CHAPTER II

Review of Literature:

2.1. Silk

According to the scientific definition of silk, the fluid proteins secreted by the silkworm caterpillar are silk [1, 2]. To prolong their lives, they consume their particular food plants and create cocoons, which also act as a protective shell for them [2, 3]. The four phases of silkworm are egg, caterpillar, pupa, and moth[4]. The process of unfolding the cocoons into a continuous strand and weaving results in the production of silk [4].

Silk is referred to as the ‘queen of textiles’ because of its shine, quality, soft touch, and glamour [5]. It is in demand for high-fashion clothing. Since insects produce silk fiber, it is an animal fiber. It is considered the only natural fiber made of protein found in filament form [6]. The mechanical properties of silk are strength, extendability, and compressibility [7, 8]. Silk is found to be useful in many applications because of its qualities like firmness, flexibility, softness, receptiveness to dyes, and adaptation to different forms of twisting [9, 10]. Due to these qualities, silk continues to be regarded as one of the premier textile materials [11]. Silk continues to reign supreme in the field of luxury clothes and a variety of other high-quality products, even though synthetic fibers are less difficult and less expensive to manufacture [11, 12]. In addition to its natural beauty, its incredible comfort in warm weather made it an ideal material for fashionable clothing [13]. Due to the aforementioned factors, researchers are curious about the synthetic production of silk fibers.

2.2. Sericulture

The rearing of silkworms for cocoon formation, that are the basic requirement for making silk, is termed sericulture [14]. It also includes the cultivation of plants for the silkworms to eat, which are further spun into cocoons, and the reeling of these cocoons to open the filaments for value addition such as processing and weaving. Archaeological evidence of silk dates to the Yangshao period, which lasted from 5000 to 10,000 BCE; however, Confucian texts from 2700 BCE are credited with the invention of silk manufacturing [15-18]. In the first half of the first century AD, it was already being practiced in ancient Khotan, and by 140 AD, it had made its way to India [13]. Later, it spread to countries in Europe, the Mediterranean, and other parts of Asia. As time went on, sericulture became a significant cottage industry in many countries, including China, Japan, India, Korea, Brazil, Russia, Italy, and France [13]. China and India are the largest producers of silk, accounting for 90 percent of the global supply [13, 19].

Sericulture in India, with manufacturing and trading, is considered to have begun in the 15th century [20]. India accounts for many species of silk moth fauna, making it one of the 34 mega bio-diversities worldwide. Along with tradition, Sericulture is also a living culture. It falls in both the cottage and small-scale sectors. Farmers, entrepreneurs, and artisans based in rural areas are ideally suited for this opportunity, as it offers high returns on modest investments [21]. It provides employment opportunities for farmers, small landowners, and marginalized and weaker sectors of society. In rural as well as semi-urban areas of India, the sericulture sector employs more than 8.7 million people. The success of the country's silk industry can be attributed in part to the local market, which is known for selling silk garments with distinctive regional designs. [21, 22].

Assam is regarded with pride in the northeastern Indian states for its long history of artistic handloom goods. This area is home to a remarkably diverse collection of tribal cultures [23, 24]. Assam is well known all over the world for its superior-quality silk production. Assam's tribal and non-tribal communities produce exquisite handwoven silk products that highlight people's creative ability and sensitivity to aesthetic beauty in color and design [24]. The textiles reflect the socio-cultural life of the communities. Traditional textiles made from these silks are renowned for their high level of craftsmanship, vivid color, and sturdiness [24]. Not only is sericulture suitable for use as a socioeconomic platform, but it also contributes to the improvement of the economies of weaker sections of society [25, 26].

2.3. Assam Silk: *Eri, Muga* and *Pat*

Silk is mainly divided into mulberry (*Pat*) and non-mulberry (*Eri, Muga*, etc.) [27]. Mulberry silk is the most popular and exclusively studied silk. India produces all the major commercial varieties of silk. Silk filament is known to consist of fibroin protein (72–81%) and sericin protein (19–28%) [28, 29]. For its shine, *Muga* silk, warm *Eri* silk, and white or off-white *Pat* silk, Assam holds a significant place in the world [30]. For decades, the entire region of North East India has relied on Assam's silk industry as a source of income [31]. The majority of Assam's silk output is exported, but it is also sold domestically and internationally [32]. When it comes to handloom weaving and the production of natural silk, Assam is the most prominent state in the country. Since the beginning of time, Assam has become well-known throughout the world for producing and manufacturing goods made of fine silk. Weavers are compelled to pay this money simply because they have no other option [33].

Eri is cultured, especially in Assam and its neighboring states. It has the insulating properties of *Eri* wool, making it special. Assam contributes to 65% of *Eri* production in India [34, 35], followed by Meghalaya and Nagaland in the northeastern region. The British referred to this silk as Palma Christi silk. Heavy garments known as "*Bor Kapoor*" were woven from *Eri* silk. *Eri* silkworms are multivoltine [36]. The cocoons produced by *Eri* silkworms are open-ended and are used for spinning purposes only [34, 37]. Cocoon filaments are typically not uniform or even, unlike *Pat* silk's continuous filament. *Eri* cultivation does not just involve the production of silk; it also involves the production of protein-rich pupae, which are considered a delicacy in the northeastern region of India [34, 36, 37].

Muga is specific to Assam and contributes 95% [38], which adds to its royalty and uniqueness. *Muga* has been associated with the state of Assam since ancient times, and it is now emerging as a trend in the world of fashion. Although it is unclear when *Muga* silk first appeared, a famous European traveler named Jean Joseph Travenier made the first official record of it by noting that "the silk is good, but the people produced little more than they require for use," with a special mention of Assam's *Muga* silkworm variety that endures on trees round the year and amazing items made by them back in 1662 [30, 39].

The *Pat* silk is ivory-white in color. *Pat* silk is produced mainly in Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, and Jammu and Kashmir, accounting for 92 percent of the country’s total production [40]. Assam and a few other states together contribute to the rest of the manufacture of *Pat* silk in India. Every Assamese bride would wear a traditional white *Pat Mekhela Chadar* to her wedding, as this is the dress that is considered to be the most auspicious for the occasion. At the time of metamorphosis, the *pat* silkworm tends to form an encasement to protect itself, which is called a cocoon [41].

2.4 Silk Status in India

The past 60 years have seen tremendous growth, both horizontally and vertically, in India's silk industry. The implementation of plans and programs by federal and state agencies, and the tireless efforts of thousands of dedicated individuals working in the fields of research and extension, have all contributed to this success [13].

Pat silk made up 73.97% (25,818 MT) of the 34,903 MT of raw silk made in India, *Tasar* silk made up 4.20% (1,466 MT), *Eri* silk made up 21.10% (7,364 MT), and *Muga* silk made up 0.73% (255 MT). Bivoltine has increased the amount of raw silk it makes by 17.07%, from 6,783 MT in 2020-21 to 7941 MT in 2021-22. The production of *Eri* and *Muga* silks increased in 2021–2022 over 2020–2021 by 6% and 6.7%, respectively [42].

Since yarn is typically produced in response to advance orders at a set price, there has been an unusually sudden increase in yarn prices, which has caused untold misery in the local industry. The weaver's income is ultimately squeezed throughout the entire process. The price of *Eri* yarn, as per the report of 2021-22 was Rs. 2500-2900 per kilogram. *Muga* raw silk yarn costs between Rs 19800-30000 per kilogram. *Pat* silk yarn costs approximately Rs. 4500-5000 per kilogram (2015-16) [43]. The price of raw silk from 2016-2022 is shown in Table 2.1.

