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Textile's green finishing and their standards: A great initiative towards eco-friendliness

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Abstract
Textiles play salient role in human life and are considered as a basic need along with food and shelter. As textiles have always been one of the most environment polluting industries, an attempt has been made to originate an appropriate textile processing method. Conventional textile wet processing presents a countless challenge to the achievement of environmentally sound and sustainable textile processes and products because of its adverse impacts on human health and the environment. Bio-finishing resulted as a good substitute of finishing of fabrics using enzymes, bio-polymer and aromatherapies. The employment of principles of green chemistry as well as additional aspects of cleaner productions will meaningfully attain ecological, economic, and social improvement. Utilization of biotechnology is one of the most important applications of emerging/sustainable technologies in textile wet processing as an eco-friendly green technology. Government has also reacted by evolving regulations and standards to accomplish global as well as national environmental objectives of eco-friendliness.

Keywords: Textile industry, standards, green finishing, eco-friendliness, sustainability

1. Introduction
Textile products play a vital role in meeting men basic needs. We often only consider textiles to be the clothes we wear. However, textiles are also imperative in all facets of our lives from birth to death (Willbanks, 2008) [39]. In textile manufacturing, finishing refers to the processes that transform the woven or knitted fabrics into a functional material and more specifically to any process performed after dyeing the yarn or fabric to renew the look, performance of the finished textile product or clothing (Sayed, 2019) [29].

It is well known that every customer product has less or more impact on the environment, which the consumer does not know. Any product, could be measured as eco-friendly product which is made, used or disposed of in a way that significantly reduces the harm it would otherwise cause to the environment. Finishing of fabrics in an eco-friendly manner is getting very unconventional these days (Shrimali, 2015) [32]. Finishing adds value to the product and makes it more attractive, useful, and functional for the end-user.

2. Methods of Textile Finishing
2.1 Mechanical Finishing Textiles
2.2 Chemical Finishing Textiles

2.1 Chemical Finishing Textiles
These are also known as wet finishes. In these, chemical treatment is given to fabric, either to change its appearance or basic properties. These finishes are generally durable and permanent. Examples are: fire proof, crease resistance, etc.

2.2 Mechanical Finishing Textiles
These are also known as dry finishes. Here the process consists of application of moisture, pressure and heat or a mechanical method to finish a fabric. Beating, brushing, calendaring, filling, etc. are some of the finishes comprised in this group. These finishes are either temporary or semi durable and do not last long.

As textiles have always been one of the most environment polluting industries, an attempt to innovate a proper textile processing technique (that delivers not only eco-friendly finished products but also does not hamper the surrounding environment due to emissions and effluent discharges) has been made. Slowly, consumers in India are taking lead in encouraging manufacturers to accept clean technologies to produce eco-friendly products (Shrimali, 2015) [32].

This resulted in a noble alternative of finishing of fabrics using enzymes and other bio-materials which is known as bio-finishing.

3. Bio-Finishing
Bio-finishing can be merely defined as a biological way of giving wet treatment to the textiles. It contains enzymatic desizing, bio-scouring, bio-bleaching, bio-washing, bio-polishing, finishing using biopolymers, aromatherapy and specialty finishes like wrinkle free effect, antimicrobial finish, deep sleep finishing etc. (Bhala *et al.*, 2012) [7].

