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Applications of Biotechnological Methods in Textile Printing and Other Areas Using Nanoenzymes

Kunal Singha*

Department of Textile Design, National Institute of Fashion Technology, Kolkata, West Bengal, India

Abstract

The textile printing techniques have been on the verge of their evolutions since the inception of biotechnological processes in textiles. In this context, the nanoenzymes play a crucial role and that has been furthermore triggered by the advancement in biochemical manufacturing, processes, methodological approaches like bioprinting and other biotech operations. These latest processes showing high quality ecological printings in the domain of textile printing. This chapter deals with all the modern information, techniques and smart printing concepts which are based on biotechnology in the domain of textile manufacturing and chemical printing arena. It also discusses about the various latest printing technology such as importance of biotechnology in textile printing, enzymatic biotechnological printing process, digital textile printing *via* biotechnological progress, membrane Biological Activated Carbon (BAC) based printing, oligomer based biotechnology, application of polyaromatic hydrocarbon remediation and anti-biofouling from surfaces using nanoenzymes and other applications of nanoenzymes in textiles.

Keywords: Bioprinting • Nanoenzymes • Textiles • Biological activated carbon

Abbreviations: NP: Nanoparticles; NC: Nanocrystals

Introduction

The usage of renewable sources in the textile industries are named sustainable textiles. Textile manufacturing biotechnology explores emerging patterns, methods and advances in natural fibres' finishing and manufacturing. Biotextiles consist of synthetic fabrics designed for use in different biotextile conditions where their output depends on biocompatibility and biological fluids and cells. Biotextiles are the most current and modified technique of the textile industry. In the current days, nanoenzymes are used in various biotextiles aided methods to meet specific objectives such as membrane biological activated carbon printing, digital printing and biotech based enzymatic printing with very high functionality. Renewable and live species are used for the nanoenzyme cycle which is also called as biotech operation. Biotextiles and biotech operations include implantable sutures, reconstruction of hernias, arterial grafts, artificial skin and portions of the artificial heart. The usage of sustainable textiles in different garment sectors is increasing every day and ideally can be able to make the atmosphere polluted. Throughout the apparel industry, the nanoenzyme cycle is basically used to extract scale starch from the garment cloth. This is also used in the treatment system for effluents (ETP) for the filtration and recovery of the textile dyeing effluent. The use of nanoenzymes in wet processing saves money, resources and water and increases the efficiency of growth. The usage of nanoenzymes in textiles is growing rapidly and the nanoenzyme manufacturing firms prefer to operate in an atmosphere that requires fewer resources and operates. Nanoenzymes are tend to fade jeans or textiles. This has also been used for microbial scouring, bio-pollination, silk degumming, peroxide reduction, fibre carbonization, reactive washing of dyeing and several other applications. Textile manufacturing biotechnology provides an important tool for researchers and consultants in Research and Development (R and D) institutes and colleges, textile development practitioners, enzymologists, biotechnology and environmental conservation practitioners as well as for textile producers and manufacturers [1].

Nanozymes are inorganic nanoparticles that have enzymatic capabilities in redox processes, enabling them to process both unique nanomaterial features and also for using as a catalytic function. Nanozymes offer a wide range of potential uses in disciplines such as chemical engineering, agriculture, medicine and the environment due to their excellent multifunctionality, catalytic activity and stability [2].

***Address for Correspondence:** Kunal Singha, Department of Textile Design, National Institute of Fashion Technology, Kolkata, West Bengal, India; E-mail: kunal.singha@nift.ac.in*

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Importance of biotechnology in textile printing using nanoenzymes and other methods

It is worth mentioning the importance of using biotechnology in textiles by the help of nanoenzymes. The following are the advantages of using nanoenzymatic biotechnology in textile printing process as;

- Enzymatic process improves the variety of plants used in the production of textile fibre. this also influences the internal properties of fibres.
- Nanoenzyme pretreatment effect of bleached and polished flax fibres.
- Used for treatment of waste.
- Prohibits adulteration with adulteration.
- Used in quality control is assisted by biotechnology.
- Boost low-energy detergents.
- Used as the finishing section with nanoenzymes.
- Used in place of harmful dyes and chemical therapies.
- Used in textiles to prohibit microorganisms and bio-polymers which grow the entire textile cycle.
- Used as enzymatic scouring of knitted textiles for better textile properties.
- Provides fibre material morphology and fibreboard mechanical properties.
- For the application in enzymatic wool fabric finishes process.
- Ultrasonic impacts on the efficiency of industrial nanoenzymes used in bio-preparation and bio-finishing applications [1-3].

