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The Importance of Nanotechnology on Sericulture as a Promising Field

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Abstract

Nano science refers to the science and discipline and nanotechnology refers to the applied part of it including the engineering to control, manipulate and structure the matter at an unimaginably small scale i.e., nanoscale. This scale is also referred to as the 'atomic' or 'molecular' scale which is 100 nanometers or smaller. Nanotechnology is an emerging interdisciplinary area that is expected to have wide-ranging implications in all fields of science and technology such as energy and aerospace, electronics, material science, medicine, mechanics, optics, plastics, and textiles. Although Nanotechnology is still in its infancy stage and it has a bright future in the sericulture sector such as protection from plant and silkworm diseases (Silver and Magnesium Oxide), improving the performance of textiles like fiber quality (Nanofiber) and fibroin quality, quality of cocoons, nanocomposite fibers. Nanoparticle application during conventional textile processing techniques like finishing, coating, and dyeing enhances product performance. This review discusses applications of Nanotechnology in Sericulture. It also provides information on identified properties of Nano textile.

Keywords: *Assam, India, Nanocomposite, Nanofiber, Nanotechnology, Sericulture, Silk.*

Introduction

Sericulture or silk farming is both an art and science of rearing silkworms for producing raw silk. Even today silk plays an important role in the fashion industry worldwide. Being a rural industry, silk production and weaving (mostly manually) is done by a relatively poorer section of India. India is the second-largest producer of silk after China. In India, silk farming is not only a tradition but also an integral part living of involving huge labor and creative ingenuity of rural artisans. Currently, Indian domestic demand for silk is 25,000 metric tons, whereas the current production figures are 18,475 metric tons, the rest being imported from China [8]

Sericulture in India is the pivotal sector for ensuring sustainable development of poor farmers and women folk and also for the alleviation of poverty. It is the key sector for generating employment opportunities for the majority of the population. During the first decade of the 21st century, two contrasting trends have been noticed i.e. India is being recognized as the global power in the key economic sectors with consistently high economic growth and its slow growth is observed in the agricultural sector. Indian agriculture contributes 8% of global agricultural gross domestic product to support 18% of the world population on only 9% of the world's arable land and 2.3% of geographical area. Nearly one-third of the country's population lives below the poverty line, and about 80% of our land mass is highly vulnerable to drought, floods, and cyclones. On the brighter side, India possesses substantial biodiversity nearly 8 % of the world's documented animal and plant species are

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found in our country).

Sericulture in Assam is a sustainable farm-based economic enterprise positively favoring the rural poor in the unorganized sector because of its relatively low requirement of fixed capital and higher returns of investment. The benefit-cost ratio of sericulture is the highest in comparison to other agricultural cash crops in the country. The additional income derived from Sericulture activities enables these farmers to meet their regular needs, especially during the "No Return" lean agriculture seasons. All the 4 known commercial varieties of silk are produced in Assam though emphasis has been on the 2 exclusive silk varieties of Muga and Eri in the context of competitiveness in the current business scenario. Production of Muga raw silk is mostly localized in Assam. The state is also a major producer of Eri silk (65%). The Muga silk production has increased from 99 MT during 2005-06 to 148 MT by 2013-14. Eri silk production has also increased from 690 MT during 2005-06 to 4237 MT by 2013-14.

Nano-science and nanotechnology combined, have revitalized material science and led to the development in the sericulture sector and the expansion of a wide array of improved materials counting polymers and textiles through nanostructuring and nanoengineering. Organized nanostructures as those exhibited by nanocoatings, nanocomposites, nanofibers, and nanofinishinghave significant potential to transform the textile industry with new functionality such as self-cleaning surfaces, conducting textiles, antimicrobial properties,controlled hydrophilicity or hydrophobicity, protection against fire, UV radiation, etc. without affecting the bulk properties of fibers and fabrics.

