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Silk-A Gift of Nature and Magical Fiber

Abstract

Silk can be described as the externally spun fibrous protein secretions, which are produced by the variety of insect's larvae to form cocoons. For many years the polymer industries had attempted to make the fabric which is similar to silk. Many synthesis like nylon are chemically similar to the silk. But the unique combination of high strength, perfect structure, and the ability to bind a wide variety of chemical dyes makes silk as the premier structure material for the fashion industry. In this paper we discuss about the nature and process of the preparation of silk. There are many physical and chemical properties in this magic fibre silk. In the history of silk has created a route between continents called Silk-Route. In India, the silk has great significance in clothing, and also a biggest maker of silk. Presently, the latest technology advances over the usage of silk in combination with other functional components, with an emphasis on improving the performance of next-generation silk-based materials.

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Keywords: Silk, Sericulture, Magic Fibre, India.

Introduction

Silk is described that the externally spun fibrous protein secretions, manufactured over the various types of insect's larvae to form cocoons [1]. Silks are manufactured by the insects like silkworms but the silk moth of a caterpillar is employed for the textile industry [2]. Also, the insects like web spinners and raspy crickets can harvest the silk in their lives. The larvae of Bombyx mori and mulberry silkworm insects are employed to yield the commercial silks. For several years the polymer industries had attempted to develop the fabric alike silk. Many syntheses like nylon are chemically alike with the silk. But the unique amalgamation of high strength, perfect structure, and capability to bind an extensive diversity of chemical dyes makes silk the premier structure material of fashion industry. Owing to its very beautiful looking, Silk also applauded as the textile queen [3]. The gleaming look of silk originates from the fiber's ''triangular prism-like structure', owing to silk cloth can refract the incoming light at diverse angles. As a textile fiber, silk is thermally insulating and capable of managing the moisturized environment.

Sericulture (Growth and Production)

Sericulture [4] is known as the care of little insects which produced the silk thread. There are four activities are involved during sericulture process which is: (1) food plant cultivation, (2) silkworm rearing, (3) silkworm reeling, (4) weaving, printing, and dying [5]. The (1) &(2) Activities are land-based activities. The (3) & (4) activities are indoor works. Initially, sericulture starts with the farming of food plants for rearing the silkworms. For the making of many cocoons, the Som and soalu rearer are required. The mulberry rearer is found from the mulberry plants. Similarly, Tassar and Eri rearer are found from the Arjuna, Sal, and Kesseru, Castor trees.

Rearing of silkworms is the second stage in sericulture. When the swarm plants are ready with the sufficient foliage, the freshly hatched silkworms are released to feed on leaves. The muga and tassar, silkworms are nurtured outdoor on the tree itself. Also, the Eri and mulberry rearing are nurtured on the indoor activity. Silkworms feed insatiably and their body weight surges very fast. They can lead through four different phases in their cycle which are an egg, larva, pupae, and moth. The moth lay an egg from the eggs, the tiny ant-like worm hatch out and feed on leaves. This is called larva which is the second phase of sericulture process. In the third stage when the larva is fully grown, it spins silk into a cocoon around itself. Inside the cocoon, the worm transforms into pupae. After certain days the pupae develop into a moth which is the last stage. This moth comes out of the cocoon. After copulation, the female moth lay eggs. The life cycle differs from region to region and from species to species depends on the factors like climate, vegetation, sunlight [6].

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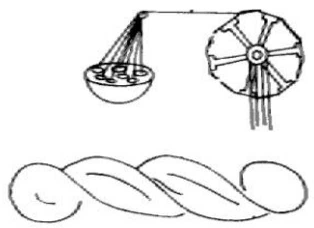
After the formation of cocoons, they are boiled and the silk filament is unwinded on reeling devices for commercial extraction of silk yarn. That is the third phase in practice of sericulture. Thereafter silk yarn is utilized to weave the fabric, which is tinted and printed for value addition of the product, which is the final stage of sericulture.

Processing of Silk

To yield an unpierced cocoon, the chrysalis is slain through heat. Then the cocoons are weighed which shows that the female moths are heavier thus the selected moths are utilized for further process. The moth's lives only a few days, during that period they mate and they lay eggs. It is calculated that nearly 3000 cocoons are required to make the single yarn of silk fabric. In many cases, silkworms are endangered to many diseases that may cause less quality of silk.