Table 2.1: Price of Raw silk from 2016 to 2022 (source: SERICULTURAL STATISTICS IN INDIA - A GLANCE, 2022, Ministry of Textiles, GOI) [43]

Silk	Unit	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Raw *Eri*	Rs./Kg	1800-2600	2100-2700	2250-2800	2500-2900	2460-2800	2500-2900
Raw *Muga*	Rs./Kg	14200-18000	13000-22000	18000-25000	19400-25500	19800-26000	19800-30000
Raw *Pat*	Rs./Kg	2864	3500	3191	3026	2562	3421

Although India is the second-largest grower of raw silk in the world, it has a relatively small (4-5%) share of the global silk trade. This is because the domestic market in India is so large; it accounts for about 85% of the sales of all silk products worldwide. However, India ships out around 15% of its total silk output, including the value-added items. Indian silk products are mostly textiles, made-ups, and ready-to-wear, but they also include carpets, bedspreads, cushion covers, and other home decor items [44, 45]. The export of silk products has increased rapidly over the past decade, resulting in a sharp rise in export revenues. One of the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of Indian Silk suggests voids in technological shift and additional support as one of its major weaknesses [44].

Projects and research that are encouraged or already underway by the Ministry of Textiles, Government of India, as per the 2022-23 Annual Report, include the following: collaborative research projects to reinforce the genetic base and hybrid vigor; promotion of research and development to grow crop cycles; expansion of organized plantation of *Vanya* silks for orderly rearing; promotion of horizontal spread of sericulture in non-traditional regions, including the North-East, by means of a cluster approach [42]. The same report also encourages beneficiaries to have their soil tested and to receive a soil health card, use of chemical-free farming methods for silk variety *Vanya* silk, improve productivity and quality in the fabric manufacturing process by providing critical input support to beneficiaries [46]. Realization of added value through the use of un-used (pupa) as poultry feed [47, 48], Sericin in cosmetics, and product diversity into non-woven clothes, silk denim, silk knit, etc. [49, 50]; Increase private sector involvement in seed production and improve state-run seed multiplication programs [51]. But post-care or maintenance research or projects generally lagged behind. There are numerous studies going on to increase the manufacture of silk, but the importance of using non-mulberry silks in applications apart from textiles is not highlighted. There is much silk waste generated in the entire sericulture process that can also be used in other applications that need to be studied [52].

2.5 Silk care

Care labels instruct consumers and garment caretakers on the optimal cleaning procedures for a specific combination of fabric, thread, decoration, and construction techniques. Before being delivered to the market, silk production requires extensive processing, including dying and washing [53]. It is common knowledge that silk clothing is delicate when it comes to laundering and requires a scientific approach, the right procedure, and the right refurbishing techniques [54]. With proper care and protection from heat, sunlight, perspiration, washing, and harsh chemicals, silk will last for many years. Silk is a naturally robust fiber with a beautiful drape that is naturally resistant to creasing. Silk's weakness when wet necessitates gentle laundering because it loses its tensile strength when wet [55, 56]. Researchers have used a variety of cross-linkers to address the issue of wet crease recovery angle and shrinkage following laundering [57]. It has been reported that silk's easy care properties can be improved with the help of formaldehyde-based cross-linkers [58, 59]. Unfortunately, human exposure to formaldehyde can be harmful or even fatal [60]. As a result, zero formaldehyde cross-linkers are becoming more significant. Although butane tetracarboxylic acid (BTCA) had been suggested for use on silk, it was extremely pricey [61]. Methacrylamide had additionally been applied using the radiation grafting technique. Although this method improved the performance of silk fabrics, a significant drawback was the need for separate, infrequently used equipment [62]. Other unconventional chemical application techniques, such as ultraviolet curing [63], had also been reported for silk, but they were less well received by the traditional textile industry because they required specialized tools. Since silk is a natural fiber that does not harm the environment, researchers are putting more effort into developing environmentally friendly methods of treating it. Examples include enzymatic degumming [64] and dyeing silk with natural dyes [65, 66]. Loss of profit results from the product being rejected because of a processing-related defect. Other defects that may be the cause of rejection and return are dimensional instability by exhibiting reversible as well as irreversible shrinkage, or less commonly, expansion under certain conditions (when in contact with available moisture and/or high-temperature during washing, machine-dry, steaming, and ironing). Fabric contractions raise issues during garment manufacture or during succeeding washing by consumers [40]. Washing is a robust method as it requires physical force, warm water, and detergent [67, 68]. In addition to this, drying in a machine impacts the structural firmness of cloth as the material remains moist initially and later encounters agitation in a hot set-up [69]. The dimensional change related to laundering can be due to a number of causes. The major types of dimensional changes in fabrics [67]:

- Hygral expansion: A fabric's dimensions can change in a way called hygral expansion, which mainly happens when it absorbs moisture. It is possible for it to happen in either the warp or weft directions. wrinkling, pattern-piece mismatch, and the resulting changes in the cloth's overall look and fit, as well as bobble appearance in pleated panels and exfoliation of fusible inner linings, are all caused by hygral expansion.
- Relaxation shrinkage: All textiles are susceptible to relaxation shrinkage, an irreversible process that reduces their size. Fibers experience significant stresses from extension, twisting, and bending during weaving and finishing. The stress reduction manifests itself as a change in shape or shrinkage during the laundering process.
- Swelling Shrinkage: When water is absorbed or ejected from a material, it causes individual fibers to expand and contract width-wise. The overall mechanism of expansion is determined by the weave's tightness.
- Felting shrinkage: Water increases a fabric's propensity for its scales to interact with rough surfaces on nearby surfaces, which raises the frictional difference.

The low wet resiliency of silk makes it inconvenient to take care of. It is suggested that the absence of intermolecular chemical crosslinking makes it poor at wet resiliency. It has been mentioned that while washing, the fibers absorb water, leading to swelling that causes breakage of the salt linkages that connect the polymers, which was the reason for crease recovery [70]. There have been chemical finishing methods to deal with the issue, like graft-copolymerization, reactions with epoxides and dibasic anhydrides, etc., but these further complicate the normal wash and wear properties [71, 72]. Formaldehyde release was an important issue with the use of Amino formaldehyde resins in silk for crease-resistant finishing. Poly-carboxylic acids like citric acid or 1,2,3,4-butanetetra carboxylic acid have a high curing temperature that reaches up to 170°C to finish silk fabrics, which further might change its physicochemical and mechanical properties [73, 74].

Thus, felting is a result of the interaction between moisture, mechanical agitation, and heat during washing or laundering. When something shrinks, the area is reduced, and the fabric thickness is increased. Additionally, it causes alterations in the way the fabrics handle and their overall texture [67]. The required dimensional changes ought to be less than a predetermined maximum, predictable, and thus controllable [74]. To handle the stresses and modifications that have occurred during the manufacturing process and withstand the washing issues, distinct laundering techniques for particular fabrics need to be encouraged [75-77]. Detergents, conditioners, or commercially available agents for washing and traditionally used agents can be checked for challenging the post-laundering changes that occur in *Eri, Muga*, and *Pat.*

When drying care was required for silk fabrics, consumers frequently used sunlight [78]. However, due to the delicate nature of silk fiber, silk fabrics are prone to a number of issues during traditional home sunlight drying, including shrinkage, yellowing, wrinkling, and mechanical property deterioration [7, 78-80]. Conventional sunlight drying also has a number of other drawbacks, including a lengthy drying time, bacterial contamination, mildew growth (especially during the rainy season), susceptibility to weather changes, and UV radiation damage [78, 81]. Laundering and drying silk fabrics became a significant challenge as a result of daily use [78, 81].