The use of nanomaterials and nanotechnology-based processes is growing at a tremendous rate in all fields of science and technology. The textile industry is also experiencing the benefits of nanotechnology in its diverse field of applications. Textile-based nanoproducts starting from nanocompositefibers, and nanofibres to intelligent high-performance polymeric nanocoatings are getting their way not only in high-performance advanced applications, but nanoparticles are also successfully being used in conventional textiles to impart new functionality and improved performance. Greater repeatability, reliability, and robustness are the main advantages of nanotechnological advancements in textiles. In disease management silver and magnesium, nanoparticles are proved to have antibacterial and antiviral activity in both the silkworm and host plant.

Protection from diseases

Silkworm farmers lose 15–20% of their larvae due to diseases [20].In some seasons, the losses are so high that the farmers have to resort to a complete overhaul of their larvae-rearing setup. Different commercial strains of *Bombyxmori* silkworm (e.g. nistari) are usually fed on cultivated mulberry (*Morusalba*) leaves and maintained at a temperature of 22–25°C with proper ventilation up to the cocoon stage. *B. mori* Nuclear Polyhedrosis Virus (BmNPV) usually affects full-grown early fifth instar larvae and the infection occurs through the oral route. This 100% deadly viral disease kills larvae within 24–30 hours of infection. This disease is popularly known as 'Grasserie'. There are no currently available antidotes against this disease in the market. However, nano-silica is effective in controlling the Grasserie disease at a concentration of 7µl [8].

The mode of action was found to be as first physical with supramolecular forces on the viral polyhedral surface which come into play due to excessive free surface energy of the amorphous nano-silica. Capping layer-like lipophilic moieties present on the surface try to stabilize the inherent instability of amorphous nano-silica. Therefore, the lipophilic capping layer interacts with the environment and redistributes the high amount of free energy either as high energyin low entropy locations, and thereby amorphous nano-silica surface then serves as an activation site. It was found that amorphous nano silica disrupts the 3-D structure of the viral polyhedron into a much thinner and narrower one resembling the 2-D structure of the virus. It can also be concluded that due to high surface free energy of amorphous nano silica acts as an activation site for severe distortion of the contour of the viral polyhedral surface resulting in the death of the viruses inside the silkworm hemolymph [4]

Similarly, [7] reported nanoparticles treated with proper surface functionalization can prevent BmNPV infection by acting on the surface of the viral polyhedral (Fig 1).

Antibacterial and anti-virucidal activity of silver nanoparticles against bacterial diseases of silkworms such as *Serratia marcescens*, *Bacillus* sp., *Bacillus thuringiensis*, *Streptococcus aureus* and viral diseases like Nuclear polyhedral virus and cytoplasmic