Producer and end user today are conscious of the positive influence that fossil and synthetic goods do not have on the environment of the earth. The need also contributed to the development of biotechnology, which involves the substitution of biological chemical processes. Industrial science or white science or cleaner technology based science includes of manufacturing systems such as living humans, synthetic compounds, and chemical elements of species. White biotechnology can lead to biodiversity and environmental conservation. Wet processing is one field for which industrial biotechnology can help to establish environmentally sustainable applications in the textile industry.

The production of oil related polymers started in the first half of the twentieth century with the introduction of organic nanochemistry, and there was no glance back since then. For dyes, textures and also garments, mineral and natural materials are usually used. But increasing environmental legislation against these products and the growing waste disposal of non-biodegradable products lead to technological developments to protect and protect nature. These issues can be solved by applying nanoenzymes (such as oxidoreductases transferases, hydrolases) in these bioprinting processes. Nanoenzymes have been used in dyeing methods since ancient times. A well-known example of the usage of white biotechnology in textile wet processing is the technique of extracting stains from woven fabrics utilizing enzymatic starch. Microbial amylases were used for the first time in the 1950's for the desiccation of processes and are now popular in many textile industries [4-6].

Literature Review

Application of biotechnology in textile printing using nanoenzymes and other methods

Enzymatic biotechnological printing process: Nanoenzymes are a catalyst which display greater stereoselectivity, specificities and can function under moderate environments. Six specific forms of nanoenzymes are used in the textile business: oxidoreductases (catalyzing or reducing reactions), transferases, which moves a functional group, hydrolases (catalyzing hydrolysis of different bonding elements), lyases (cutting separate bonding elements), isomerases (including adjustments in single molecules).

The use of bio-processing nanoenzymes has several advantages, as opposed to traditional techniques and methods in the textile industry. Nanoenzymes reduce the reaction initiation energy to increase the reaction rate. As nanoenzymes are like catalysts, they always remain intact in a reaction. They do have an ideal temperature and ideal PH (in a range of 4-6) and are thus simple to monitor in any specific reaction. The main advantages of nanoenzymes are that they are fully biodegradable, avoiding the usage of chemicals and hazardous compounds otherwise required for textile processes. The usage of nanoenzyme helps to reduce unnecessary water and energy consumption which does not induce emissions.

Cellulases substituted nanoenzymes can be applied with the help of pumice stone while using stonewashing methods in denims. Another important application of nanoenzymes in textile processing is to produce an anti-pilling finish that is supposed to increase fabric quality. In processing machines, cellulases are used to synergize actions that in turn reduce fibroids and produce a smooth surface. This technique is also known as bio-polishing and is used in woven and knitted fabrics and especially in demin (jeans) throughout the world [7].

In textile and garment dyeing and printing, hydrogen peroxide is increasingly used particularly for blanching purposes. It is necessary to extract hydrogen peroxide from the paint bath until the textiles are bleached, or else the paint hue may shift and may result in irregular dyeing. These issues can be readily solved by using nanoenzymes while using the process as white finishing or cleaner finishing biotechnology. In the textiles sector, white manufacturing approaches of nanoenzymes are used to remove harmful compounds in scouring natural fabrics such as cotton. Scouring removes chemical impurities such as pectins, xylomanians and waxes. Alakaline pectinase is an nanoenzyme that acts well within fibrils of cellulose to eliminate impurities. The organic scouring method requires less water, less energy and increases the consistency of the fabric due to reduced strength loss. In manufacturing processes are often employing bleaching processes use glucose oxidase to generate hydrogen peroxide and molecular oxygen for the formation of peroxide in situ [8].

The highly hydrophobial and crystalline synthetic fibres such as Polyamide (PA), Polyethylenetephthalate (PET), and Polyacrylonitrile (PAN) make it difficult to process and finish such fibres. Chemicals such as sodium hydroxide have been used to increase water affinity and fibre flexibility. The chemical cycle is therefore challenging to monitor and lead in synthetic fibres to permanent yellowness. Nanoenzyme therapy with lipase improves the water absorbing properties of these synthetic fibres. This also adds to the anti-pilling, desiccation and susceptibility of PET products to sticky stains.

The future for the use of nanoenzymes in the textile industry lies in biotransformation, the bio-catalytic conversion between the chemicals. White technological advances will result in the use in the textile industry of nanoenzymes such as amylases, hemicellulases and cellulases. White technology will also make textile wet processing processes competitive and environmentally safe [9].