2.6 Antimicrobial components in silk and dyeing

There have been contradictory reports regarding whether silk has natural antibacterial agents or if it actually supports bacterial growth [82]. In support, Royet et al. reported that silkworms produce effector proteins in their hemolymph that act as antimicrobials [83]. In order to protect the cocoons from micro-predators, seroins, and proteinase inhibitors are expressed in their glands [82]. A fungal protector (protease inhibitor) was also reported to be present in wild Indian *Tasar* silkworms [84]. In silkworms, *B. mori,* Moricin (antibacterial peptidein hemolymph) is reported to be present [85]. However, these suggest protection for the silkworm from microbes, but it isn’t clear if the same is passed to the cocoons and subsequently to the silk fabric. Contradictory to these studies, there have been reports that sericin aids the growth of *Escherichia coli*. Kaur et al. conducted extensive research to find a solution to the contradictory findings, and they dismissed all claims that the results had an antibacterial effect [82]. It was found that silk cocoons and individual components of silk cocoons show no antibacterial effect and, in some cases, enhance in its growth. Their study supports that a high pH or the remains of the chemicals used in silk processing might have acted as an antibacterial agent, resulting in misleading antibacterial test results [82].

Silk's rigid storage conditions prevent it from being used effectively because bacteria can easily attach to and grow on it, leading to deformation and even degradation. The presence of protein (as a nutrient), moisture, etc., platforms microbial growth and multiplication in silk fiber [86, 87]. This leads to fiber degradation, foul odors, discoloration, mildew formation, dermal infection, allergies, and related diseases [88, 89]. The wearer's health is adversely affected by all of these. There have been many works on the antimicrobial fictionalization of silk, like quaternary ammonium organosilanes, inorganic materials, antimicrobial peptides, etc., to tackle the problem of microbial attack [90]. The topological coating of silver nanoparticles blocks the growth of a particular type of bacteria (*Staphylococcus aureus*) [91, 92]. The presence of *S. aureus* makes the fabric surface appear pale [91].

2.7 Silk dyeing

Many different kinds of dyestuffs can be used to color silk in various ways. Almost any type of dye suitable for use with cotton or wool can also be used with silk [92]. The physical structure of the fiber also affects how readily dyes bind to a specific fiber structure. It has been found that silk contains regions with varying levels of molecular order and disorder, referred to as crystalline and amorphous regions, respectively [93] [94]. The groups -COOH and -NH 2 are those that are found in abundance and are ionized at a suitable pH [95]. Ionic or covalent bonds mediate the interaction between dye and fiber. The process of coloring silk is determined by free amino and carboxyl groups as well as phenolic groups with available –OH [96, 97]. Shade, brightness, and fastness grades are key considerations when selecting a color [98-100]. Dyestuffs colored with dyes that are acid and metal-complex have a stronger affinity for fiber, up taken quickly, and do not fade much in the wash, but their washing fastness is only fair. Reactive dyes provide excellent wash fastness and a wide variety of dischargeable colors that are also highly perspiration-fast [101, 102]. Due to the development of colored cations, which forbid the reaction with protonated amino groups when dyeing in an acidic bath, silk that has been basic dyed has low light fastness. The major structural characteristics of fibers that control their reactivity or dyeability and they must both be taken into account in any attempt to establish a correlation between fiber structure and dyeing behavior [103-105]:

1. permeability, or how easily dye molecules disperse into the fiber matrix;
2. the receptive functional groups in the fiber.

Natural dyes make quite vibrant hues on *Pat* silk, whereas *Tussar*, spun, and textured varieties are the only ones capable of producing deep tones. To make the color permanent, mordants are frequently required for these dyes [106, 107]. Even though some of the mordants are damaging to silk, some dyes have good lightfastness and washfastness [108, 109]. A complicated series of procedures is used to extract coloring matter from almost all parts of different plants, as well as from some insects and shellfish [110,111]. Turmeric, berberis, *Dolu* (yellow), *Annato* (orange), and *Henna* (brown) produce vibrant hues. Tannins, which act as a natural origin mordant, may be partially responsible for the substantivity of these dyes [112, 113].

There has been a one-step dyeing and finishing process where a specific dye is chosen that possesses the potential for antimicrobial activity, which saves time and energy, reduces cost, increases production and efficiency, and reduces effluent load. Natural dyes are considered better for possessing antimicrobial agents and exhibiting good biodegradability and compatibility with the environment [114-117]. *Cuminum cyminum L.*, also known as cumin seeds, were used to dye silk fabric, and pre-mordanting with tannic acid and metal salts like potassium aluminum sulphate, ferrous sulphate, copper sulphate, etc. resulted in intense hues with a wider range of yellow-brown tones and improved fastness [118, 119]. Also, the usual addition of colors into fabrics needs robust dyeing set-ups (e.g., high temperature and high pH), subsequently repeated washing to remove unbound dyes, which not only demand high water usage and energy but also damage the structures and thus the original properties of silk fibers [120, 121]. In this regard, it is very important to opt for natural dyes and dyeing methods that will be eco-friendly and, similarly, can meet the problem of microbial growth [111]. Using certain natural agents with anti-microbial activities can be an option for this. It is needed to study how natural dyes can be optimized to be comparable with any synthetic dye.

2.8 Biodegradation of Silk

It is important to know the status of silk in the environment before it breaks down. Hence, it is important to know how ecologically friendly silk is. Being a protein fiber, silk biodegrades over time in the environment [122, 123]. Interestingly, it takes time to degrade compared to the rest of the natural origin fibers [124, 125]. The crystallites of silk fabric are orderly situated in amorphous chain residues, whereas the amorphous area is defined by the presence of tyrosine and is thought to have distorted β-sheets, distorted β-turns, and α-helices conformations, loose structures that count on the elastic property of silk [126]. This complex structure is a big challenge to understanding the degradation pattern of fibroin. There were studies where measurable units were considered for the physical deterioration of silk, such as spectroscopic, chromatographic, and chemical aspects. It was seen that during the process of degradation, there is a distinct break in the amorphous region where the crystallites lose their strong link with the fiber axis, but it still remains intact till the last stage [126, 127]. The degradation pattern of natural silk is complex due to its complex and specific orderly structure. Silk fiber starts signs of biodegradation after approximately four years, however, it has been established that using enzymes (acidic) can accelerate it [128, 129]. It is essential to study the biodegradation methods of *Eri, Muga*, and *Pat* and also to know the impact of protease-producing bacteria during the process of both untreated silk and silk fabric treated with different agents.