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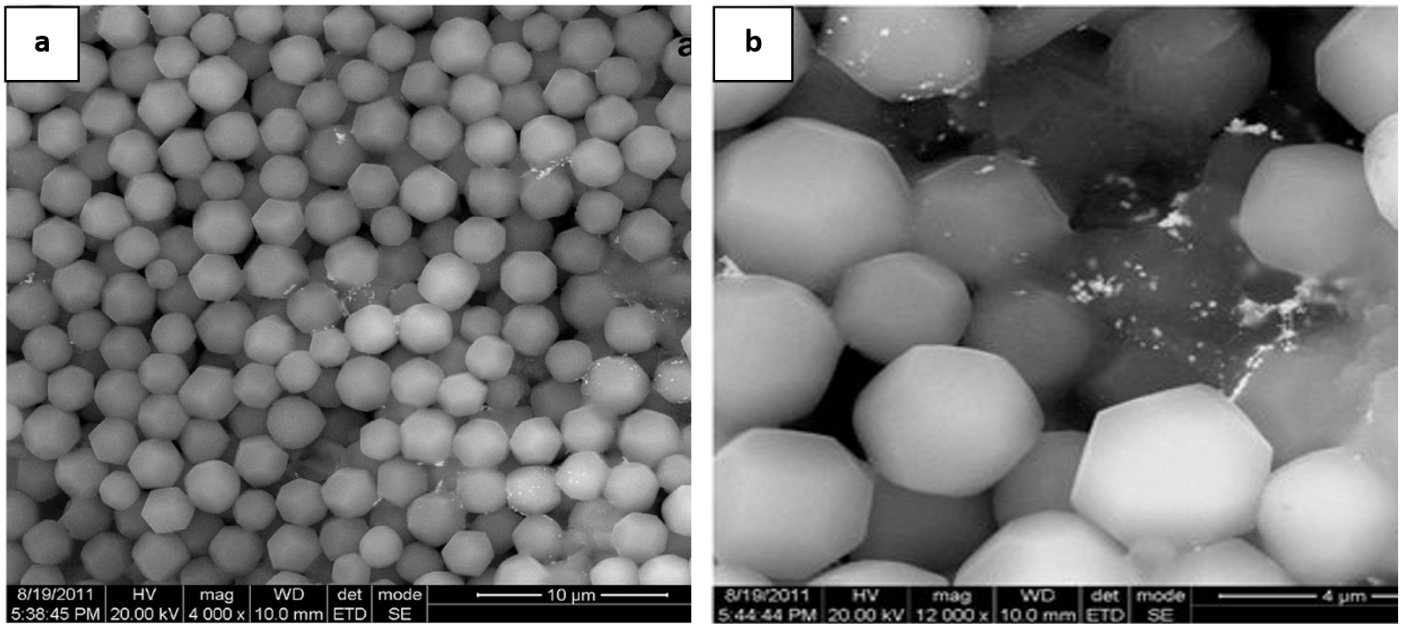

Figure 1. (a) SEM image of BmNPV isolated from the infected *Bombyxmori* L (b) SEM image of BmNPV treated with silver nano particles [35]

polyhedral virus at a concentration of 1:100 [14]. Even they were also found to be effective in controlling pebrine diseases at the same concentration.

Antifungal activity of PNIPAM nanoparticles against microbial infestation (*Aspergillus niger*) of Tasar silkworm. PNIPAM is a nanoparticle and can form microfilm which is acting as a barrier both externally and internally around the infected silkworms, thus, preventing the microbial infection therein. The result indicates that the application of "PNIPAM" at a concentration of 0.4 and 0.6 mg/mL shows a significant decrease in microbial infestations in these silkworms [29].

Enhancement of protein and fibroin content

Silk is a natural protein fiber produced by the silkworm to form the cocoon. It consists mainly of two proteins, fibroin (70–80%), and sericin (20–30%). Fibroin is the structural center of the silk, and sericinis a gelatinous protein produced by *Bombyxmori* (silkworms) that glues two fibroin filaments in a silk fiber [17].Sericin is mainly composed 18 amino acids, among which glycine, serine, aspartic acid, and threonine are commonly present.

The differential role of gold nanoparticles synthesized from *Allium cepa* on the sericin and fibroin content of silkworms. Gold nano treatment resulted in significant alterations in the percentage of fibroin and sericin proteins in the 5th instar as compared to that of control. At a 300ppm dose of green nano gold, the percentage of fibroin was 78.07, while sericin decreased from 39.46 (control) to 21.92. It proved that gold nanomaterials cannot only alter the fibroin protein but also enhance the cocoon and silk traits. [19]

Nano finished textiles

Nano-finished textiles are those textiles that apply a nanoscale property added after the base textile. Nano-finished textiles care free fabrics that are stain proof, superior liquid repellency and wrinkle resistant. Nano-finished textile manufacturing process include coatings to apply nanomaterials or create nanostructured surfaces on fiber media. Additive nanomaterials to date include metal nano-objects such as silver for antimicrobial functionality or clay nano-objects for fire resistance. For self-cleaning hydrophobicity treatments can be used to roughen nanostructured surfaces. Nanofinishing can provide accessible means for established textile manufacturers to engage with nano textiles (Table 1)

Nanocomposite coatings on textiles

The nanocomposite is a multiphase solid material where one of the phases has one, two, or three dimensions of less than 100 nanometers (nm), or structures having nano-scale repeat distances between the different phases that make up the material.The purpose of nanocomposite is the right use of building blocks in the range of nanometres so that creation of new materials with flexibility and advanced physical properties. Different methods for nanocoating on textiles are sol-gels technique, Magnetron Sputter Coating, Plasma, Layer-by-layer technique, and nanomaterial embedded textile [12]..

