Spider Silk Future of Material Science

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Abstract—*Cracking the genetic code of the spider DNA for the particular protein code, this produces the spider silk. By the biotechnology process the expression of protein is done so as to the produce the silk material for the several applications. Spider silk involves its potential use as an incredibly strong and versatile material.*

1. INTRODUCTION

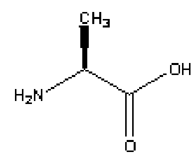
In contrast, the production of spider silk is completely environmental friendly. It is made from spiders at ambient temperature and pressure and is drawn from water. In addition, silk is completely biodegradable. The interest in spider silk is mainly due to a combination of its mechanical properties and the non-polluting methodology in which it is made.

2. SPIDER BASICS

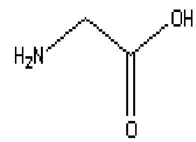
Spiders basically look like insects and come in to the category of **ARTHROPODA,** but they belong to a completely different class of animals called **ARACHNIDA**. Spiders make up the order Araneae within this class, which also includes mites, ticks and scorpions. Spiders vary considerably in size, shape and behavior. They can produce silk.fibers.

3. CHEMICAL STRUCTURE

Spider silk is a natural polypeptide, polymeric protein and is the scleroprotein group which also encompasses collagen (in ligaments) and keratin (nails and hair). These all are proteins which provide structure. The protein in dragline silk is fibroin (M r200,000-300,000) which is a combination of the proteins spidroin 1 and spidroin 2. The exact composition of these proteins depends on factors including species and diet. **FIBROIN CONSISTS OF APPROXIMATELY 42% GLYCINE AND 25% ALANINE AS THE MAJOR AMINO ACIDS.** The remaining components are mostly glutamine, serine, leucine, valine, proline, tyrosine and arginine. Spidroin 1 and spidroin 2 differ mainly in their content of proline and tyrosine.



Structure of Ananine



Structure Of Glycine

4. STRUCTURE OF SPIDROIN

Spidroin contains polyalanine regions where 4 to 9 alanines are linked together in a block. The elasticity of spider silk is due to glycine-rich regions where sequences of five amino acids are continuously repeated. **A 180°TURN (B-TURN) OCCURS AFTER EACH SEQUENCE, RESULTING IN A B-SPIRAL**. Capture silk, the most elastic kind contains about 43 repeats on average and is able to extend 2-4 times (>200%) its original length whereas dragline silk only repeats about nine times and is only able to extend about 30% of its original length. There are also glycine-rich repeated segments which consist of three amino acids. These turn after each repeat to give a tight helix and may act as a transitional structure between the polyalanine and spiral regions.

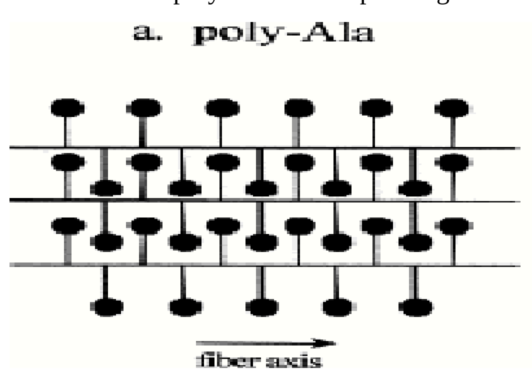


Fig. 1: Structure of spidroin

5. STRUCTURE OF SPIDER SILK

The fluid dope is a liquid crystalline solution where the protein molecules can move freely but some order is retained in that the long axis of molecules lie parallel, resulting in some crystalline properties. It is thought that the spidroin molecules are coiled in **rod-shaped structures** in solution and later uncoil to form silk. During their passage through the narrowing tubes to the spinneret the protein molecules align and partial crystallization occurs parallel to the fibre axis. This occurs through selfassembly of the molecules where the polyalanine regions link together via hydrogen bonds to form pleated b-sheets (highly ordered crystalline regions).**These b-sheets act as crosslinks between the protein molecules and imparts high tensile strength on the silk.**

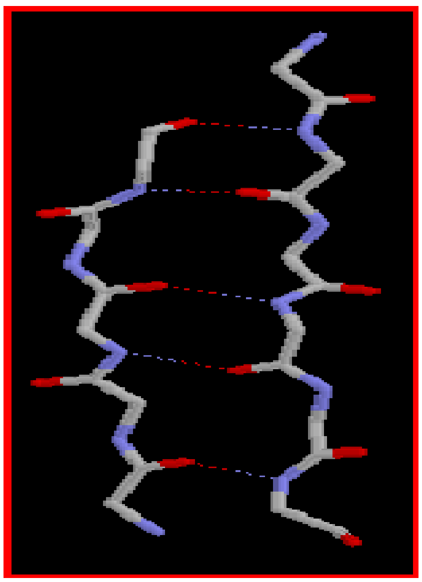


Fig. 2: B-shaped

I t is not purely coincidence that the major amino acids in spider silk are alanine and glycine. They are the smallest two amino acids and do not contain bulky side groups so are able to pack together tightly, resulting in easier formation of the crystalline regions. The crystalline regions are very hydrophobic which aids the loss of water during solidification of spider silk. This also explains why the silk is so insoluble - watermolecules are unable to penetrate the strongly hydrogen bonded b-sheets. The glycine-rich spiral regions of spidroin aggregate to form amorphous areas and these are the elastic regions of spider silk. Less ordered alanine-rich crystalline regions have also been identified and these are thought to connect the b-sheets to the amorphous regions. Overall, a generalized structure of spider silk is considered to be crystalline regions in an amorphous matrix. Kevlar has a similar structure. It is not entirely clear how the protein molecules align and undergo self-assembly to form silk but it may involve mechanical and frictional forces that arise during passage through the spider’s spinning organs.