2.9 Biocompatibility and uses of Silk

Increased environmental consciousness around the world has sparked a surge in research into biocomposites for use in a wide range of medical settings [130-133]. A preliminary demonstration of silk's biocompatibility is the first step toward transferring silk technologies from the laboratory setting into clinical practice [127]. Silk polymer's beneficial properties include its ability to promote tissue formation, biodegradability, hemocompatibility, cytocompatibility, and cell interactions. Many studies have focused on surface modification to increase silk fibroin's blood compatibility [134]. The molecular simplicity of silk fibroin's structure has frequently led to its classification as a "model biomaterial". In general, it has been referred to as a “clinically approved” biomaterial for human use, but the term biocompatibility needs to be application-specific

[135, 136]. Clinical approval is widespread for the use of silk in load-bearing applications, such as the knitted surgical mesh made from Bombyx mori silk fibers (degummed), silk sutures, and silk garments used to treat dermatological conditions [127, 137]. Biocompatibility evaluation is an essential part of any process involving novel silk formats (hydrogels, nanoparticles, films, etc.) or the use of uncommon silks to touch unexplored areas of clinical need or even the application of any existing technology [138]. In a straightforward in vivo comparison of silk against other natural (collagen) and synthetic (polylactic acid) biomaterials, it was proven that *B.mori* silk fibroin matches the synthetic counterpart and shows better results than other natural biomaterials [139]. More biocompatibility studies on silk are needed to support the new medical developments [140]. Deducing results from macroscopic films to nanoscale particles isn't always valid in biological performances, and so, for any such tests as intravenous administrations of drugs through silk, hemocompatibility assessment is required [141, 142]. The association between silk and biocompatibility in humans started with silk sutures, which have been in use for several centuries, and the market launch of SERI Surgical Scaffold after attaining clearance by the FDA [143, 144]. When it comes to using implantable materials like artificial blood vessels and orthopedic implants, hemocompatibility is a very important consideration that needs to be taken into account [145, 146]. It is important to improve hemocompatibility while developing materials that are in contact with blood [147]. When blood comes into contact with a foreign body, it starts the competitive adsorption of plasma proteins [148]. The effectiveness of using silk fibroin (SF) films in the skin regeneration procedure using rabbits and pigs as animal models was reported [149]. This study highlights the remarkable biocompatibility and effectiveness of SF as a biomaterial. The sericin of the silkworm Bombyx mori inhibits lipid peroxidation and tyrosinase activity[150]. As an antioxidant, it can protect the cocoon and silkworm from oxidative stress [151]. The free radicals hydroxyl, superoxide, and 2-diphenyl-1-picrylhydrazyl (DPPH) are all successfully inhibited by sericin. Sericin from Bombyx mori has a powerful chelating and reducing effect on ferrous ions, establishing it as a natural antioxidant [47, 152]. Sericin's physicochemical properties make it a potential biocompatible substance for future use in a variety of biomedical fields [153]. According to reports, sericin possesses a vast array of biological properties, including anti-oxidation, anti-bacterial, anti-coagulation, and promotion of cell growth and differentiation [154].

Sericin is frequently copolymerized, crosslinked, or combined with other polymers to create scaffolds in the field of regenerative medicine due to its biodegradability, accessibility, and hydrophilicity [150].

2.10 Applications

Apart from textiles, silk is known to have many applications, which is increasing its demand. Silk is a widely accessible, biocompatible, and ecologically supportable natural material [129]. Silk technology and design have a lot of room to grow in areas like "smart" clothing and cutting-edge performance garments. Innovative textiles enhanced with senses other than vision are on the horizon [155]. In the coming decades, research and development could revolutionize the silk industry by creating silks that are cooling, scented, and mosquito-repellent[114]. Because of its unique biocompatibility, biodegradability, and mechanical properties, silk has been used in a wide variety of applications, including structural composites, tissue engineering, drug delivery systems, and sensing technologies [135]. However, raw silk is not useful and must be functionalized or surface-modified to improve properties and stability before it can be put to good use. Suturing, the process of stitching wounds, is a process where silk has dominated for centuries [156].

There are silk nano-fiber air filters that exhibit superior filtration [129, 157]. Silk paper was used to filter bacteria-contaminated solution. It was found that the bacteria remained as residues on the surface of the paper. Thus, it implies that silk paper can be a micro-filter [158]. There are reports where fibroin is used for optics and sensing because it has mechanical strength, low weight, biocompatibility, and bio-restorability. These are useful in bio instrumentation, pharmaceutics, medical diagnostics, and therapeutic applications [117]. Most notably, fibroin has been developed as waveguides (i.e., optical fibers), diffraction gratings, lens arrays, electrical sensors, oxygen sensors, pH sensors, glucose sensors, food sensors, etc. [117]. Sericin from silk is a well-known biocompatible and biodegradable substance. Due to additional properties such as gelatinizing, moisture holding, and skin adhesion, it has a wide range of uses in the medical, pharmaceutical, and cosmetics industries [159]. Cosmetics for the skin, hair, and nails contain sericin alone or in combination with silk fibroin [160]. Sericin's anti-aging, anti-wrinkle, and skin-tightening effects are most noticeable when applied topically in the form of a lotion, cream, or ointment [161]. Sericin gel maintains the skin's moisture well, as demonstrated by the hydroxyproline assay, impedance measurement, and trans-epidermal water loss (TEWL) test [162]. It is believed that silk will have a variety of a range of new functions that will contribute as a natural replacement for many synthetic substances and open up prospects for many novel applications [117].

2.11 References

[1] Hardy, J. G., Römer, L. M., and Scheibel, T. Polymeric materials based on silk proteins. *Polymer*, 49(20): 4309-4327, 2008.

[2] Mondal, M., Trivedy, K., and NIRMAL, K. The silk proteins, sericin and fibroin in silkworm, Bombyx mori Linn.,-a review. *Caspian J. Env. Sci.* 2007.

[3] Danks, H. Modification of adverse conditions by insects. *Oikos*, 99(1): 10-24, 2002.

[4] Ikeya, Y., Wakkary, R., and Barati, B. Metamorphonic: A Reflective Design Inquiry into Human-Silkworm Relationship. in *Proceedings of the 2023 ACM Designing Interactive Systems Conference.* 808-819.

[5] Savithri, G., Sujathamma, P., Ramanamma, C. Glory of Indian traditional silk sarees. *International Journal of Textile and Fashion Technology*, 3(2): 61-68, 2013.

[6] Ghosh, S. K., Das, A. B., Bhattacharyya, R. Care label issues of silk fabric. *International Journal of Research in Engineering and Technology*, 3(07): 176-179, 2014.

[7] Ma, M., You, L., Chen, L., and Zhou, W. Effects of ultrasonic laundering on the properties of silk fabrics. *Textile Research Journal*, 84(20): 2166-2174, 2014.

[8] Reddy, N., Warner, K., Yang, Y. Low-temperature wet-cross-linking of silk with citric acid. *Industrial & Engineering Chemistry Research*, 50(8): 4458-4463, 2011.

[9] Buchanan, R. *A Weaver's Garden: growing plants for natural dyes and fibers*. Courier Corporation, 1999.

[10] Panda, H. *The Complete Book on Textile Processing and Silk Reeling Technology: Silk Reeling, Silk Reeling Methods, Silk Reeling Process, Sericulture, Textile Processing and Silk Reeling, Silk Reeling Industry, Sericulture Industry in India, Silk Textile Industry, Silk Reeling Machine, Profits in Silk Reeling, Silk Reeling Unit, Silk as Textile Fibre, Fabric Varieties, Chemical Modification of Textile Celluloses, Silk Reeling Technology*. Asia Pacific Business Press Inc., 2010.

[11] Babu, K. Natural textile fibres: Animal and silk fibres. In, *Textiles and fashion*, of, pages 57-78. Elsevier, 2015.

[12] Franck, R. R. *Silk, mohair, cashmere and other luxury fibres*. Elsevier, 2001.

[13] Datta, R. K. and Nanavaty, M. *Global silk industry: a complete source book*. Universal-Publishers, 2005.

[14] Yamada, H., Nakao, H., Takasu, Y., Tsubouchi, K. Preparation of undegraded native molecular fibroin solution from silkworm cocoons. *Materials Science and Engineering: C*, 14(1-2): 41-46, 2001.

[15] Konda, J. Sericulture Mulberry Cultivation. *Krishi Udyan Darpan*, 1.