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Table 1: Identified propertiesof Nano textile

Property	Nanotechnology	Functionality/Application	Example Process	References
Antibacterial/ odor control	Silver nanoparticles	Silver nanoparticles inhibit bacterial metabolism, which causes infection and odor.	Nano-silver colloids are used in wet chemical reduction treatments on textiles	[3], [10], [18], [26] [36]
Bioactivity	Drug Nano capsules	Nanocapsules with loaded drugs adhere to fiber surface using chemical processes particular to nano capsule composition	Nano capsules with drugs are dispersed into medical textiles, such as wound dressings.	13]
Electrical conductivity	Organic conductive polymers and metal nanoparticles	They are added to textile fibers in nano-coatings to create conductive coatings and transistors (basic devices)	Conductive polymers and noble metal nanoparticles are deposited in thin, conformal nanocoatings	[16]
Flame resistance	Intumescent Nanocoatings	They are coated onto fibers and expand to insulate fibers when heated	Charged polymer nanocoatings are applied layer by layer on fiber surface to achieve desired coating material	[1]
High filter efficiency	Nano fibrous media (with added functionality)	High surface-to-weight ratios from nano-scale fiber thickness increase efficiency with possible nanoparticle andnano-composite functionality for antibacterial and chemisorption properties	Electro spinning for nano fiber fabrication using nanocomposite polymers	[2] ,[22] , [23]
High strength	Carbon nanotube polymer composite	Provide very high strength properties due to graphitic structure.	Carbon nanotubes are dispersed into thepolymer matrix, which is drafted into a fiber	[9], [11]
Luminescence	Rare earth Nanocomposites	Nanocomposite fibers use rare earth metals to detect infrared in textile electroluminescent tagging systems	Metal doped inorganic nanoparticles are integrated into polymermatrix for fiber drafting	[25]
Moisture transport	Hydrophilic /hydrophobic titanium dioxide nanocoating	Coatings of titanium dioxide are applied to textiles that are changed from hydrophobic to hydrophilic by light, moving moisture from the dark side to the bright side	Surface reaction between titanium dioxide and textile fiber using hot water treatment	[6]
Shrink Resistance	Keratin nanocoating	Keratin cross-links with textile fibers to provide increased structural strength. This resists shrinking due to fiber rearrangement	Solutions and dried keratin powders applied to textile in a non-digestive enzyme solution	[5]
Stain resistance / self-cleaning / water repellant	"Lotus Effect" (superhydrophobic) polymer nanofilaments	Polymer nanofilaments grown on textile fibers create a rough geometry that repels water due to low surface contact.	Gas phase coating procedure grows polymer nano filaments onto exposed textile fiber surfaces.	[31], [32], [37]
Static protection	Zinc oxide nanoparticles	Conductive zinc oxide nanoparticles disperse static charge developed ontextile fibers	Aqueous dispersion of zinc oxide with surfactants applied to textile using a pad-drying method	[34]
Thermal insulation	Aerogels	Super-lightweight silica aerogel used in any insulating textiles	During fabrication processes aerogels are incorporated into nonwoven reinforcing battings	[30]
UV protection	Titanium dioxide Nanoparticles	It is incorporated into textiles to protect against UV transmission and degradation of textiles	Textile treated withtitanium dioxide nanoparticles aqueous solutionand thencured using a pad-drying method	[24]

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Figure 2. Application of nanotechnology in textiles [33]

Nanocomposite textiles consist of fiber materials that consist of more than one nanostructured or nanoscale component. This type of nano textile required materials to produce nanocomposite and such materials are carbon nanotubes for improving the fiber strength and luminescence. Apart from the carbon nanotube polymer matrices are the most prevalent in nanocomposite fibers.