Softening the sericin

The sorted cocoons are further put through the series of cold and hot immersions. It is used to soften the sericin [7] for filament unwinding which produced the incessant thread. The Raw silk contains 80% of fibroin and 20% of sericin. During that, only 1% of the sericin is detached because the silk gum needs the sericin to shield, further filament handling phases.



Reeling of Filament

Reeling [8] is defined that the procedure of relaxing filament through cocoon. The feeling is also utilized to avoid the defects of raw silks. The threads of the cocoon are extremely thin for viable use so 3 to 10 strands of threads are reeled at the time to yield the preferred diameter of raw silk thread. The cocoons are the float in the H_2O by bobbing up and down, as threads are strained skyward by the porcelain eyelets and are quickly looped on wheels or drums. In this case, the operator monitors the procedure to sense the flaws in the thread.

The sericin helps to hold numerous filaments when they are grouped to form the single thread. The remaining filaments found from the raw material is further employed to manufacture the spun silk. In the Final stage of reeling threads are wound into the skeins which are grouped into the small bundles known as books.

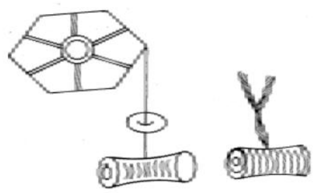


Figure 1.2: Filament

Throwing

Throwing [9] is the technique of converting the reeled silk into the silk yarns. The silk skeins are classified depends on the size, colour, quality, and length of the filaments. Next, to the mechanical drying, the skeins are located on the light reels through the reels the silk is looped over the bobbins. If two or yarns are doubled in their size, then they twisted again in the same direction or in a reverse direction based on the kind of thread to be made.

Degumming

The silk found from the "Throwing" process contains some sericin which is further sent to soap bath to get the natural soft feel of silk. The degumming technique [10] removed around 25% of weight which changed the colour of silk to creamy white. At the end phase, a hill of beans of sericin is left to give the strength of the finished product.

Weighing

The weighing process is used to takes place after the degumming technique.Because the industries buy silk for their use. So weighing silk after degumming process reduced the manufacturing cost of the silk industry. The weighed silk already drops the natural elasticity of fiber and it also subjects to deterioration while they exposed to the sunlight and the dry cleaning.

Noil Silk

Comber noils [11] are the waste fibers which is found from the spun silk processing. It is further converted into stiffer, uneven neppy yarns through the woollen spinning system which is known as Bourette Silk.

Degummed Cultivated Silk	Weighted Cultivated Silk	Wild Silk
Wrinkles little, fine lustre fine and smooth Types: spun silk, noil silk	Full, heavy, wrinkles less, durable and has the strong lustre	Coarser, heavier than cultivated silk, darker

Characteristics of Silk [12]

Among all natural and synthetic fibers, silk occupies a prime position for its outstanding characteristics. Silk has very strong tensile strength. A silk filament is as strong as repelling damage upto a weight of 4g per thread and much stronger than cotton or wool. Silk also contains low density than cotton, wool or nylon. Moreover, silk is highly moisture absorbent and is able to absorb the moisture which is three times higher than its own weight. Silk can take on many different appearances. Silk can retain brilliant colour shades obtained by dyeing and printing. A raw silk fabric looks similar to cotton or synthetic fabrics. The more filtered the silk and the smaller the yam results from the look and feel that we use to call as silky.

Varieties of Silk [13]

Although various varieties of natural silk are there, only four varieties are commercially valuable. Silk is categorized as domesticated/cultivated and wild/semi-domesticated on the base of feeding and rearing of silk-producing worms. The mulberry silk produced by Bombyx mori and the non-mulberry silk produced by Philosophia ricini these are two well-known diversities of silk produced by domesticated silkworms. These silks are white in colour. However, wild silk is different in texture and color from the domesticated silk. The wild/semi-domesticated silks are made by wild silkworms belonging to the genus Antheraea such as A. assama, A. pernyi, A. mylitta, A. yamamai etc. also have practical importance as they produce quality silk fibers.

The physical and the chemical properties of silk fibre is portrayed below:

Physical Property [14]

The physical property of silk contains the tenacity, specific gravity, elastic plastic nature, elongation, Hygroscopic nature, Thermal properties, Electrical properties, Hand feel, Drapes Property, Abrasion resistance, Effect of sunlight.

Tenacity

Silk contains the beta arrangement polymer and crystalline polymer so filament of silk is strong.

