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REVIEW ARTICLE

Review on Spider Silk and its Application

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ABSTRACT
Spider web is the strongest polymer bio-fiber used in making Bullet proof clothing, Light-weight clothing, Rope, Nets, Seat belts, Parachutes, Biodegradable material and Optical industry. While in agricultural industry spider web act as biological control agent against plant pest and reduce plant damage by insect pests. At the same time in medical field have applications as Biodegradable Carrier, Artificial tendon or ligaments supports for weak blood vessels and making Bandages and surgical threads. The regenerative potential of silk is used in repair of peripheral nerve injury. Spider silk is also used in drug delivery and Human bone marrow stromal cell and ligament fibroblast responses on Rat Genome Database. Mixture of spider dust with different medicinal plant can cure various types of diseases while spider silk is act as wound Healer, anti- inflammatory, Antibacterial and Antimicrobial in nature. Spider web have many beneficial applications to human hence, work on spider silk is obligatory.
Key words: *Spider, Silk, Biological activities*

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INTRODUCTION

Spiders are the seventh largest order of arachnids in total species diversity among all other group of organisms. They are abundant and widespread play significant role in ecology. Specialized abdominal glands synthesized spider silk proteins to produce large quantities of silk fibroins; these fibroins are spun into silks which is have different properties, compositions and morphologies [60, 61]. Number of researchers reported various species science 1900 to 2016. However, scanty information on silk was reported [32-58].

Over the past two decades, due to the broad range of diverse mechanical properties of spider silk, scientists have been attempting to unravel the molecular details of spider silks.

Here an attempt has been made to review the spider silk and its applications.

Silks are defined as "highly repetitive sequences of amino acids containing fibrous proteins and are stored in the animal as a liquid and configure into fibers when spun at secretion" [9-15]. Spider silks are composed of proteins that generally show a repetitive core region flanked by non-repetitive N- and C-terminal domains [22, 23, 24, 40].

Spider silks represent natural composite biopolymer. Biochemical analyses reveal that the different silk types contain at least 2-3 distinct structural proteins, commonly referred to as spidroins [1, 25, 56].

PHYSICAL PROPERTIES

Various researchers worked on spider silk and reported its physical properties and find spider silk is light, five times stronger than steel biomaterial [31]. Spider silk thread has diameter of 0.0003 mm and 16 ounces (450 g) silk circle the Earth. It is ductile streach up to 140% of its length with Tensile strength 1.3-2.9 Gpa, elastic modulus 10-50 Gpa [48, 10]. Dragline Silk's Tenacity is about 8- 12 gpd, while average tenacity is 45.9 cN/tex. Density - 1.25-1.35 g/cc [43]. Glass Transition temperature lies in the range of -50°C to -60°C [44, 45]. Thermally it is stable at 230°C and below -40°C [11, 21].

CHEMICAL PROPERTIES

Extensive work carried out by researchers, they conclude following chemical properties:
The spider silk can be blended with few metals like zinc, titanium, or aluminum to make it even more resilient and the metal makes each strand 10 times strong. It is resistant to most of the common solvents and enzymes except chymotrypsin. It is partially soluble in Mineral acids and Alkaline Hydroxide. It is completely soluble in concentrated solutions of LiBr, Lithium thiocyanate or $CaCl_2$, C_2H_5OH, mercaptoethanol and mixture of boiling HCl and C_3H_7COOH. It is flexible and waterproof. The water treated filaments have very large breaking extension of 56% [31, 48, 10, 43, 44, 45].

USES OF SILK

Spiders are one of the most abundant predators of insects of terrestrial ecosystems [4, 5, 12-15]. They are generalist predators, not only kill a large number of insects per unit time but also have a great importance in reducing and even in preventing outbreaks of insect pests in agriculture too [53, 54]. The dragline silk of orb-weavers approaches the tensile strength of steel and is more extensible than rubber or tendon collagen [17,1 8].
Traditionally it uses to catch small fish [25]. In certain areas in Madagascar, spider silk has also been used in bag and clothing production. Spider silks use as crosshair in microscopes and telescopes [5]. It is used in making bullet proof jackets. It is light in weight, hence easy to carry [1].
A biodegradable material can be prepared based on silk fibroin and keratin present in spider silk [59, 64].Spider silk suggested to be used as a load bearing biomaterial by Brown *et al.,* (2011) due to its biocompatibility, strength and toughness. Spiders have a wide insect host range and thus can act as biological control agents of insect pests in agro-ecosystems (Jeyaparvathi et al., 2013).
The spiders cast a trail of silk before taking off in the wind using the silk as a "parachute" to disperse them far. Recently it is observed that certain species of spiders use silk as an "anchor" against the wind when the spider has landed in water [22-26].

