*α-amylase, protease*
2. Fungi	
A. niger	*Amylases, protease, pectinase, glucose oxidase*
A. oryzae	*Amylases, lipase, protease*
Candela lipolytica	*Lipase*
P. notatum	*Glucose oxidase*
Rhizopus sp.	*Lipase*
Trichodermareesei	*Cellulase*
T. viride	*Cellulase*
Ascomycetes	*α-amylase*
Basidomycetes	*α-amylase*
Aspergillus sp.	*Pectinase, lipase*

Enzymes are categorized according to the compounds they act upon: *pectinases* which break down pectins, *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 industry and their application are given in Table 3.

Table3 -Major types of enzymes used in textile industry

Type of enzyme	Application
Pectinase	Breaks down pectins in scouring (Bio-scouring)
Proteases	Scouring of animal fibres, degumming of silk and modification of wool properties
Cellulase	Break down cellulosic chains to remove protruding fibres by degrading & create wash-down effect by surface etching on denims (Bio-denim washing)
Lipases	Elimination of natural triglycerides (in scouring) or present in desizing (tallow compounds)
Amylase	To decompose starches applied in sizing (Bio-desizing)

Moreover, *cellulases*, *pectinases*, *hemicellulases*, *lipases* and *catalases* are used in different cotton pre-treatment and finishing processes [Meyer-Stork, 2002].

Cellulase enzymes were first introduced after decades of *amylase* usage as an industry standard for desizing processes. Today, efforts within the textile industry seem to focus on replacing traditional natural-fiber scouring processes with enzyme-based solutions. As the purpose of scouring is to remove natural impurities such as polymeric substances like pectins, waxes and xylomannans, among others from cotton or other natural fibers, there are plenty of enzyme that can act on such impurities. Alkaline *pectinases*, which loosens fiber structure by removing pectins between cellulose fibrils and eases the wash-off of waxy impurities, is the key enzyme for a bio-scouring process. Other enzymes including *cellulases*, *hemicellulases*,*proteases* and *lipases* have been tested, but at present, the only commercial bioscouring enzyme products are based on *pectinases*.An efficient biopreparation process should be based on a combination, preferably simultaneously, of enzymes for desizing, scouring and bleaching in one bath. Success in developing such a process would result in a simple process, including savings in water, time and energy consumption.Compared to conventional alkaline boiling off, the advantages of bioscouring are obvious that it can save water and time by reducing one rinsing cycle: saveenergy by lowering the treatment temperature fromboiling to around 50-60□C, and permit less fibre weightloss and less COD and BOD in the effluent.. The novel enzyme allows forthe system to perform at much lower temperatures forbleaching and at neutral pH levels.

2.2.1 Advantages of enzymes used in textiles:

Textile processing has benefited greatly in both environmental impact and product quality through the use of enzymes. From the 7000 enzymes known, only about 75 are commonly used in textile industry processes [Quandt and Kuhl 2001]. The principal enzymes applied in textile industry are hydrolases (*amylases, cellulases, proteases, pectinases and lipases/esterases*)and *oxidoreductases* (*catalases*).*Amylases* are still used to remove starch-based sizes from fabrics after weaving. *Cellulases* have been employed to enzymatically remove fibrils and fuzz fibres, and have also successfully been introduced to the cotton textile industry to produce the aged look of denim and other garments. *Proteases* was assessed for the removal of wool fibre scales, resulting in improved anti-felting behavior. *Esterases*have been successfully studied for the partial hydrolysis of synthetic fibre surfaces, improving their hydrophilicity and aiding further finishing steps. *Catalases* have been used to remove H_2O_2 after bleaching, reducing water consumption [Lenting2007].

Advantages:

- Lower discharge of chemicals and wastewater and decreased handling of hazardous chemicals for textile workers.
- Improved fabric quality.
- Thanks to the introduction of *cellulase* enzymes, the jeans industry can reduce and even eliminate the use of stone. Enzymes give the manufacturer a newer, easier set of tools to create new looks. By using enzymes, the manufacturer can give consumers the look they want, without damaging the garment.

- Reduced waste, less energy, less stone dust and fewer worn out machines.
- More fashion choices longer garment life due to lower damage of original fabric.
- Reduced chemical load, reduced water consumption, lower energy consumption.

2.3 Enzymatic Scouring (Bio-scouring):

Scouring is removal of non-cellulosic material present on the surface of the cotton. Raw cotton contains about 90 % of cellulose and various noncellulosics such as waxes, pectins, proteins, fats, lignin-containinig impurities and colouring matter.