[16] Tanner, H. M. *China: A History (Volume 1): From Neolithic Cultures through the Great Qing Empire,(10,000 BCE-1799 CE)*. Hackett Publishing, 2010.

[17] Zhang, Q. *An introduction to Chinese history and culture*. Springer, 2015.

[18] Krosinsky, C., McDermott, M., Krosinsky, C., and Zhong, H. Understanding Chinese History: A Brief Look at China from Its Origins Through the 1700s. *Modern China: Financial Cooperation for Solving Sustainability Challenges,* 65-74, 2020.

[19] Anitha, R. Indian silk industry in the global scenario. *International Journal of Multidisciplinary management studies*1(3): 100-110, 2011.

[20] Nimgare, S., Fule, U., and Telkhade, P. Present status and future of sericulture in Maharashtra State, India. *Int J Res Biosci Agricult Technol*, 5(1): 41-43, 2017.

[21] Sharma, K., Kapoor, B. Sericulture as a profit-based industry—a review. *Indian Journal of Pure and Applied Biosciences*, 8(4): 550-562, 2020.

[22] Thakur, J. and Bali, R. Innovations for reviving sericulture in Jammu and Kashmir. *The Pharma Innovation Journal*, 11(7): 1126-1131, 2022.

[23] SAIKIA, R. Handloom Silk Textile”-A Path To The Development Of People In Assam: In Reference To Sualkuchi ‘Manchester Of Assam. *Think India Journal*, 22(4): 4889-4900, 2019.

[24] Dutta, M., Borah, M. P., Kalita, A., Bhuyan, A., and Goswami, M. Cross Sectional Analysis of Domestic Weavers of Assam. 2022.

[25] Gogoi, B. Soil productivity management and socio-economic development through agroforestry in north-east India. *Asian Journal of Science and Technology*, 6: 2048-2053, 2015.

[26] Saikia, A. A. and Goswami, C. Promoting Sustainable Rural Development in Assam through Rural Tourism: Opportunities.

[27] Chakravorty, R., Dutta, P., and Ghose, J. Sericulture and traditional craft of silk weaving in Assam, Indian Journal of Traditional Knowledge, 2010

[28] Naskar, D., Barua, R., Ghosh, A., and Kundu, S. Introduction to silk biomaterials. In, *Silk biomaterials for tissue engineering and regenerative medicine*, 3-40. Elsevier, 2014.

[29] Joshi, M., Purwar, R., Ali, S. W., Rajendran, S. Antimicrobial textiles for health and hygiene applications based on eco-friendly natural products. *Medical and Healthcare Textiles*, 84-92, 2010.

[30] Mahan, B. Silk industry among the Tai-Ahom of Assam, India as an attraction of tourist. *International Journal of Scientific and Research Publications*, 2(12): 1-4, 2012.

[31] Kalita, S. A journey of empowering a community for self reliance: Endogenous tourism project in Sualkuchi, Assam, India. *Field Actions Science Reports. The Journal of Field Actions*, 4, 2010.

[32] Barua, R., Banik, G. A Theoretical Review on the Status and Trend of Exports (Goods and Services) and Investments (Foreign and Domestic) in Assam and North-East India and their Untapped Impact on the Economic Growth of the Region: The Story so far. *Journal of Management and Science*, 3(3): 356-377, 2013.

[33] Khakhlari, P. Silk products and marketing strategy of a weaving industry in Assam. *Humanities & Social Sciences Reviews, GIAP Journals*, 14, 2020.

[34] Babu, K. Silk production and the future of natural silk manufacture. In, *Handbook of natural fibres*, pages 3-29. Elsevier, 2012.

[35] Kalita, T., and Dutta, K. Biodiversity of Sericigenous insects in Assam and their role in employment generation. *Journal of entomology and zoology studies*, 2(5): 119-125, 2014.

[36] Choudhary, H. Reviving the Magic of Silk for Beauty and Health. *International Journal of Research in Engineering and Applied Sciences*, 6(4): 77-86, 2016.

[37] Tamta, M. and Mahajan, S. The novel silk fiber: Eri. *International Journal of Home Science* 7(1): 101-104, 2021.

[38] Goswami, D., Rabha, B., and Veer, V. Muga Silk-The Golden Thread of Assam. *Bioprospecting of Indigenous Bioresources of North-East India*, 279-294, 2016.

[39] Gogoi, M., Gogoi, A., and Baruah, B. Exotic muga silk: pride of Assam. *International Journal of Applied Home Science*, 4(1): 72-78, 2017.

[40] Kumaresan, P., Devi, R. G. G., and Kamble, C. Determinants of mulberry silk cocoon quality. *IUP Journal of Agricultural Economics*, 7(1/2): 20, 2010.

[41] Zhu, B., Wang, H., Leow, W. R., Cai, Y., Loh, X. J., Han, M. Y., and Chen, X. Silk fibroin for flexible electronic devices. *Advanced Materials*, 28(22): 4250-4265, 2016.

[42] India, M. *Annual Report 2022-23*. Retrieved on from https://www.texmin.nic.in/sites/default/files/English%20Final%20MOT%20Annual%20Report%202022-23%20%28English%29_0.pdf, 2023.

[43] India, M. *Textile Data*. Retrieved on from https://texmin.nic.in/textile-data, 2023.

[44] Bharathi, D. Sericulture industry in India-A source of employment generation. *International Journal of Advanced Engineering Research and Science*, 3(10): 236881, 2016.

[45] Teli, M. Textile coloration industry in India. *Coloration Technology*, 124(1): 1-13, 2008.

[46] Prakash, Y., Charwak, B., Kumar, P. Textile industry in new India: challenges and opportunities. *International Journal of Indian Culture and Business Management*, 21(4): 435-458, 2020.

[47] Jaiswal, K. K., Banerjee, I., and Mayookha, V. Recent trends in the development and diversification of sericulture natural products for innovative and sustainable applications. *Bioresource Technology Reports*, 13: 100614, 2021.

[48] Reddy, P. M., Kumar, M. Value Added Products of Tasar Silkworm Cocoon by Utilization. *International Journal of Science and Research*, 3(9): 155-157, 2014.

[49] Bandyopadhyay, A., Chowdhury, S. K., Dey, S., Moses, J. C., and Mandal, B. Silk: A promising biomaterial opening new vistas towards affordable healthcare solutions. *Journal of the Indian Institute of Science*, 99(3): 445-487, 2019.

[50] Sehnal, F. Biotechnologies based on silk. *Insect biotechnology*, 211-224, 2011.

[51] Amarnath, S., Sathyanarayana, K., Khanna, R. Tasar Silkworm Seed Production in Private Sector under Special SGSY Projects in Bihar and Jharkhand-A Breakthrough. *Black, Caspian Seas and Central Asia Silk Association (BACSA) www. bacsa-silk. org*,204, 2007.

[52] Manjunath, R., Kumar, A., Arun Kumar, K. Utilisation of sericulture waste by employing possible approaches. *Contaminants in Agriculture: Sources, Impacts and Management*, 385-398, 2020.

[53] Li, L. *Silk solution processing automation*, Doctoral dissertation, Tufts University, (2011).

[54] Padaki, N., Das, B., Basu, A. Advances in understanding the properties of silk. *Advances in silk science and technology*, 3-16, 2015.

[55] Lau, L. and Fan, J. Laundry performance of fabrics and garments. *Eng. Appar. Fabr. Garments*, 1: 339-360, 2009.

[56] Krishnamoorthi, K., Jagannathan, S. Study on the Effects of Perfume on the Mechanical and Colour Propertiesof Silk Fabrics. *Fibres & Textiles in Eastern Europe,* 2017.