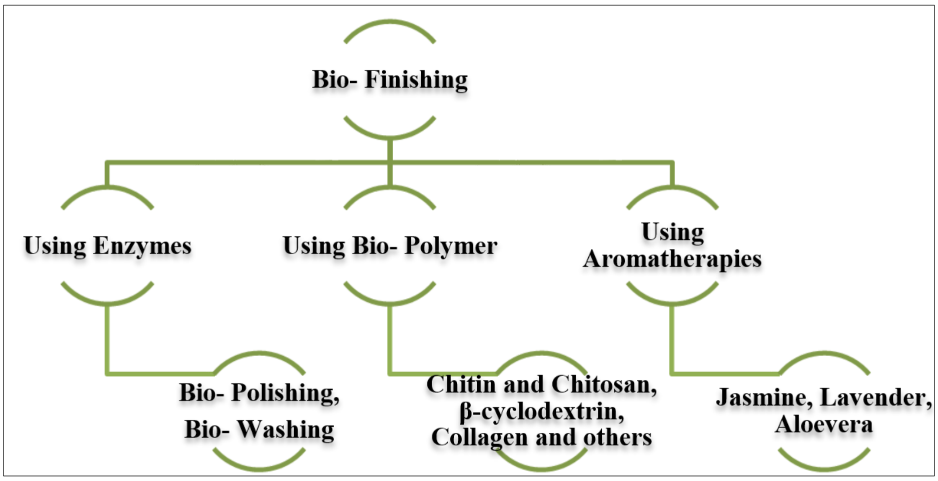

Fig 1: Classification of Bio-finishings

3.1 Finishing Using Enzymes: Enzymes are biological catalysts that facilitate virtually all of the biochemical reactions that establish metabolism in living systems. They expedite the rate of chemical reaction without themselves undergoing any lasting chemical change, i.e. they are true catalysts. (Cavaco-Paulo and Gubitz, 2003).

Cellulase enzymes are classified into two classes

- **Acid cellulase**: It works best in the pH range of 4.5 - 5.5 and displays optimum activity at 50 °C.
- **Neutral cellulase**: It works best at pH 6; however its activity is not harmfully affected in the range of pH 6- 8 and shows maximum activity at 55 °C.

Finishing done with the enzymes are classified as

3.1.1 Bio-polishing

3.1.2 Bio-washing

Bio-polishing of Cellulosics: In bio-polishing, woven or knitted cotton is treated with cellulase to eliminate surface fuzz fibers. The bio-polishing of cotton fabric with cellulase can provide not only smooth appearance but also softness by removing small fuzzes on the fabric surface. Bio-polishing is becoming increasingly popular because of its aptitude to replace singeing presently used by the textile industry. Cellulose is a β-1,4 linked linear polymer of glucose units (Jabasingh and Nchiyar, 2011) [11]. In nature, cellulose degradation can be executed by cellulases. Many studies have been carried out to comprehend the mechanism of cellulose degradation (Csiszar *et al.*, 2006). It is generally accepted that the enzymatic degradation of cellulosic fibers is originated by the accidental attack of an endocellulase on the internal glucosidic bonds of an intact glucan chain (Mizutani and Sethumadhavan, 2002) [22]. However, the meticulous action mechanism of the cellulase system has not been fully elucidated. Cellulase treatment can result in flexible weight loss of cotton fabric which accompany the reducing of textile tensile strength by decomposing the cellulose molecules (Lee *et al.*, 2007) [17]. Thus, the whole process should be measured precisely in order to attain appropriate softness and smooth appearance (Bai *et al.*, 2012) [5].

Mccloskey and Jump (2005) [20] noted the enzymatic bio-polishing, offers a finish for pill prevention and also defines that a cutinase can be used for bio-polishing of polyester fabrics and pooled with a compatible cellulase to treat polyester and cotton blended fabrics. Samples of jute-cotton blended fabric were treated with commercial cellulases, xylanases and pectinases individually and in combination at various concentrations in order to smooth and soften the fabric also treated with the enzyme which benefits to assess the changes in sugar and surface appearance of fabrics (Sreenath *et al.*, 1996) [33].

Bio-washing of Cellulosics: Cellulases act as catalysts in a complex hydrolysis of reaction which contains several intricate steps. Their primary object is to break down the cellulose chains in simply available areas of the fibres into smaller soluble saccharides, the final end-product being glucose. According to prevailing hypothesis, cellobiohydrolase (CBH) attacks the chain ends of cellulose polymers to release cellobiose, the repeating unit of cellulose. Endoglucanase (EG) decrease the degree of polymerization of cellulose by attacking the amorphous region of cellulose by unplanned scission of cellulose chains. Beta-glucosidase (BG) completes the process of hydrolysing cellobiose to glucose (Abbott and Ellison, 2008) [1].