Greige or untreated cotton contains various noncellulosicimpurities, such as waxes, pectins, hemicellulosesand mineral salts, present in the cuticleand primary cell wall of the fibre [Batra 1985; Etterset al. 1999].The goal of the cotton preparatory process is the remove the hydrophobic and noncellulosic components and produce highly absorbent fibres that can be dyed and finished uniformly. These are responsible for the hydrophobicproperties of raw cotton and interfere withaqueous chemical processes on cotton, like dyeingand finishing [Freytag &Dinze 1983]. Therefore,before cotton yarn or fabric can be dyed, it needs tobe pretreated to remove materials that inhibit dyebinding. This step, named scouring, improves thewetability of the fabric and normally uses alkalis,such as sodium hydroxide. However, these chemicalsalso attack the cellulose, leading to reduction instrength and loss of fabric weight. Furthermore, theresulting wastewater has a high COD (ChemicalOxygen Demand), BOD (Biological Oxygen Demand) and salt content [Buschle-Diller et al. 1998]. Enzymaticor bioscouring, leaves the cellulose structurealmost intact, preventing cellulose weight andstrength loss. Bioscouring has a number of potentialadvantages over traditional scouring. It is lower BOD, COD, TDS(Total Dissolved Solids), performedat neutral pH, which reduces total water consumption,the treated yarn/fabrics retain their strengthproperties, the weight loss is reduced or limitedcompared with processing in traditional ways, andit increases cotton fibre softness. Several types ofenzyme, including *pectinases*[Karapinar&Sariisik 2004; Tzanov et al. 2001; Choeet al. 2004;], *cellulases* [Li &Hardin 1997; Karapinar&Sariisik 2004], *proteases*[Karapinar&Sariisik 2004], and *lipases/cutinases*, alone or combined [Deganil et al. 2002;Hartzell& Hsieh 1998] have beenstudied for cotton bioscouring, with *pectinases* beingthe most effective.

Factors influencing scouring are the nature of the substrate, the kind of enzyme used, the enzyme activity, the use of surfactants and mechanical impact. The mild reaction conditions offered by enzymatic treatment provide an environmentally friendly alternative.The starting studies of enzyme treatment for scouring that is, cleaning of cotton fibres, werecarried out by German researchers [Schacht et al. 1995; Rößner 1995], and they included*pectinases*, *proteases* and *lipases* that act upon impurities and *cellulases* which hydrolysethe cellulose chain. Many other researchers followed in their path. They established that*cellulases* and *pectinases* are the most effective ones, *lipases* less with *proteases* being theleast effective. On the basic of their studies they concluded that a simple procedure with *pectinases* in presence of non-ionic surfactant is sufficient to attain good absorbency [Li & Hardin1998; Hartzell & Hsieh 1998; Buchert et al. 2000; Traore&Buschle-Diller 2000; Galante&Formantici 2003]. *Pectinases, cellulases, proteases* and *lipases* have been investigated most commonly and compared to alkaline scouring.Favourable effects of scouring have beenobtained with the enzymes *pectinases*[Etters 1999; Hartzell & Hsieh 1998; Li & Hardin1998; Csiszar et al. 2001; Anis & Eren 2002; Buchert et al. 2000], that catalyse the hydrolysisof pectin substances. Three main types of enzymes are used to break down pectinsubstances [Jayani 2005]: *pectin esterases, polygalacturonases* and *pectin lyases.*In generally *cellulase* and *pectinase* are combined and used for Bio-scouring. In this *pectinase* penetrate into the fibre through the cuticle in places where there are cracks and microscopes, and catalyse the reaction of hydrolysis of the pectin molecules, whereas *cellulase* can destroy cuticle structure by digesting the primary wall cellulose immediately under the cuticle of cotton [Li & Hardin 1998]. But at present, the only commercial bioscouring enzyme products are based on *pectinases.*