Gravity

The Gravity of the degummed silk is 1.25, which is very less than the cotton, flax, and wool.

Elastic-Plastic Nature

Silk contains high plastic than the elastic owing to its crystalline polymer system.

Elongation

Silk fibre contains the elongation at break of 20-25% under normal condition. At 100% R.H., the extension at break is 33%.

Hygroscopic Nature

Silk contains crystalline polymer system so it has less absorbing capacity than the wool and high absorbing capacity than cotton. So the silk can absorb water (M.R.11%), also it can quickly dry.

Thermal Properties

Silk is tremendously sensitive against the heat than wool. It is because of the lack of covalent cross-links in the polymer system.

Electrical Properties

Silk has poor electricity conducting capacity. It causes difficulties for silk during pre-processing and processing in the dry atmosphere.

Hand Feels

Handling of silk is very soft because of the smooth, even and the regular surface of silk filaments. It is because the crystalline polymer system provides the specified quantity of stiffness.

Drapes Property

The drapes property is depend on the flexibility of silk fibre. Based on the flexible property the fibre drapes well and tailored well too.

Abrasion Resistance

Silk has high abrasion resistance capacity and also contains the high pilling resistance.

Chemical Property [15]

The Action of Water

During absorption of the water molecules in the amorphous regions, the water molecules strive with free active side groups in polymer system which is used to form the cross-links with the fibroin chains. Its result, relaxing of total infrastructure accompanied by a reduction in the force required to break the fibre and rise the extensibility.

Effect of Acids

Silk is inferior rapidly than wool owing to its acids. Concentrated sulphuric and hydrochloric acids, particularly when hot, cause hydrolysis of peptide linkages and readily dissolve silk.

Effect of Alkalis

Alkaline solutions made the silk filament to swell. This is because of the partial division of the silk polymers through molecules of alkali. Salt linkages, Van der Waals' forces, and hydrogen bonds can hold the polymer system of silk together.

The Action of Oxidizing Agent

Silk fibre is extremely sensitive to the oxidizing agents. The attack of oxidizing agents may happen in three probable points of protein: (1) At the peptide bonds of adjacent amino groups, (2) At the N-terminal residues and (3) At side chains

An Action of Reducing Agents

`The technique of decreasing agents on the silk fibre is still a little bit unclear. It is, however, described that reducing agents are commonly obtained in textile processing such as c acids, hydrosulfite, and their salts which do not implement any harsh action on the silk.

The rest of this paper is organized as follows: Section 2 examines literature review in Silk Road and its uses. Section 3 briefly discussed the Aim of the study and hypothesis. Section 4 concludes the paper.

Review of Literature

Silk Road

Historical evidence shows that silk was revealed in China [16] and from there it spread to other parts of the world. Silk was featured prominently in public rituals as a symbol of homage for the emperor was evidenced by Chou King (2200 B.C), First, it was kept as the secret within China due to jealousy but when commercial relations were established between China and Persia and later to other countries, export of raw silk extended up to southern Europe [17]. Initially, the secret was learned by Korea and then Japan. War was a key in the spread of the silk industry especially to Japan when Semiramus, a general in the army of Empress Singu Kongo invaded and conquered Korea. The other reason for the spread of the industry was migration. During the latter part of 19th century, Japan gave a serious attention to the silk industry [18], introducing the use of processing machinery and improved techniques and to perform exhaustive research in sericulture. In Indian silkworms were first trained in the foothills of Himalayas. When the British came to India they implemented flourishing silk trade through the British East India Company. Sericulture spread over the century from China to other portions of country and silk became a valuable commodity extremely sought after [19].

The quantitative overviewed and comparison the isolation of silk proteins by employing a variety of degumming and salvation processes demonstrated that the elementary concepts of silk-based electronics/optoelectronics with latest technological advances on the usage of silk in combination with other functional components. Silk-based bioelectronics has abundant latent for futuristic bio-applications including e-bandages, biosensors, wearable displays, implantable devices, artificial muscles, e-skins, silk-based organic field-effect transistors have highly promising applications in e-skins and biosensors. These Innovative improvements have paved the way to progressively thin, flexible, tough, stretchable and cost-effective devices for bio-mimicry such as artificial skins with enhanced tactile sensing through multivariate stimuli response, micro- and Nano-electro-mechanical systems (MEMS/NEMS) for artificial musculature, and even fully bio-restorable electronic implants[22].