There are various different parameters, e.g. synergism of cellulases, pre-treatment of cotton, treatment solution conditions, and machinery that affect the capacity of cellulases to act on cotton cellulose. The optimum treatment solution conditions for commercial T Reesei (fungi) cellulases are approximately 50 °C and pH 5. The enzyme movement declines rapidly above 65 °C or on both sides of the optimum pH range. Due to the huge molecular size of cellulases, their availability is considered to be restricted to large pores in disordered areas and crystalline surfaces (Bhala *et al.*, 2012) [7]. The enzymatic hydrolysis decreases the volume and surface area of pores smaller than 60 Angstrom in cotton fabrics. The adsorption of cellulases on cellulosic substrates is a precondition for succeeding hydrolysis. The mechanical agitation that takes place during enzymatic hydrolysis plays a chief role in opening up the substrate and allowing the enzyme to cleave the cellulose chain. Comprehension of important features of the process, such as enzyme adsorption/desorption mechanisms and preferred enzyme attacking sites, however, are indispensable to take advantage of the benefits of this interesting reaction. According to Maryana and Montazerb (2013), the bio-treatment process using amylase, cellulase, laccase, and their combinations applied on denim garment to conduct one step bio-desizing and bio-washing producing old-look appearance garment is proposed and analyzed. The color changes of denim samples and the whiteness of the back and staining on the pocket was measured and the surface morphology of the samples were observed using Scanning Electron Microscope.

3.2 Finishing using Biopolymer: Currently, a massive proportion of textile fabrics are made from synthetic petroleum-based fibers, which enact hostile impacts on the environment. Biopolymers, which are green alternatives to petroleum-based fibers, are defined as polymers directly produced by living organisms or polymers derived from bio-based monomers, called bio-based polymers (Thangavelu and Subramani, 2016) [35]. Biopolymers are sustainable, carbon neutral, biodegradable, and renewable (Jahandideh *et al.*, 2021) [13].

Biopolymers can be classified in different ways: according to their monomeric units, they can be classified into polynucleotides (composed of nucleotide monomers), polypeptides (composed of amino acid monomers), and polysaccharides (with carbohydrate structures) (Karthik and Rathinamoorthy, 2017) [15]. From another point of view, biopolymers can be categorized into animal-based, plant-based, and bacterial biopolymers based on their source. Biopolymers from plants consist of lipid and phenolic biopolymers, carbohydrate biopolymers, protein-based biopolymers and isoprene biopolymers. Bacterial biopolymers comprise a group ranging from microbial polysaccharide to polyhydroxyalkanoates (PHAs). Finally, animal-based biopolymers are a massive class of biomaterials, including wool, silk, chitosan, collagen, etc. (Thomas *et al.*, 2013) [37].

3.2.1 Chitin and chitosan: These are naturally arising polysaccharides with numerous molecular weights, purities, and crystallinities, with a structure similar to the structure of cellulose. Their structures vary with cellulose, due to the existence of nitrogen, i.e., acetamide group (Pillai *et al.*, 2009) [28]. Chitin, a semicrystalline biopolymer with the formula $(C8H13O5N)n$, is a non-soluble biopolymer of N-acetylglucosamine, and has several natural sources ranging from the cell walls of fungi to the exoskeleton of arthropods. Deacetylation of chitin results in the formation of chitosan, primarily with a molecular weight of over 100,000 (Kumar, 1999) [16].

Various finishes given to textile material using chitosan can be listed as follows:

A. Wrinkle free finish
B. Antimicrobial finish
C. Fragrance release finish
D. Microencapsulation

3.2.2 β-cyclodextrin: Cyclodextrins are cyclic oligosaccharides composed of glucose units linked by a-1,4-glycosidic bonds. These are of three types: α-cyclodextrin, β-cyclodextrin, γcyclodextrin, which are composed of 6, 7 and 8-a-1, 4-glycosidic bonds. Each cyclodextrin unit has a hydrophobic cavity which can perform as a host for a hydrophobic guest molecule. This property is convenient for solubilizing and stabilizing highly hydrophobic molecules in solvents such as water. No hydrogen bonds are made during the formation of such host guest complexes. Solubilizing is also said to arise through the formation of micellar types of aggregates in aqueous solutions. The combination of β-cyclodextrin and textiles to generate new functionalized fabrics, therefore, received a lot of attention over the last decade. β-cyclodextrins can be incorporated onto textiles by means of spraying, printing, padding, grafting, surface coating, impregnation, inkjet printing or via sol gel (Tonelli, 2010; Thilagavathi and Kannaian, 2010) [38, 36].