[57] Raza, Z. A., Anwar, F. Low-formaldehyde hydrophobic cum crease resistant finishing of woven silk fabric. *Fibres & Textiles in Eastern Europe*, (6 (114): 116-119, 2015.

[58] Xin, J. and Lu, H. Easy-care treatments for fabrics and garments. In, *Engineering of high-performance textiles*, of, pages 187-215. Elsevier, 2018.

[59] Yang, Y. and Li, S. Crease-proofing silk. Textile Asia, 23(7), 72-75 1992.

[60] De Groot, A., White, I. R., Flyvholm, M. A., Lensen, G., and Coenraads, P. Formaldehyde-releasers in cosmetics: relationship to formaldehyde contact allergy: Part 2. Patch test relationship to formaldehyde contact allergy, experimentalprovocation tests, amount of formaldehyde released, and assessment of risk to consumers allergic to formaldehyde. *Contact Dermatitis*, 62(1): 18-31, 2010.

[61] Yang, Y., Li, S. Crease Resistant Finishing of Silk Fabric with BTCA. *Textile Chemist & Colorist*, 26(5), 1994.

[62] Liu, J., Shao, J., and Zheng, J. Radiation grafting/crosslinking of silk using electron-beam irradiation. *Journal of applied polymer science*, 91(3): 2028-2034, 2004.

[63] Periolatto, M., Ferrero, F., and Vineis, C. Antimicrobial chitosan finish of cotton and silk fabrics by UV-curing with 2-hydroxy-2-methylphenylpropane-1-one. *Carbohydrate Polymers*, 88(1): 201-205, 2012.

[64] More, S., Khandelwal, H., Joseph, M., and Laxman, R. Enzymatic degumming of silk with microbial proteases. *Journal of natural fibers*, 10(2): 98-111, 2013.

[65] Narayanaswamy, V., Ninge Gowda, K., and Sudhakar, R. Dyeing and color fastness of natural dye from Psidium guajuva on silk. *Journal of Natural Fibers*, 10(3): 257-270, 2013.

[66] Shukla, D. and Vankar, P. Natural dyeing with black carrot: New source for newer shades on silk. *Journal of natural fibers*, 10(3): 207-218, 2013.

[67] Ng, S., Hui, C. Dimensional stability of fabrics: Resistance to shrinkage and other dimensional changes. *Understanding and improving the durability of textiles. Cambridge, UK: Woodhead publishing*, 59-69, 2012.

[68] Lynn, J. L., Nguyen, T. Detergents and detergency. *Bailey's Industrial Oil and Fat Products*, 1-46, 2005.

[69] Anand, S., Brown, K., Higgins, L., Holmes, D., Hall, M. Effect of laundering on the dimensional stability and distortion of knitted fabrics. *Autex Research Journal*, 2(2), 2002.

[70] Hu, C. and Jin, Y. Wash-and-wear finishing of silk fabrics with a water-soluble polyurethane. *Textile research journal*, 72(11): 1009-1012, 2002.

[71] Mori, H. and Tsukada, M. New silk protein: modification of silk protein by gene engineering for production of biomaterials. *Reviews in Molecular Biotechnology*, 74(2): 95-103, 2000.

[72] Choudhury, A. Advances in the finishing of silk fabrics. In, *Advances in silk science and technology*, of, pages 81-110. Elsevier, 2015.

[73] Shirvan, A. R., Shakeri, M., Bashari, A. Recent advances in application of chitosan and its derivatives in functional finishing of textiles. *The impact and prospects of green chemistry for textile technology*, 107-133, 2019.

[74] Shahid, M. and Mohammad, F. Recent advancements in natural dye applications: a review. *Journal of cleaner production*, 53: 310-331, 2013.

[75] uz Zaman, S., Tao, X., Cochrane, C., Koncar, V. Launderability of conductive polymer yarns used for connections of e-textile modules: Mechanical stresses. *Fibers and Polymers*, 20: 2355-2366, 2019.

[76] Bhattacharjee, S., Joshi, R., Chughtai, A. A., and Macintyre, C. Graphene modified multifunctional personal protective clothing. *Advanced materials interfaces*, 6(21): 1900622, 2019.

[77] Bishop, D. Physical and chemical effects of domestic laundering processes. In, *Chemistry of the textiles industry*, of, pages 125-172. Springer, 1995.

[78] Yao, Y., Tang, B., Chen, W., Sun, L., and Wang, X. Sunlight-induced coloration of silk. *Nanoscale research letters*, 11: 1-9, 2016.

[79] Helliker, M., Carr, D., Lankester, C., Fenton, L., Girvan, L., and Horsfall, I. Effect of domestic laundering on the fragment protective performance of fabrics used in personal protection. *Textile research journal*, 84(12): 1298-1306, 2014.

[80] Hipparagi, S. A., Srinivasa, T., Das, B., Naik, S. V., and Purushotham, S. Studies on application of aroma finish on silk fabric. *Journal of the Institution of Engineers (India): Series E*, 97(2): 159-165, 2016.

[81] Hino, T., Tanimoto, M., Shimabayashi, S. Change in secondary structure of silk fibroin during preparation of its microspheres by spray-drying and exposure to humid atmosphere. *Journal of colloid and interface science*, 266(1): 68-73, 2003.

[82] Kaur, J., Rajkhowa, R., Afrin, T., Tsuzuki, T., and Wang, X. Facts and myths of antibacterial properties of silk. *Biopolymers*, 101(3): 237-245, 2014.

[83] Royet, J. and Dziarski, R. Peptidoglycan recognition proteins: pleiotropic sensors and effectors of antimicrobial defences. *Nature Reviews Microbiology*, 5(4): 264-277, 2007.

[84] Shrivastava, B., Ghosh, A. Protein purification, cDNA cloning and characterization of a protease inhibitor from the Indian tasar silkworm, Antheraea mylitta. *Insect biochemistry and molecular biology*, 33(10): 1025-1033, 2003.

[85] Hara, S. and Yamakawa, M. Moricin, a novel type of antibacterial peptide isolated from the Silkworm, Bombyx mori (∗). *Journal of Biological Chemistry*, 270(50): 29923-29927, 1995.

[86] Lu, Z., Meng, M., Jiang, Y., Xie, J. UV-assisted in situ synthesis of silver nanoparticles on silk fibers for antibacterial applications. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 447: 1-7, 2014.

[87] Duan, H., Li, J., Bai, S., and Qi, D. Preparation of durable multi-functional coating silk fabrics with persistent fragrance release, antibacterial, fluoride-free superhydrophobic and self-cleaning properties. *Surface and Coatings Technology*, 443: 128583, 2022.

[88] Gao, Y. and Cranston, R. Recent advances in antimicrobial treatments of textiles. *Textile research journal*, 78(1): 60-72, 2008.

[89] Zhou, Y., Zhang, J., Tang, R.-C., Zhang, J. Simultaneous dyeing and functionalization of silk with three natural yellow dyes. *Industrial crops and products*, 64: 224-232, 2015.

[90] Heine, E., Knops, H., Schaefer, K., Vangeyte, P., Moeller, M. Antimicrobial functionalisation of textile materials. *Multifunctional Barriers for Flexible Structure: Textile, Leather and Paper*, 23-38, 2007.

[91] Jiang, S., Yuen, C., Zhang, L., Guo, R., Choi, P. Characteristics of silver-plated silk fabric with plasma pre-treatment. *Fibers and Polymers*, 10: 791-796, 2009.