Nanocomposite fibre does not require any changes in the process of manufacturing because the material that has to be integrated would be of the same shape and sizefor the process that has been designed. But there is an exceptional case such that if we want to change the fiber material by choosing a different material matrix than significant changes may be needed. It is found that nanocompsite fibre are promising but their commercialization is at a nascent stage.

Nanofibrous textiles

Nanofibrous textiles are then materials in which the fibers are in the nanoscale.In this material it is found to have a cross sectional area of nanoscale but the length might not to have at the nanoscale. In nanofibrous the content of fiber material be single, composite or nanocomposite. These technologies mainly work in the direction of fabrication of fibers at nanoscale properties and may arise from the carbon nanotube which will have properties like increased fiber surface area, tensile strength and nanoscale porosity.

Nano-enabled nonwovens:

The science of nanotechnology in nonwoven may be useful in the textile industry by improving the enhancement properties of adhesiveness by adhering with nanostructured surfaces. Besides this other functions of the nanoscale is the utilization of nanoafilms or nanocoating which have antibacterial properties and luminescence for colour control.

Nano silk sericin:

The wastewater from the silk industry largely contains the sericin group of proteins which are discarded unused and polluting the nearby area. Sericin contains 18 amino acids including essential amino acids. The major amino acid composition in sericin is 32% of serine, 18% aspartic acid, and 16% glycine. The wastewater degumming process of the silk industry is utilized for the extraction of sericin groups of proteins and their conversion to nanoparticles.

Nanofibre:

Nanofibers are considered to be fiber having a diameter at the nanoscale. This nanofiber can be produced or manufactured from a polymer having unique physical property and applications [28]. Examples of natural polymers include collagen, cellulose, silk fibroin, keratin, gelatin, and polysaccharides such as chitosan and alginate. Examples of synthetic polymers include poly lactic acid (PLA), polycaprolactone (PCL), polyurethane (PU), poly (lactic-co-glycolic acid) (PLGA), poly(3-hydroxybutyrate-co-3-hydroxy valerate) (PHBV), and poly(ethylene-co-vinyl acetate) (PEVA) [28]. It is believed that polymer chain are interconnected with covalent bonds [27] . The range of diameters of nanofibers depends on the method of production and the type of polymer used [21] . The polmers thar are utilized for the manufacturing of nanofiber should have properties like large surface-area-to-volume ratio, high porosity, appreciable mechanical strength, and flexibility in naturen. [15],[27],[28].

Nanofiber can be obtained from many different methods electrospinning, self-assembly, template synthesis, and thermal-induced phase separation. Out of the different methods used electrospinning is found to be the most common one to produced nanofiber. Electrospinning is a very easy and most affordable method for generations of nanofiber because of easy to handle and it is capable of producing continuous nanofiber depending upon the polymer used. Moreover electrospinning has the capacity to produced ultrathin fibers in nanoscale diameter,

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compositions and orientations[15]. Because of this properties different structures of fiber can be made like hollow, flat, and the ribbon shaped which can be fabricated depending on the application and purpose of used.

Conclusion

The science of nanotechnology and its application can uplift the sericulture industry which is considered to be a cottage industry. Being a livelihood to millions of people in India, especially in Assam sericulture sector is still lagging in terms of production, productivity, and quality. But with the application of nanotechnology, this can be improved at a much faster rate than the conventional ones.

Future prospects

In order to comprehend the relationship between NPs and silkworms, more nanomaterials must be utilised to research the recovery impacts following an exposure of sick silkworms to nanoparticles**.**

Conflict of interest

The authors report there are no competing interests to declare.

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