3.2.3 Collagen: Collagen is a biocompatible and bioresorbable natural polymer plentifully found in the connective tissue of animals. It accounts for about 20-30% of the total body proteins in vertebrates, existing in tissues of primarily mechanical functions (half of the total body collagen is found in the skin). And it accounts for some 70% of the dry weight of dermis and tendon. Collagen occurs naturally in the form of fibre; in structure, one collagen fibril is composed of three polymer chains in a triple helix, and thousands of overlapped fibrils form one collagen fibre. Collagen is one of the most often used bio-materials for such medical applications as wound care and tissue regeneration because of its many advantages: it is nontoxic, is bio-compatible and can be effortlessly absorbed in the body with very little immunogenicity (Lee *et al.*, 2001; Mattews *et al.*, 2002).

Other natural polymers that have been consumed in the design and development of biomedical nanofibres comprise hyaluronic acid (Schiffman and Schauer, 2007) [30], polyN-acetylglucosamine (Muise-Helmericks *et al.*, 2009) [24], fibrinogen (Wnek *et al.*, 2003), elastin (Miyamoto *et al.*, 2009) [21], alginate-based materials (Park *et al.*, 2008) [25], poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (Han *et al.*, 2007) [10], wheat gluten (Woerdeman *et al.*, 2005) [41] and zein (a protein derived from corn) (Suwantong *et al.*, 2011; Jiang *et al.*, 2010) [34, 14]. The desire for the usage of natural polymers is partly due to the fact that they are commonly attained from such renewable resources as animals, agricultural crops or plants. One of the most important benefits of these natural polymers is that they are usually highly biocompatible and able to promote cell adhesion and proliferation. However, most natural polymers display such drawbacks as relatively low stiffness and low mechanical strength, which can, though, be improved by having the nanofibres cross-linked or by using synthetic polymers in combination.

Paul *et al.* (2012) [26] noted the effect of the hydrolyzed collagen in dyeing of cotton as well as leather. Initially the compatibility of direct and anionic dyes with hydrolyzed collagen was studied at different pHs. Dyeing of cotton and leather was then carried out using various fractions of hydrolyzed collagen. The pH plays a very important role and the results indicated that there is synergistic effect of hydrolyzed collagen in the dyeing of leather.

3.3 Finishing using Aromatherapies

i. Jasmine: Jasmine**,** (genus *Jasminum*), also spelled jessamine, genus of about 200 species of fragrant-flowered shrubs and vines of the olive family (Oleaceae). The plants are innate to tropical and to some temperate zones. It is widely used for fragrance in aromatherapy which considerably upsurges in blood oxygen saturation, breathing rate, and blood pressure could be beneficial for relieving depression and improving mood. Linalool along with other volatile components is one of main ingredient responsible for aroma of oil obtained from flowers (Moon *et al.,* 1994) [23].

ii. Lavender: Lavender is one of the most convenient and versatile herbs available both, as a fresh or dried herb and as an essential oil. Throughout history in its inborn regions of Europe, it has been broadly used for treating a range of problems. Probably the most ordinarily used property of lavender is to pleasantly and gently tempt sleep. This combined with its calming and relaxing properties, gave it admiration in British hospitals for many years. Simply a drop or two of lavender essential oil, or a few more drops in a relaxing pre-bedtime bath, can be fairly convenient for people who suffer from mild insomnia, specifically if due to stress.

iii. *Aloe vera*: *Aloe vera* (*Aloe barbadensis*), belongs to the family Liliaceae, has been used in traditional medicinal practices as well as cosmetic uses. *Aloe vera* has admirable skin care properties which comprises anti-inflammatory and anti-aging. Application of *Aloe vera* on textiles as an anti-ageing and moisturising agent has been patented by Kimberley Clark Inc Ltd. DyStar Auxiliaries GmbH has established a textile finishing product encompassing a combination of vitamin E, *Aloe vera* and jojoba oil in a silicon matrix for moisturising and UV protection effect. This finish can also be applied on silk fabric.