MEDICINAL IMPORTANCE OF SPIDER SILK

- **Biodegradable Carrier**
  A constant drug release rate could be realized for a period of two weeks using spider silk, and concluded that spider silk particles have high potential to be used for diverse applications when there is a requirement for controlled release from biodegradable carriers [59].
- **Bandages and surgical threads**
  There are records indicating that spider silk has historically been used by humans and it is now the subject of research. One traditional use of tubular shaped webs of *Atypus* spiders as topical bandages to heal wounds. This was believed to be beneficial due to the antiseptic properties of the spider silk [25-30].
- **Regenerative potential of silk conduits in repair of peripheral nerve injury**
  Modern uses of spider silk have involved helping in mammalian neuronal regeneration using *Nephila clavipes* silk [2]. Spider silk was successfully used to regenerate peripheral nerves in rats [2].
- **Wound Healing Activity**
  Spider web is being used in India and other countries as wound healer. Its ointment at 2.5 and 5% w/w concentrations was tested for wound healing activity in excision and incision wound models in rats. Significant reduction in the area of excision wound was observed for both the treatments when compared to normal healing and control ointment treatments. The period of epithelization for spider web treatments was much lower than the standard povidone iodine ointment and significant when compared to normal and control ointment treatments (Preeti Kumari et al., 2013).
- **Mixture of spider dust with different medicinal plant can cure various types of diseases**
  Spider silk is mixed with medicinal plant like Durba root (*Cynodon dactylon*), Kuksima (*Blumea odorata*) and used to stop haemorrhages and bleeding in piles (Majumder and Dey, 2005).
- **In-situ self-assembling protein polymer gel systems for administration, delivery, and release of drugs.**
  This study also found that spider silk did not appear to provoke an auto immune response in human cells. This is an important point to rise because; if a material is to be used therapeutically then it is important that the material is neither toxic nor swiftly destroyed by human immune systems, negating any potential beneficial effects. Another recent biotechnological application of spider silk described is for using recombinant spider silk particles as drug delivery vehicles [34].

- **Human bone marrow stromal cell and ligament fibroblast responses on RGD (Rat Genome Database)-modified silk fibers.**
  Spider silk fibers have remarkable mechanical properties that suggest the component proteins could be useful biopolymers for fabricating biomaterial scaffolds for tissue formation. Two bioengineered protein variants from the consensus sequence of the major component of dragline silk from *Nephila clavipes* were cloned and expressed to include RGD cell-binding domains [6].
- **An innovative material in a biocompatible**
  Dragline silk fibers and egg sacs have been studied for their biocompatibility in a few human cell culture systems [2, 16]. Primary chondrocytes have been shown to attach and survive for several weeks on natural dragline silk and egg sacs [16]. Natural dragline silk fibers have also been used to culture human primary Schwann cells and demonstrate these cells can adhere and elongate [2]. *In vivo* biocompatibility of native dragline silks has also been demonstrated by subcutaneous implantation in pigs [61], mice and rats [16].
- **An Antibacterial Activity**
  Spider webs have significant potential as an antibacterial compound. The maximum diameter of inhibition zone for bacteria was at 48 hours and concentration was 0.035 g/ml [36].
- **An Antimicrobial Activity**
  Heimer [25], in a general book on spiders, mentions that microbes are unable to grow on spider silk and attributes this to the silk having a acidic property, but this appears to be the result of speculation and not findings from an experiment. Borders [7] gives details of a school project that investigated spider silks antimicrobial properties, but these data were inconclusive. Chakraborty [9] submitted an abstract to the 25 European Congress of Clinical Microbiology and Infectious Diseases in 2009, suggesting the dissolved proteins of spider silk possessed antimicrobial properties, but it appears that these findings were not published further.
  Silk from the common house spider, *T. domestica*, appears to reduce the growth of *B. subtilis* under laboratory conditions [62].

LIMITATIONS OF SPIDER SILK

- Spiders are hard to breed and there is no economic production on large scale possible.
- The spiders are cannibalistic and cannot be breed in bulk amounts like silkworms.
- When grown in the lab, they have to be put in separate boxes and even then they are hard to be breed in laboratory conditions.
- Spiderlings are only coming out when the temperature is rising, after a determined period.
- Having a good breed, the production of silk is still limited.
- Silk fibers are quite stable but they degrade above 160 °C [20].

FUTURE POTENTIAL USES OF SPIDER SILK

For future potential uses with applications ranging as wide from artificial tendons to rust free panels has been suggested. Spider silk has been suggested as a suitable replacement material for many existing products such as clothing, ropes, seat belts, body armor, parachutes and biodegradable bottles, all of which could show both cost and environmental benefits if made from spider silk rather than current manmade materials. The work on spider silk protein is scanty. For medicinal purpose spider silk protein must be available at an industrial scale, since it has much medicinal property. This problem solve by novel bioengineering method that is recombinant production of spider silk protein.

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