The enhanced understanding of silk protein degradation during cocoon processing is the next logical step in harnessing silk protein-based biomaterials for tissue engineering and biomedical applications. Silk polymer is one of the promising resources of biomedical materials. Silk is employed in the field of medicine for the manufacture of fibrous medical equipment's. Silk is used in medical devices that deliver a long-term drug delivery with higher extrude uptake and natural biodegradation, that supported rapid wound healing with short span. Depend on the wound healing, silk scaffold, silk hydrogel, and silk film are used for healing wounds [23].

Cytocompatibility and controllable biodegradability facilitated the use of fibroin in biomedical applications by their Specified mechanical properties. Aqueous solutions of silk proteins are preferred in all kinds of uses in biomedical. Sericin serves as a preservative in cosmetic and food industries, as a mitotic factor in cell culture media, anti-cancerous drug, and an anticoagulant and as the biocompatible coating. Silk sericin as the lyophilized powder for years and regenerated fibroin solution at 4 ◦C up to 2 weeks are the suitable conditions for silk protein preservation [24].

In Kenya, an introduction of sericulture was a joint venture between experts of the Overseas Technical Co-operation Agency (OTCA) from Japan and the Ministry of Agriculture of Kenya in 1974. The first task was to establish a mulberry cultivation orchard at National Horticultural Research Centre (NHRC) in Thika. To establish this task, preliminary research to recognize indigenous mulberry cultivars was undertaken. To assess their performance in Kenyan climatic conditions, some high yielding cultivars were imported from India and Japan. In 1996, the International Centre of Insect Physiology and Ecology (ICIPE), an advanced research institute situated in Nairobi, opened a sericulture unit under its commercial insect's programme. The unit is developing innovative sericulture technologies geared to augmenting the proficiency and economic returns of small-scale land users. The unit has laid emphasis on the preservation and consumption of wild silk moth rearing of the domesticated silkworm for raw silk production. The unit has successfully developed a new inland silkworm hybrid, which flourishes in the African environment and produces high-quality silk. The unit has also developed a full package of silk technology from mulberry cultivation to weaving.

Importance of Silk [20]

1. Silk can absorb water up to a third of its weight.
2. Silk is the breathable fabric. It can keep people cool on the hot days.
3. Silk can also regulate the human body temperature, which can also preserve the body heat in the cold decades.
4. Silk has imposing moisture wicking characteristics, which can keep the people dry and comfortable in any climate.
5. Silk naturally prevents the mold & mold.
6. Silk is the hypoallergenic fabric which means it won't irritate the sensitive skin.
7. Silk is the lightweight and soft fabric which make it easy to wear.
8. Silk has the natural luster through its smooth threads, giving a beautiful look.
9. Silk doesn't make static, so it does not adhere or wrinkle easily.
10. Silk fibers are the elastic nature and can stretch around 20% without breaking.
11. Silk fabrics make perfect base layers which are available in the light, mid & heavyweights.

Silk is the easy to upkeep fabric and which will retain its beauty for years. Infact, that's why silk is so often utilized in the legacy and heirloom pieces which are delivered from generation to generation. It is a really ageless textile, lending itself perfectly to a variety of uses–from casual, everyday clothing to cozy bedding, warm accessories, and even formal attire for those extra special events.

The features of the silk make it suitable for the textiles and threads also make it perfect for items such as surgical sutures. Here the strength of the silk and its organic composition can enable it to act as the strong suture thread that is non-absorbable through the human body. Also, because silk does not trigger a response from the autoimmune system, it has been utilized to produce ligaments and bones from the people who have continuous damage to these parts of the body. The silk fibers could be utilized to offer a repair structure for muscles, bone, cartilage, and tendons. But the modern use of the silk does not end in the medical field. Silk is also being utilized in the fields of photonics and optics as well as in the electronic applications. While still a dominant player in the textile industry, silk is rapidly making its way into other areas of our contemporary lives.

Comparison

Silk vs. Polyester

The polyester is measured as the most durable material than the silk. Also, the Silk materials can wrinkle easily when they get wet. Polyester and silk are both ideals for cool weather. Both polyester and silk fabrics are heavier than the cotton or linen. The polyester is not a proper fabric for summer which tends to stick to the skin and making related dresses quite uncomfortable to wear. So during summer season silk is the best fabric to wear because silk is lighter than the polyester. Due to the meticulous nature of silk, dresses of this material are more luxurious. This is why silk wedding dresses are among the most expensive in the fashion industry. Polyester is more affordable because which is a synthetic material.