[92] Tansil, N. C., Koh, L. D., and Han, M. Functional silk: colored and luminescent. *Advanced materials*, 24(11): 1388-1397, 2012.

[93] Gulrajani, M. Degumming of silk. *Review of Progress in Coloration and Related Topics*, 22(1): 79-89, 1992.

[94] Guan, J., Wang, Y., Mortimer, B., Holland, C., Shao, Z., Porter, D., and Vollrath, F. Glass transitions in native silk fibres studied by dynamic mechanical thermal analysis. *Soft Matter*, 12(27): 5926-5936, 2016.

[95] Rujiravanit, R., Kruaykitanon, S., Jamieson, A. M., and Tokura, S. Preparation of crosslinked chitosan/silk fibroin blend films for drug delivery system. *Macromolecular Bioscience*, 3(10): 604-611, 2003.

[96] Teli, M., Pandit, P., Samanta, K. K., Basak, S., and Gayatri, T. Salt-free and low temperature colouration of silk using He–N2 non-thermal plasma irradiation. *Journal of Cleaner Production*, 296: 126576, 2021.

[97] Rehman, R., Mahmud, S., Habib, M. A., and Islam, A. A revolution of silk dyeing with FL based cotton-reactive dyes. *International Journal of Textile Science*, 4(2): 42-52, 2015.

[98] Chattopadhyay, S., Pan, N., Roy, A., Saxena, S., and Khan, A. Development of natural dyed jute fabric with improved colour yield and UV protection characteristics. *Journal of the textile Institute*, 104(8): 808-818, 2013.

[99] Gulrajani, M. L. *Colour measurement: principles, advances and industrial applications*. Elsevier, 2010.

[100] Vankar, P. Structure-mordant interaction, replacement by biomordants and enzymes. *Natural dyes for textiles: Sources, chemistry and applications*, 89-102, 2017.

[101] Maradiya, H. R. and Patel, V. Synthesis and dyeing performance of some novel heterocyclic azo disperse dyes. *Journal of the Brazilian Chemical Society*, 12: 710-714, 2001.

[102] Maradiya, H. R., Patel, V. Dyeing performance of disperse dyes based on 2-aminothiazole for cellulose triacetate and nylon fibers. *Fibers and Polymers*, 3: 43-48, 2002.

[103] Chakraborty, J. Metal-complex dyes. In, *Handbook of textile and industrial dyeing*, of, pages 446-465. Elsevier, 2011.

[104] Mansour, H. Textile dyeing: Environmental friendly Osage orange extract on protein fabrics. *Eco-Friendly Textile Dyeing and Finishing*, 207-231, 2013.

[105] Kiernan, J. Classification and naming of dyes, stains and fluorochromes. *Biotechnic & histochemistry*, 76(5-6): 261-278, 2001.

[106] Yu, S., Xu, D., Zhang, X., Yu, T., Liu, Y., Wang, X., and Li, N. Development of dyeing mechanism of wood with reactive dyes. in *2015 International Symposium on Energy Science and Chemical Engineering.* 141-144 (Atlantis Press).

[107] Wardle, T. *The Wild Silks of India, Principally Tusser*. HM Stationery Office, 1880.

[108] Prabhu, K., Teli, M., Waghmare, N. Eco-friendly dyeing using natural mordant extracted from Emblica officinalis G. Fruit on cotton and silk fabrics with antibacterial activity. *Fibers and Polymers*, 12: 753-759, 2011.

[109] Samanta, A. K. and Konar, A. Dyeing of textiles with natural dyes. *Natural dyes*, 3(30-56), 2011.

[110] Gokhale, S., Tatiya, A., Bakliwal, S., and Fursule, R. Natural dye yielding plants. 2004.

[111] Saxena, S. and Raja, A. Natural dyes: sources, chemistry, application and sustainability issues. In, *Roadmap to sustainable textiles and clothing: eco-friendly raw materials, technologies, and processing methods*, of, pages 37-80. Springer, 2014.

[112] Ebrahim, S. A., Mosaad, M. M., Othman, H., Hassabo, A. A valuable observation of eco-friendly natural dyes for valuable utilisation in the textile industry. *Journal of Textiles, Coloration and Polymer Science*, 19(1): 25-37, 2022.

[113] Patel, B. Natural dyes. In, *Handbook of textile and industrial dyeing*, of, pages 395-424. Elsevier, 2011.

[114] Babu, K. M. *Silk: processing, properties and applications*. Woodhead Publishing, 2018.

[115] Khatri, A., Peerzada, M. H., Mohsin, M., and White, M. A review on developments in dyeing cotton fabrics with reactive dyes for reducing effluent pollution. *Journal of Cleaner Production*, 87: 50-57, 2015.

[116] Periyasamy, A. P., Militky, J. Sustainability in textile dyeing: recent developments. *Sustainability in the textile and apparel industries: Production Process Sustainability*,37-79, 2020.

[117] Koh, L.-D., Cheng, Y., Teng, C.-P., Khin, Y.-W., Loh, X.-J., Tee, S.-Y., Low, M., Ye, E., Yu, H.-D., and Zhang, Y. Structures, mechanical properties and applications of silk fibroin materials. *Progress in Polymer Science*, 46: 86-110, 2015.

[118] Tayade, P. B. and Adivarekar, R. Dyeing of silk fabric with Cuminum Cyminum L as a source of natural dye. *International Journal of ChemTech Research*, 5(2): 699-706, 2013.

[119] Teli, M. Advances in the dyeing and printing of silk. In, *Advances in silk science and technology*, of, pages 55-79. Elsevier, 2015.

[120] Shamey, R. and Hussein, T. Critical solutions in the dyeing of cotton textile materials. *Textile Progress*, 37(1-2): 1-84, 2005.

[121] Szostak-Kotowa, J. Biodeterioration of textiles. *International Biodeterioration & Biodegradation*, 53(3): 165-170, 2004.

[122] Aramwit, P., Siritientong, T., Srichana, T. Potential applications of silk sericin, a natural protein from textile industry by-products. *Waste Management & Research*, 30(3): 217-224, 2012.

[123] Cheung, H.-y., Ho, M.-p., Lau, K.-t., Cardona, F., and Hui, D. Natural fibre-reinforced composites for bioengineering and environmental engineering applications. *Composites Part B: Engineering*, 40(7): 655-663, 2009.

[124] Warnock, M., Davis, K., Wolf, D., and Gbur, E. Biodegradation of three cellulosic fabrics in soil. *Summ Ark Cotton Res*, 2009: 208-211, 2009.

[125] Garside, P. and Wyeth, P. Crystallinity and degradation of silk: correlations between analytical signatures and physical condition on ageing. *Applied Physics A*, 89: 871-876, 2007.

[126] Li, M.-Y., Zhao, Y., Tong, T., Hou, X.-H., Fang, B.-S., Wu, S.-Q., Shen, X.-Y., Tong, H. Study of the degradation mechanism of Chinese historic silk (Bombyx mori) for the purpose of conservation. *Polymer degradation and stability*, 98(3): 727-735, 2013.

[127] Holland, C., Numata, K., Rnjak-Kovacina, J., and Seib, F. The biomedical use of silk: past, present, future. *Advanced healthcare materials*, 8(1): 1800465, 2019.

[128] Gutarowska, B. and Michalski, A. *Microbial degradation of woven fabrics and protection against biodegradation*. chapter, 2012.

[129] Wang, C., Wu, S., Jian, M., Xie, J., Xu, L., Yang, X., Zheng, Q., and Zhang, Y. Silk nanofibers as high efficient and lightweight air filter. *Nano Research,* 9: 2590-2597, 2016.