Digital textile printing *via* biotechnological progress: Digital Textile Printing (DTP) is known as an environmentally friendly technology because it generates very little pollution compared to traditional textile printing systems. DTP is typically performed in garment manufacturing complexes for making garment manufacturing method and treatment of textile wastewater. The DTP system is compact and reliable in nature. For the treatment of DTP wastewater, a hybrid method consisting of ozone, Ultrafiltration (UF) and Reverse Osmosis (RO) were required along with the usages of nanoenzymes. Ozone was added before UF and RO into DTP wastewater in order to eliminate organic loads for nanomembrane filtration and to handle UF and RO recycled concentrates. The removal output of Chemical Oxygen Demand (COD) and colour was 63 and the efficiency of the wastewater removal efficiency was reported as high as of 81% while using nanoenzyme based DTP process. Colloidal particulate matter was aggregated by ozonation of the DTP waste water to the cake resistance measured after ozone and UF (without ozonation) which can be providing a greater preozonation and that makes a rise in wastewater flow or flux. Consequently, this make the higher filtration and finally wastewater converted into healthy permeated water content. Additional treatment of UF permeates using RO was done as the UF permeates were not appropriate for immediate release or reuse. Final effluents over the whole ozonation cycle, UF and RO meet the requirements for direct waste and reuse and which indicating a suitable usage of the DTP wastewater treatment [10-13].

Membrane Biological Activated Carbon (BAC): Membrane Biological Activated Carbon (BAC) based bioprinting can be done on the textile fabric. The efficiency of this process can be readily increased by using of hydroxyl-based nanoenzymes. Pre-ozonisation and ozonisation are also done in this process to further increase the purity and effectiveness of the nanoenzymes. This process can eliminate microorganisms which could have adverse effects on organic matter and nitrite removals throughout the bioprinting operation [14-16].

Oligomer based biotechnology: Polyurethane acrylate oligomers and nanoenzymes (such as dibutylic tin dilaurate, polyurethane diisocyanates, polyethylene glycol and hydroxy ethyl acrylate based mixed nanoenzymes) mixture are used as inkjet bioprinting on cotton, viscose, linen, polyester and nylon fabric materials. The usage of nanoenzymes increases the rheological properties and as an ultraviolet protector for the textile materials. Pre-ultrafiltration (UF) coagulation can be also used to make the polyurethane acrylate oligomers utilised for this process.

The concentration of bacteria (especially bacteria per suspended solid) are reduced by ozonisation in this process [17]. The concentration of Extracellular Polymer Substances (EPS) such as polysaccharides and proteins decreased inside the membrane cake layer; decreased EPS and bacterial concentrations resulted in a much diluted cake layer while the concentration of suspended solids remained slightly higher inside the membrane tank attached to the ozone. Ozone also reduced organic matter aggregation and hydrophobicity in membrane pores (which contributed to limited permanent fouling) during the bioprinting process.

Nanofiltration based biotechnological printing: Nanofiltration (NF), Ultra-Filtration (UF) and pilot scale ozonization tests can increase the efficiency of bioprinting using nanoenzymes. This is particularly useful in using wastewater treatment plant and use those recycled water sources for the bioprinting from a broad range of dangerous industrial processes. This process is able produce excellent bioprinted materials with less final rejection coefficients due to less production of 31% for Total Dissolved Solid (TDS), 94% for Chemical Oxygen Demand (COD), 9% less for Chlorine discharge, 47% less for surfactants, 66% less for phenols and 91% for sulphate ion discharge. Moreover, the ozonization and recycling to the physico-chemical level is also a successful approach in terms of COD elimination and biodegradeability inside this process. Similarly, it has been found that NF permeate ozonization is the best process solution before final treatment and effluent discharge. This process also help to produce antibacterial bioprints with the applications of nanoenzymes (hydroxyl and alkyl-based) along with ZnO nanoparticles, which can resist the gram-positive bacteria over any textile materials [18]. The other examples of nanoparticles have been listed in the Table 1.

The other various applications of nanostructures and nanoenzymes are illustrated in the Figure 1 [19].

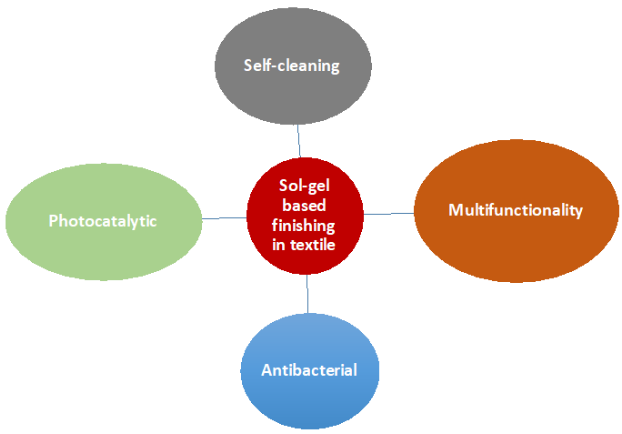

Figure 1. The various applications of nanoenzymes and nanostructures in textiles.