Silk Vs. Cotton

Considering warmth-keeping, the mulberry silk is the great insulator while cotton is mediocre in this regard. Silk is the best moisture wicker in textile markets because of the structure of silk. Initially cotton is a decent moisture wicker and quickly becomes inefficient when it has absorbed a certain amount of moisture. Silk is known for its smoothness, lightness. Also sleeping on silk is highly comfortable. Cotton is also quite light and is significantly coarser than silk in terms of surface smoothness, which is the main reason of sleeping on cotton tends to create wrinkles and broken hair.

Silk Vs. Satin

Silk is the fabric yield through silkworm, whereas satin is a fabric weave. Both satin and the silk offer benefits to the skin and hair through decreased friction. This could decrease the split ends in hair. However, because silk is a natural protein, it also provides additional benefits.

Uses of Silks [21]

1. Silk is mainly utilized in the clothing manufacturing field such as dresses, ties, shirts, trousers, pajamas, underwear and folk costumes. It is also utilized in skiing garments due to its lightweight and its ability to keep a body warm.
2. Silk is also utilized to yield the duvets which are lightweight and hypoallergenic. It is used as the fabric for curtains, upholstery, rugs, and bedding such as sheets
3. Sometimes silk is used in the construction of parachute materials and its cords. It is rarely used to yield the casing of the bicycle tires;
4. For the biomedical applications, protein-based natural fiber like silk; feather and spider silk fibres are proposed rather than another type of plant-based natural fiber. Silk fibres are used for human wound dressing for centuries. Recently, the renewed silk solutions are utilized to form numerous biomaterials, which are gels, sponges, and the films. Those are used for the medical related applications. Furthermore, silk has been broken as the scaffold biomaterial for cell culture and tissue engineering in vitro and in vivo.
5. Silk has been used to yield the disposable cups and tableware.
6. It has been used to make capsules for the drug delivery.
7. Spider silk was once used to create the crosshairs in instruments which are microscopes and telescopes. Spider silk is still used in the field of optics to make fine diffraction patterns in optical communications.

Aim of the Study

1. The present investigation aims to develop silk production & uses of silks and compared the analysis between the natural fibres silk with the several synthetic fibres.
2. Importance of silk in biomedical field and optoelectronics field and importance of sericulture.

Hypothesis

Hypothesis 1a

H_1

There is a significant difference between silkworms and the making of silk.

H_0

There is no significant difference between silkworms and the making of silk.

Hypothesis 1b

H_2

There is a significant difference between the action of oxidizing agent and action of reducing agents

H_0

There is no significant difference between the action of oxidizing agent and action of reducing agents

Hypothesis 1c

H_3

There is a significant difference between silk materials used in clothing and textile industry

H_0

There is no significant difference between silk materials used in clothing and textile industry.

Hypothesis 1d

H_4

There is a significant relationship between technology and production of silkworms and silk.

H_0

There is no significant relation between technology and production of silkworms and silk.

Hypothesis 1e

H_5

There is a significant relationship between the change of chemical solvents and quality of silk.

H_0

There is no significant relationship between the change of chemical solvents and quality of silk

Conclusion

The silk polymer, a representative fibrous protein has been investigated as one of the capable resources, indeed the most ideal fabric to use at home and in the furnishings industry. Furthermore, to its unique mechanical properties, silk possesses other properties, such as biocompatibility, biodegradability, and ability to self-assemble, which make it an interesting material for biomedical applications. Silk biomaterials are extensively intended and accepted for applications including tissue modelling (bone, cartilage, ligament, nerve etc.) flexible electronic diagnostic devices and implantable optical systems such as eco-restorable transient electronics and bio-memristors. And mainly include their designs and requirements for advanced users as wearable displays, implantable devices, and bio-actuators, re-skins, e-bandages, wound-dressings, biosensors.

Silk fibroin can exist in an amorphous state as well as in different degrees of crystalline conformations. Silk fibroin is casted in 3D printing and

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copolymerized with other biological materials, such as elastin, collagen, and DNA, as well as be processed with several methods, such as tyrosine and β-sheet crosslinking diazonium coupling, and alcohol or water treatments. From ancient decades to the modern times, silk has always been stared at the most luxurious product which represents the ultimate comfort for the people who can possess in daily life. So due to such kind of quality silk is always considered as the “magic fibre” in the fashion industry.

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