[130] Aramwit, P. Introduction to biomaterials for wound healing. In, *Wound healing biomaterials*, of, pages 3-38. Elsevier, 2016.

[131] Lamboni, L., Li, Y., Liu, J., and Yang, G. J. B. Silk sericin-functionalized bacterial cellulose as a potential wound-healing biomaterial. *Biomacromolecules*, 17(9): 3076-3084, 2016.

[132] Napavichayanun, S., Bonani, W., Yang, Y., Motta, A., and Aramwit, P. Fibroin and polyvinyl alcohol hydrogel wound dressing containing silk sericin prepared using high-pressure carbon dioxide. *Advances in Wound Care*, 8(9): 452-462, 2019.

[133] Ramachandran, C., Gupta, P., Hazra, S., Mandal, B. In vitro culture of human corneal endothelium on non-mulberry silk fibroin films for tissue regeneration. *Translational Vision Science & Technology*, 9(4): 12-12, 2020.

[134] Wang, D., Liu, H., Fan, Y. Silk fibroin for vascular regeneration. *Microscopy research and technique*, 80(3): 280-290, 2017.

[135] Kundu, B., Kurland, N. E., Bano, S., Patra, C., Engel, F. B., Yadavalli, V. K., and Kundu, S. Silk proteins for biomedical applications: Bioengineering perspectives. *Progress in polymer science*, 39(2): 251-267, 2014.

[136] Adalı, T. and Uncu, M. Silk fibroin as a non-thrombogenic biomaterial. *International journal of biological macromolecules*, 90: 11-19, 2016.

[137] Ricci, G., Patrizi, A., Bendandi, B., Menna, G., Varotti, E., and Masi, M. Clinical effectiveness of a silk fabric in the treatment of atopic dermatitis. *British Journal of Dermatology*, 150(1): 127-131, 2004.

[138] Koh, L.-D., Yeo, J., Lee, Y. Y., Ong, Q., Han, M., Tee, B. Advancing the frontiers of silk fibroin protein-based materials for futuristic electronics and clinical wound-healing (Invited review). *Materials Science and Engineering: C*, 86: 151-172, 2018.

[139] Thurber, A. E., Omenetto, F. G., and Kaplan, D. In vivo bioresponses to silk proteins. *Biomaterials*, 71: 145-157, 2015.

[140] Li, G., Li, Y., Chen, G., He, J., Han, Y., Wang, X., and Kaplan, D. Silk-based biomaterials in biomedical textiles and fiber-based implants. *Advanced healthcare materials*, 4(8): 1134-1151, 2015.

[141] Tran, S. H., Wilson, C. G., and Seib, F. A review of the emerging role of silk for the treatment of the eye. *Pharmaceutical research*, 35: 1-16, 2018.

[142] Deptuch, T., Penderecka, K., Kaczmarek, M., Molenda, S., and Dams-Kozlowska, H. In vivo study of the immune response to bioengineered spider silk spheres. *Scientific Reports*, 12(1): 13480, 2022.

[143] Bucciarelli, A. and Motta, A. Use of Bombyx mori silk fibroin in tissue engineering: From cocoons to medical devices, challenges, and future perspectives. *Biomaterials Advances*, 139: 212982, 2022.

[144] Janani, G., Kumar, M., Chouhan, D., Moses, J. C., Gangrade, A., Bhattacharjee, S., and Mandal, B. Insight into silk-based biomaterials: From physicochemical attributes to recent biomedical applications. *ACS Applied Bio Materials*, 2(12): 5460-5491, 2019.

[145] Tathe, A., Ghodke, M., Nikalje, A. A brief review: biomaterials and their application. *Int. J. Pharm. Pharm. Sci*, 2(4): 19-23, 2010.

[146] Sharma, B., Sharma, S., and Jain, P. Leveraging advances in chemistry to design biodegradable polymeric implants using chitosan and other biomaterials. *International journal of biological macromolecules*, 169: 414-427, 2021.

[147] Elahi, M. F., Guan, G., and Wang, L. Hemocompatibility of surface modified silk fibroin materials: a review. *Rev Adv Mater Sci*, 38(2): 148-159, 2014.

[148] Weber, M., Steinle, H., Golombek, S., Hann, L., Schlensak, C., Wendel, H. P., Avci-Adali, M. Blood-contacting biomaterials: in vitro evaluation of the hemocompatibility. *Frontiers in bioengineering and biotechnology*, 6: 99, 2018.

[149] Gholipourmalekabadi, M., Sapru, S., Samadikuchaksaraei, A., Reis, R. L., Kaplan, D. L., and Kundu, S. Silk fibroin for skin injury repair: where do things stand? *Advanced drug delivery reviews*, 153: 28-53, 2020.

[150] Arango, M. C., Montoya, Y., Peresin, M. S., Bustamante, J., Álvarez-López, C. Silk sericin as a biomaterial for tissue engineering: A review. *International Journal of Polymeric Materials and Polymeric Biomaterials*, 70(16): 1115-1129, 2021.

[151] FAN, J. B., WU, L. P., CHEN, L. S., MAO, X. Y., and REN, F. Antioxidant activities of silk sericin from silkworm Bombyx mori. *Journal of Food Biochemistry*, 33(1): 74-88, 2009.

[152] Parveen, A. *Protective Effect of Aabresham (Bombyx Mori) Against Atherosclerosis*, Dissertation Rajiv Gandhi University of Health Sciences (India), (2016).

[153] Takechi, T., Wada, R., Fukuda, T., Harada, K., and Takamura, H. Antioxidant activities of two sericin proteins extracted from cocoon of silkworm (Bombyx mori) measured by DPPH, chemiluminescence, ORAC and ESR methods. *Biomedical reports*, 2(3): 364-369, 2014.

[154] Pal, R. K. *Fabrication of flexible, biofunctional architectures from silk proteins*. Virginia Commonwealth University, 2017.

[155] Quinn, B. *Textile Visionaries: Innovation, Sustainability in Textile Design*. Hachette UK, 2013.

[156] Bai, L., Zhu, L., Min, S., Liu, L., Cai, Y., and Yao, J. Surface modification and properties of Bombyx mori silk fibroin films by antimicrobial peptide. *Applied Surface Science*, 254(10): 2988-2995, 2008.

[157] Min, K., Kim, S., and Kim, S. Silk protein nanofibers for highly efficient, eco-friendly, optically translucent, and multifunctional air filters. *Scientific reports*, 8(1): 9598, 2018.

[158] Zheng, K., Zhong, J., Qi, Z., Ling, S., and Kaplan, D. Isolation of silk mesostructures for electronic and environmental applications. *Advanced Functional Materials*, 28(51): 1806380, 2018.

[159] Padamwar, M. and Pawar, A. Silk sericin and its applications: A review. 2004.

[160] Fatahian, R., Fatahian, A., Fatahian, E., Fatahian, H. A critical review on application of silk sericin and its mechanical properties in various industries. *Journal of Research and Applications in Mechanical Engineering*, 9(2), 2021.

[161] Trehan, S., Soskind, R., Moraes, J., Puri, V., Michniak-Kohn, B. Natural Products and Stem Cells and Their Commercial Aspects in Cosmetics. *Cosmetic Formulation*, 221-250, 2019.

[162] Daithankar, A., Padamwar, M. N., Pisal, S., Paradkar, A., and Mahadik, K. Moisturizing efficiency of silk protein hydrolysate: Silk fibroin. *Indian Journal if Biotechnology,* 115-121, 2005.