Application processes	Examples of nanoenzymes
Hydrothermal process	V_2O_5 nanowires
	CeO_2 NPs
	Co_3O_4 NPs
	$FePO_4$ NPs
	Mn_3O_4 octahedrons
Solvatothermal process	Fe_3O_4
	Au/CuS NCs
Co-precipitation process	Fe_3O_4 NPs
	Fe_3O_4 NPs
Sol-gel process	$ZnFe_2O_4$/ZnO NCs
	Fe_2O_3 NPs

Table 1. Examples of nanoezymes.

Other applications of nanoenzymes in textiles

Application of polyaromatic hydrocarbon remediation and anti-biofouling from surfaces using nanoenzymes: Nanoenzymes can be applied for restrict the pollutant free antifouling usages. This process is also helpful for the usages of its potential remediation using microbial-derived nanoenzymes [20]. As, Polyaromatic Hydrocarbons (PAHs) are one of the critical industrial contaminants for any industry which actually creates the environmental damages due to their ubiquitous occurrence, toxicity and proclivity for bioaccumulation. Therefore, Natural ligninolytic enzymes such as MnP (manganese peroxidase), LiP (lithium peroxidase), peroxidases, laccase, and polysaccharide and protein degradative enzymes are found to be highly efficient for PAH degradation and antifouling respectively. However, large-scale applications of these enzymes is unmanageable due to various reasons like their poor stability, adaptation and high-cost production of these enzymes. In latest time, the use of nanoparticles and nanoenzymes are showing a very innovative and synergistic way to detoxify contaminated areas with concomitant maintenance of enzyme stability mainly causing from PAH compounds in specially related to the textile industry [21].

Applications of cotton textile/iron oxide nanozyme with peroxidase as low-cost catalysts for a variety of textile process applications: At present, both native and immobilized nanoparticles are of great importance in many areas of science and technology. Applications of cotton textile/iron oxide nanozyme with peroxidase is very useful as low-cost catalysts for a variety of textile process applications (Figure 2).

Simple modification processes are possible because to the usage of magnetic iron oxide nanoparticles and their aggregates bound to woven cotton textiles. The ease of immobilised nanozyme preparation and the cheap cost of all precursors make it suitable for a wide range of applications, including the decolorization and degradation of a variety of organic dyes and other contaminants. Other forms of textile-bound nanozymes can also be manufactured and employed as low-cost catalysts [22].

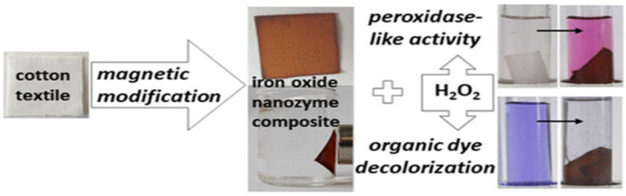

Figure 2. Applications of cotton textile/iron oxide nanozyme with peroxidase as low-cost catalysts.

Discussion

Industrial applications of immobilized nanobiocatalysts: Because of their high catalytic activity and reaction selectivity, immobilised enzyme based catalytic constructs can be considerably enhancing a variety of industrial processes. Nano-enzymes, which are enzymes immobilised on nanomaterials, have grown in prominence in recent decades due to their enhanced stability, reusability, and ease of removal from the biocatalytic process. Nanoporous particles, nanofibers, nanoflowers, nanogels, nanomembranes, metal organic frameworks, multi-walled or single walled carbon nanotubes, and nanoparticles with adjusted form and size may all be selectively combined into nanostructured materials to build nano-enzymes. In the synthesis and catalytic qualities of nanoenzymes, the surface area to volume ratio, pore volume, chemical compositions, electrical charge or conductivity of nanomaterials, protein charge, hydrophobicity, and amino acid composition on protein surface play critical roles.

The adjustment of the above-mentioned parameters would lead to suitable micro-environments for biocatalysts of industrial importance with adequate knowledge. As a result, nanoenzymes have the potential to accelerate developments in catalysis, biotransformation, biosensing, and biomarker identification. This review paper focuses on current advancements in nano-enzyme creation and their potential applications in biomedicine, biosensors, bioremediation of industrial pollutants, biofuel generation, textile, leather, detergent, food sectors, and antifouling [23].