Handle is very soft in enzymatic scouring compared to harsh feel in alkaline scouring process. Enzymatic scouring makes it possible to effectively scour fabric without negatively affecting the fabric or the environment. It also minimises health risks ence operators are not exposed to aggressive chemicals. Bio-scouring process provides many advantages, such as reduced water and wastewater costs, reduced treatment time and lower energy consumption because of lower treatment temperature (the optimal temperature is from 40 to 60 ºC) [Li & Hardin 1998]. Moreover, the weight loss in fabric is reduced, and fabric quality is improved with a superior hand and reduced strength loss [Pawar et al. 2002]. The potencial advantagesthat make the enzyme scouring commercially appealing, are a higher quality of the fibres(softer to the touch and better strength), less waste waters, economy of energy andcompatibility with other procedures, equipment and materials [Cavaco-Paulo & Gübitz2003].*Pectinase*, as the name suggests, hydrolysis pectins that are present in cotton as a non-cellulosic impurity. The best kinds of *pectinase* are those, which can function under slightly alkaline conditions even in the presence of chelating agents. Such enzymes are called "alkaline pectinases". Most conventional *pectinases* are usually inactive under these commercially useful conditions, their optimum activity lying in the slightly acidic region.During the*pectinase* treatment the pectin content of cotton fibre can be decreased by about 30 %. The bioscouring process results in textiles being softer than those scoured in the conventional sodium hydroxide process [Nierstrasz and Warmoeskerken 2003].

Bio-scouring can also be used for mixtures of cotton and silk, wool and cashmere.

2.3.1 Bioscouring systems and advantagesof bio-scouring:

The bio-scouring process is built on protease, pectinase and lipase enzymes that act on proteins, pectins and natural waxes to effect scouring of cotton.

Advantages of bio-scouring [Vigneswaran et al. 2001]:

- 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 teryy towel/knitted goods.

Integrated Bio-desizing and Bio-scouring system:

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 [Vigneswaran et al. 2001].

3. Future Directions:

Today, white biotechnology is geared towards creating new materials and biobased fuels from agricultural waste and providing alternative biobased routes to chemical processes. These efforts could lead to the development of improved enzymes such as *amylases*, *hemicellulases*or*cellulases* that could be used in the textile industry. The possibility of leveraging innovations over industries could lead to new opportunities for biobased textile processes. Enzymes can be used in order to develop environmentally friendly alternatives to chemical processes in almost all steps of textile fibre processing. There are already some commercially successful applications, such as *amylases* for desizing, *cellulases* and *laccases* for denim finishing, and *proteases* incorporated in detergent formulations. New enzymes with high specific activity, increased reaction speed, and tolerance to more extreme temperatures and pH could result in development of continuous processes for bioscouring or biofinishing of cellulosic fibres. Development of other processes in the future could also expand the use of enzymes on natural fibers into use on man-made fibers such as nylon and polyester.

New and exciting enzyme applications are likely to bring benefitsin other areas: less harm to the environment; greater efficiency;lower costs; lower energy consumption; and theenhancementof a product's properties. New enzyme molecules capable ofachieving this will no doubt be developed through protein engineeringand recombinant DNA techniques.

The use of enzymes not only make the process less toxic (by substituting enzymatic treatments for harmful chemical treatments) and eco-friendly, they reduce costs associated with the production process, and consumption of natural resources (water, electricity, fuels), while also improving the quality of the final textile product.

There is still considerable potential for new and improved enzyme applications in future textile processing.Advances in enzymology, molecular biology and screening techniques provide possibilities for the development of new enzyme-based processes for a more environmentally friendly approach in textile industry. It seems that in the future it will be possible to do every process using enzymes.

4. Conclusion:

The textile industry was identified as a key sector where opportunities available from adapting biotechnology are high but current awareness of biotechnology is low. Biotechnology offers a wide range of alternative environmentally-friendly processes for the textile industry to complement or improve the conventional technologies.In textile processing the enzyme can be successfully used for preparatory process like desizing, scouring and bleaching.

Bioscouring can be recommended as an adequate procedure for scouring of cotton. It is a simple, repeatable and safe procedure. The removal of pectin components from cotton adequately improves the water absorbencies of the fibres and facilitates the penetration of thedye and other substancesinto the fibre.Naturalqualitiesof the cottonfibre are preserved, the fabric is softer to the touch than after classic scouring. Fibres are also less damaged. These are just a few applications of Biotechnology, however many such potentials are yet to be explored.

Enzymes are not only beneficial from ecological point of view but they are also saving lot of money by reducing water and energy consumption which ultimately reduce the cost of production. It seems that in the future it will be possible to do every process using enzymes.

Enzyme producing companies constantly improve their products for more flexible application conditions and a more wide-spread use. The main hindrance in using enzymes is their high cost. If their cost can be managed, enzymes can be put to use in a much bigger way for textile processing applications.

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