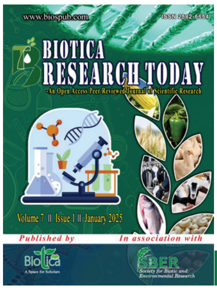

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Spider Silk: Nature's Marvelous Material

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Abstract

Spider silk is considered as nature's stronger biomaterial known to science with properties like strength (stronger than Kelvar), elasticity (flexible than rubber) and completely biodegradable, making its versatility in wider applications. With advanced technologies in genetic engineering, we can now recreate spider silk in labs using bacteria or other organisms, but producing the spider silk at large scale has always been a challenge until now. Imagine ecofriendly body armor, wear-resistant lightweight clothing, biodegradable bottles or sutures that gets completely dissolve in body. Spider silk even holds the potential to grow artificial nerves, tendons or ligaments, skin regeneration and 3D cell scaffolding, making it a valuable material for 3D bioprinting and advanced biomedical applications. As science getting equipped with optimized and new analytical tool, spider silk acting as one of the agents to transform biomedical and material science.

Keywords: Biodegradability, Biomaterials, Recombinant protein, Sustainability

Introduction

The spider silk is nature's wonder material, renowned for its extraordinary tensile strength, elasticity and wide range of applicability, is revolutionizing diverse sectors from biomedical engineering to materials science. For thousands of years, humans have found the uses for spider silk. The ancient Greeks used cobwebs to stop bleeding while the Aborigines used silk as fishing lines to catch small fish. Today scientists and researchers are striving to explore the mysteries of spider silk which possess the extraordinary properties to revolutionize fields ranging from medical, aerospace to material science.

A Marvel of Nature: Stronger than Steel more Elastic than Rubber

Chemically, spider silk is semi-crystalline in nature having properties like high tensile strength and elasticity. This structure allows it to absorb more energy before reaching the point of breakage. Spider silk is known to possess high strength of 1.75 GPa at a breaking elongation of over 26%. On weight by weigh basis, spider silk is five times stronger than steel, three times toughest to Kelvar and two times more flexible than nylon. The unique strength and flexibility of spider silk make it an ideal biomaterial for making parachutes and body armor. Apart from this, the properties like biocompatibility and biodegradability makes it a suitable for biomaterial for biomedical applications.

Molecular Structure: The Secret behind the Extraordinary Powers

What makes spider silk so extraordinary lies in its molecular structure. The key role is played by proteins known as spidroin. Spiders typically possess seven types of silk glands, each producing a specific type of spider silk having specific function. The type of silk produced and secreted varies, depends on the spider's specific need. Among the various types of spider silk, the dragline is the best kind of silk. It is produced by the major ampullate gland with constituent proteins, MaSp1 and MaSp2. Structurally, both the proteins possess repeating sequence region in the middle and non-repeating sequence at both the ends. The molecular weight of naturally synthesized MaSp1 and MaSp2 proteins is approximately 250-300 kDa. Both the proteins possess repeating sequence of 3500 Amino acid residues and on the flanking sides of central repeating sequence are non-repeatitive regions of nearly 100 amino acid residues. The spatial arrangement of atoms in the protein gives it a peculiar structure which includes alpha helix, beta sheet and irregular curl including random coils, U-shaped structure. Together, they give spider silk a high tensile strength and excellent

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elastic properties.

The Challenge of Production: Why Harvesting Spider Silk from Spider's doesn't Work

Despite its extraordinary properties, harvesting it from spiders is a real challenge. Spider farming is impractical due to their territorial and cannibalistic behaviour. Additionally, each spider produced a minimal amount of silk. For an instance, over millions of spiders produced enough silk to produce a single 11-foot by 4-food textile, showcased at the 1900 Paris Exhibition (Figure 1). These challenges have compelled researchers to find some alternative way to produce a bulk of silk and here the biotechnology comes into play, offering the possible solutions.

Figure 1: Spider silk in fashion [Golden garment; over a million spiders required to create golden garment 11-foot by 4-foot; a Model showcasing the garment at 1900 Paris Exhibition]

Role of Biotechnology: Spining Spider Silk without Spiders

Scientists have successfully cloned the spider genes and introduced them into various organisms, from bacteria to goat. Each organism presents its own set of challenges and advantages; while bacteria like *E. coli* are the fast growing, cost effective but they struggle to produce large sized proteins. Yeast can handle large proteins but they grow slowly and are more expensive. Mammalian like the famous "Spider Goat" can produce huge amount of spider silk in milk but cost remains a major issue. Plants are also being explored as a cost-effective protein factory, promising a sustainable solution to the silk production (Whittall *et al.*, 2021).