Synthesis of cost-effective magnetic nanobiocomposites mimicking peroxidase activity for remediation of dyes: Cellulose Incorporated Magnetic Nanobiocomposites (CNPs) can be used as nanoenzymes to synthesis the cost-effective magnetic nanobiocomposites mimicking peroxidase activity, that can be used for the remediation of textile and fashion (by using cellulose as base material) industry based dyes. The CNPs exhibited higher pH and thermal stability compared to commercial peroxidase. Under acidic circumstances (pH 3.0), these nanocomposites were able to completely remove a persistent azo dye, methyl orange at a concentration of 50 ppm in just 60 minutes. In addition, these CNP material can also decolorize a commercial textile dye mixture in 30 minutes. Spectroscopy verified the CNP mediated breakdown of dyes into simple metabolites. Because of their magnetic characteristics and associated reusability, CNPs are a very appealing method for dye remediation from environmental samples or textile industry effluents [24].

Nanozymes for environmental pollutant monitoring and remediation: Nanozymes are advanced nanomaterials which mimic natural enzymes by exhibiting enzyme like properties. As nanozymes offer better structural stability over their respective natural enzymes, they are ideal candidates for real-time and/or remote environmental pollutant monitoring and remediation. In the recent years, enzyme mimicking nanozymes have been invented and they can be further classified into four types depending on their enzyme mimicking behaviour (as active metal centre mimic nanoenzymes, functional mimic nanoenzymes, nanocomposite nanoenzymes and 3D structural mimic nanoenzymes) and offer mechanistic insights into the nature of their catalytic activity. Moreover, the current environmental translation of nanozymes into a powerful sensing or remediation tool through inventive nano-architectural design of nanozymes and their transduction methodologies. The enzyme-mimicking nanoenzymes are the critical solutions which can provide higher practical deployment rather than the normal/commercial nanozymes in terms of their effectiveness, reusability, real-time in field application, commercial production and regulatory considerations [25].

Use of nanoenzymes in therapeutic activity regulation and biomedical applications: advances in oxidase mimicking nanozymes: Recently, great varieties of engineered nanostructures and nanoenzymes have been demonstrated to show greater oxidase mimetic activity power, which can serve as ideal candidates for oxidase mimicking nanozymes.

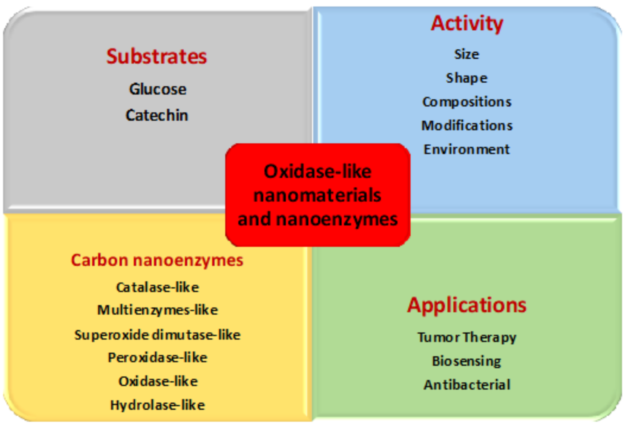

Figure 3. The applications of oxidase-like nanostructured/ nanoenzymes.

In view of the significant progress of nanozymes, the oxidase mimicking nanozymes can be classified in terms of the acting group of representative substrates and discuss their possible catalytic mechanisms (Figure 3). Researchers have also produced higher activity modulation of oxidase mimicking nanozymes by tuning the physicochemical property of nanomaterials and surrounding environments. These nanostructure/nanoenzymes can be used in the many of their potential biomedical applications in biosensing, antibacterial and cancer treatment [26-27].

Conclusion

Nanoenzymes, nanostructures and nanoparticles are playing crucial role in textile and fashion and other industrial domain as they can mimic the enzyme like properties in redox reactions, by showing greater unique properties of nanomaterials and an excellent catalytic function. Due of high catalytic activity, stability and multifunctionality, nanozyme are of increasingly wide interest in the field s of environmental science and technology. In this review chapter, we have discussed the most recent advances of nanoenzymerese for the applications in bioprintings in textile and fashion along with the other applications of nanostructures/nanoenzymes such as for environmental pollutant detection, treatment and as catalyst. Nanozymes can be used to detections, molecules and organic compounds both qualitatively and quantitatively. They have also been applied for destruction multi-drug resistant bacteria and the degradation of various organic pollutants.

Despite the wide potential of nanozymes in environmental science and technology, the current research and applications of nanoenzymes are still limited, which need further expansions in the future.

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