4. Importance of Bio-Textile Finishes

Textile finishes are vital because of the following reasons. The finishes help to:

- improve the appearance of fabric and enrich its looks;
- create variety in fabrics through dyeing and printing;
- improve the feel or touch of fabric;
- make the fabric more useful;
- develop the draping ability of light weight fabrics;
- make fabric suitable for an end (specific) use.

5. Global Environmental Requirements-Textile Industry

The textile industry disturbs the environment in various ways. Some environmental facets that are generally applicable to textile industry include: energy consumption spending fossil fuels directly or indirectly through power (which is generated by fossil fuels), contributing to the green-house gas (GHG) emissions; usage of fossil fuels like petroleum and coal for producing some synthetic fibers and auxiliary chemicals, usage of water that could have been otherwise used for drinking, etc; displacement of agricultural and forest lands; methyl bromide, which is used for cotton growing, announces most of the bromine content to stratosphere, depleting ozone layer; noise pollution; chemical hazards etc.

Some means in which textiles distress the environment uniquely are: wet treatments like desizing and scouring using oxygen-depleting substances decrease the cleanliness of the water; adsorbable organic halides (AOX) emissions produced by fewer biodegradable organic halogenated compounds product from bleaching processes; high chemical oxygen demand (COD) increasing from cotton desizing; strong alkaline waste from mercerization; dyeing process creates effluent with high COD, metals, toxic substances, salts, etc., instigating from the dyes and dispersing agents. Such discharge is released to water sources such as river, causing in pollution (Schönberger and Schäfer 2003) [31].

Therefore, the main environmental unease in the textile industry is wastewater, both in terms of its volume and the pollutants it carries, because the textile industry mainly employs wet processes to treat textile goods. Some emissions stem from constituents that are already present on the raw materials before they extent the processing stage, including pesticides, impurities, knitting oils and preparation agents. Eliminating these materials produces a very high chemical oxygen demand (COD) as well as several non-biodegradable and to some extent hazardous substances (Kahlenborn *et al.,* 2009).

Generally speaking, destructive substances in textiles and clothing products include the following categories:

- Formaldehyde, fluorescent bleacher, and softener (may cause allergies)
- Residues of pesticides, antiseptics, and mold inhibitors in cotton and in wool fiber, such as pentachlorophenol (e.g., PCP)
- Residues of heavy metals
- Residues of azo monomers, formaldehyde, and halide carrier in chemical fiber
- Residues of pesticide and fertilizer used in cotton farming

Environmental issues are now becoming a fragment of the expansion in production field and services and an imperative aspect of international cooperation. Environmental requirements such as charges and taxes for environmental purposes, requirements linked to products, including standards and technical regulations, eco-labeling, packaging and recycling requirements used for the attainments of global as well as national environmental purposes have natural influence on market access and competitiveness of products. While not solely a developed-country phenomenon, consumers in OECD countries increasingly need the goods and services they purchase be protected by environmental requirements. Governments have reacted by developing regulations and standards, and non-governmental organizations (NGOs) are taking on a new part in the growth of standards and codes of conduct.

6. Global Environmental Standards for Textile Products-

6.1 The ISO 14000: The ISO 14000 family speaks various aspects of environmental management. The very first two standards, ISO 14001:2004 and ISO 14004:2004, deal with environmental management systems (EMS). ISO 14001:2004 offers the requirements for an EMS, and ISO 14004:2004 gives general EMS guidelines. An EMS meeting the requirements of ISO 14001:2004 is a supervision tool enabling an organization of any size or type:

- to find and control the environmental impact of its activities, products or services,
- to expand its environmental performance continually,
- to implement a methodical approach to setting environmental purposes and targets, to attain these and to demonstrate that they have been achieved.

ISO 14001:2004 does not postulate levels of environmental performance. If it specifies levels of environmental performance, they would have to be precise to each business activity and this would necessitate a specific EMS standard for each business. However, that is the not the goal of ISO 14000 standards.

6.2 Eco-Labeling: Eco-labeling guarantees definite ecological criteria for all kinds of textile items and their manufacturing processes. It identifies whether:

- Products are environmentally harmless
- Manufactured by eco-friendly material
- Escapes harmful chemicals
- Oekotex 100 is one of its classified standards.