From Medicine to Aerospace: Spider Silk's Applications

The spider silk possesses quite vast applications. In medical sector, biocompatibility and its strength make it an ideal material for sutures, wound dressings and scaffolds to support tissue growth. Additional, spider silk is being used to create artificial nerve, artificial tendons or ligaments and also as a drug delivery system to specific cells. In material science, its outstanding properties of high tensile strength to weight ratio could transform various industries. From bulletproof vests to aerospace components, spider silk-based materials offer superior performance, being lighter and more environmentally sustainable option as compared to the traditional materials. The automobile industry is keen to utilize spider silk to develop stronger and lighter vehicles with improved fuel efficiency (Guessous *et al.*, 2024).

Spider Silk and Cutting-Edge Electronics

Undoubtedly, spider silk possesses a great potential in the field of electronics. By coating the spider silk which is naturally an insulator with conductive material such as gold, iodine or carbon nanotubes can transform it into conducting material with remarkable properties. It is having the ability to maintain conductivity at cryogenic temperatures and adapt to environmental changes such as humidity. Additionally, the fusion of spider silk with nanotechnology and functional coatings could lead to breakthroughs in microelectronics, heat management and bio-integrated devices (Maithani *et al.*, 2022).

Spider Silk in Cosmetic Products

Spider silk has made a lot of contributions to the cosmetic industry in various ways. Spider silk proteins are widely utilized as active ingredients in various commercial cosmetic products such as skin care and hair care products including lotions, gels, anti-ageing creams, dyes, bleaches, cleansers, shampoos and conditioners. The lustrous sheen of my expensive cosmetics can be attributed to the inclusion of finely chopped silk.

The Pioneer Companies: Bringing Spider Silk to Markets

With the advancement in research, several companies were at the forefront of bringing spider silk products to the market. In the U.S., Bolt Threads used genetically engineered yeast to produce their trademark Microsilk™, in collaboration with high-fashion brands like Stella McCartney to create high-performance textiles. German company AM Silk is focussed on both fibres and cosmetic ingredients using bacterial fermentation. AM Silk's Biosteel® fibre is being explored for various applications from high performance sneakers to advanced medical devices. Meanwhile, Japan's Spiber Inc. has developed QMONOS™, a high-performance spider silk fiber being used in outdoor gear and automotive applications. Kraig Biocraft Laboratories in the U.S. developed a unique approach by creating transgenic silkworms that produce spider silk proteins, leading to Dragon Silk™. Meanwhile, Spider Silk Industries in France majorly focussing on medical applications like tissue engineering and drug delivery, highlighting it's potential to revolutionize healthcare industry (Zhang *et al.*, 2021).

Challenges with Production: Scale Up and Cost

Despite great progress in this area, bringing spider silk products to the market has always been a great challenge. Scale up of products, while maintaining the quality and keeping price low is the major hurdle. The complexity in the structure of spider silk protein makes them difficult to produce and process at large scales (Ramezaniaghdam *et al.*, 2022). Additionally, regulatory approval for medical applications adds another layer of complexity, requiring extensive testing and validation. However, with advancement in genetic engineering, production techniques are continually improving and costs are gradually decreasing, suggesting that these hurdles may be overcome in the near future.

Conclusion

Recent advances in the genetic engineering are helping in optimising production process of spider silk. The future of spider silk seems promising and likely to become more accessible and widespread. Innovative applications ranging from biodegradable sensors to artificial blood vessels, are continuously being discovered. Its unique properties make it ideal to be exploited in the fields like medicine, electronics and environmental conservation, there by bridging how natural systems can cater future needs. The role of spider silk in the upcoming years, will be seminal in shaping sustainable, high-performance solutions for the modern world.

References

Guessous, G., Blake, L., Bui, A., Woo, Y., Manzanarez, G., 2024. Disentangling the web: An interdisciplinary review on the potential and feasibility of spider silk bioproduction. *ACS Biomaterials Science & Engineering* 10(9), 5412-5438. DOI: https://doi.org/10.1021/acsbiomaterials.4c00145.

Maithani, A., Sahni, I., Joshi, V.V., 2022. A review of thermal, physical, electrical properties of spider silk and their experimental setups. *Materials Today: Proceedings* 62(Part 6), 3940-3949. DOI: https://doi.org/10.1016/j.matpr.2022.04.565.

Ramezaniaghdam, M., Nahdi, N.D., Reski, R., 2022. Recombinant spider silk: Promises and bottlenecks. *Frontiers in Bioengineering and Biotechnology* 10, 835637. DOI: https://doi.org/10.3389/fbioe.2022.835637.

Whittall, D.R., Baker, K.V., Breitling, R., Takano, E., 2021. Host systems for the production of recombinant spider silk. *Trends in Biotechnology* 39(6), 560-573. DOI: https://doi.org/10.1016/j.tibtech.2020.09.007.

Zhang, Q., Li, M., Hu, W., Wang, X., Hu, J., 2021. Spidroin-Based biomaterials in tissue engineering: General approaches and potential stem cell therapies. *Stem Cells International* 2021(1), 7141550. DOI: https://doi.org/10.1155/2021/7141550.