6.3 Bluesign®: The bluesign® standard starts from the ground up. It’s not about trying finished products. Instead, before production begins components and processes are carefully chosen to ensure they encounter the specified criteria. This is the only way to guarantee maximum execution of resource productivity and EHS—that’s environment, health and safety—in the most efficient and cost-effective method for everyone involved.

The bluesign® standard is extensively recognized within the whole textile production chain. To assure efficient and economical solutions, the bluesign® standard includes all levels of the manufacturing chain. It is recognized by leading chemical companies, numerous textile manufacturers as well as well-known retailer and brand companies.

6.4 Made in Green®: Made in green is a superior symbol for all those who deliver textile products manufactured with the assurance that they are free from substances injurious to health. This certifies that the product manufactured in factories which respect the environment, universal rights and the universal rights of workers, is free from harmful substances.

6.5 Impact of REACH: Other initiatives include registration, evaluation and authorization and restriction of chemicals (REACH) legislation which targets to reassure safe and eco-friendly chemical production. In the USA, the Toxic Substances Control Act (TCSA) allows the US Environmental Protection Agency (EPA) to track industrial chemicals produced in or imported into the country. Some man-made fibers, such as Lenzing’s lyocell fiber Tencel, have a negligible influence on the environment. Also, organic cotton making is growing fast but still accounts for only a small segment of global cotton output. Nonetheless, organic cotton is being accepted by high profile companies such as C&A, Coop, Nike, Wal-Mart, and Woolworths. And a rising number of brand and manufacturing companies are pursuing environmentally friendly strategies. Such companies contain American Apparel, Gap, Interface, Patagonia, and Wal-Mart in the USA as well as Rohner Textil in Switzerland, and a small knitwear company in India, MaHan, which was established by an ex-teacher from the Netherlands.

6.6 Textile/Clothing Eco-Labeling Schemes: Environmental labels are attached to a diversity of products to fascinate the attention of consumers about the environmentally progressive features of the products. Usually these labels are voluntary and mostly used for the promotion of the products on the basis of their environmentally approachable characteristics. In the case of textiles and clothing, there are currently no eco-labels, the use of which has been enforced by mandatory rules.

Eco-labels are normally distributed either by government supported or private enterprises once it has been showed that the product of the claimant has met the criteria set by them for the label. Eco-label usually represents a holistic judgment, giving an complete assessment of a product’s environmental quality relative to other products in the same category. In other words it is a claim which designates the environmental aspects of a product or service. Environmental labels drive as informative and voluntary market instruments. At least, 15 countries including India have launched the eco-labeling schemes that are subsidized either by the governments or by the charitable organizations that receive technical and financial support from their government.

6.7 Types of Eco-Labels

- Independent or Private Eco-labels
- Institution Related—Eco-Tex 100, Eco-Tex, 1000, eco-tex®, AKN Trademark
- Producer’s association—AKN members, Company eco-labels (e.g., Steilmann, Otto, Versnad, Hess Natur, Green Cotton)
- National and International Labels
- Multinational: EU-label, Nordic Swan
- National: Green Mark (China-Taiwan Province), Environmental Eco-Mark (Japan), Eco-Mark (India), EKO-Seal (Netherlands), etc.

8. Conclusion

Growing responsiveness towards sustainable progress and environmental matters has resulted in many attempts at using renewables, i.e., enzymes, biopolymers and aromatherapies, in the textile industry. Replacement of the orthodox fossil-based platforms for green alternative technologies in the textile industry is favorable in various ways: using bio materials for textile practices decreases the reliance of the textile industry on various fossil built resources and substantially supports the environmental profile and sustainability of textile goods. The disadvantage of bio-finishing is less durability, which is eluded by recent technologies. Government and related organizations should take appropriate steps in standardizing the use of bio-finishing methods in countries as India, where atmosphere protection has to be taken seriously now. Environmental requirements are also becoming more rigorous as a result of amplified knowledge of the risk and harm to health and the environment, in specific of certain chemicals. Standards and regulations concerning maximum residue levels (MRLs) for pesticides and other chemicals are thus an matter of concern to developing countries, which, even if they desired to comply, may not have access to the equipment needed to monitor and exhibit compliance.

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