6. APPLICATION OF SPIDER SILK

Spider silk involves its potential use as an incredibly strong and versatile material.. The production of modern manmade super-fibres such as Kevlar involves petrochemical processing which contributes to pollution. Kevlar is drawn from concentrated sulphuric acid. In contrast, the production of **spider silk is completely environmentally friendly** It is made by spiders at ambient temperature and pressure and is drawn from water. In addition, silk is **completely biodegradable.**

If the production of spider silk ever becomes industrially viable, it could replace Kevlar and be used to make a diverse range of items such as:

- Bullet-proof clothing
- Wear-resistant lightweight clothing
- Ropes, nets, seat belts, parachutes
- Rust-free panels on motor vehicles or boats
- Biodegradable bottles
- Bandages, surgical thread
- Artificial tendons or ligaments, supports for weak blood vessels. (There are lot more application of the spider silk

Spider silk has incredible tensile strength and is often touted as being several times stronger than steel of the same thickness .Kevlar has higher tensile strength but it's not very stretchy like spider silk so the spider is superior than all the materials.

1. Now days we are all seeing that the computer chips, processors are made using Nano technology, the spider silk which is also obtained from Nano technological process can be used in making of the integrated chips which would be even lighter than normal ICs.
2. The transmission cables or over head lines which are made up of aluminum is the lightest material, but compared to spider silk it cannot withstand much weather conditions and also the silk has less transmission losses compared to aluminum .
3. The insulation materials generally used has less elasticity compared to silk fiber.

7. PROPERTIES OF SPIDER SILK MECHANICAL PROPERTIES

Each spider and each type of silk has a set of mechanical properties optimized for their biological function. Most silks, in particular dragline silk, have exceptional mechanical properties. They exhibit a unique combination of high tensile strength and extensibility (ductility). This enables a silk fiber to absorb a lot of energy before breaking (toughness, the area under a stress-strain curve). A frequent mistake made in the mainstream media is to confuse strength and toughness when comparing silk to other materials. Weight for weight, silk is stronger than steel, but not as strong as Kevlar. Silk is, however, tougher than both.

8. STRENGTH

In detail a dragline silk's tensile strengthis comparable to that of high-grade alloy steel(450- 1970 MPa), and about half as strong as aramid filaments, such as Twaronor Kevlar (3000 MPa).

9. DENSITY

Consisting of mainly protein, silks are about a sixth of the density of steel (1.31 g/cm3) .Spider dragline silk has a tensile strength of roughly1.3 GPa. The tensile strength listed for steel might be slightly higher—e.g. 1.65 GPa, but spider silk is a much less dense material, so that a given weight of spider silk is five times as strong as the same weight of steel.

10. ENERGY DENSITY

The energy densityof dragline spider silk is 1.2x108 J/m Extensibility Silks are also extremely ductile, with some able to stretch up to five times their relaxed length without breaking

11. TOUGHNESS

The combination of strength and ductility gives dragline silks a very high toughness which "equals that of commercial polyaramid (aromatic nylon) filaments, which themselves are benchmarks of modern polymer fiber technology".

12. TEMPERATURE

Whilst unlikely to be relevant in nature, dragline silks can hold their strength below −40°C (-40°F) and up to 220°C (428°F).

13. SUPERCONTRACTION

When exposed to water, dragline silks undergo supercontraction, shrinking up to 50% in length and behaving like a weak rubber under tension

14. HIGHEST-PERFORMANCE

Thus, the spider silk more than twice as tough and over 10 times tougher than Kevlar".

15. PROCESSING OF SPIDER SILK

1. The first step to be taken is

- Proteins are biochemical compounds involved in virtually every process within cells.
- Protein synthesis requires two steps: transcription and translation.

Replication------DNA----------transcription---mRNA------------translation—protein

- Proteins –Giant molecules constructed from 20 different amino-acids
- The code for a protein is carried by a single gene, 4 code letters.

2. To find the particular DNA strand which produce spider silk protein?
3. Then decoding the DNA strand to mRNA of that particular protein using biotechnology techniques.
4. Introducing the DNA which is decoded to the embryo of the goat/Silkworm so that a new species of goat/silk worm is obtained in such a way that the milk produced by goat contains spider silk protein or the cocoon produce by the worm contain the spider silk in place of the silk produced by the silkworm.
5. The process of extraction of spider silk protein is done know from the milk extraction of water contain in the milk.
6. Then separating the other milk protein from the spider silk protein to get the pure silk protein powder.
7. Keeping the extracted protein in a vacuum bottle so that it does not react with external atmosphere.
8. The last part is to be done which is spinning process of the protein extracted to get the spider silk fiber.
9. The process can be done in another way to obtain spider silk using **Escherichia coli (E.Coli)** by culturing the E.Coli's with a particular strain BL21 as this is a genetically engineered coli so the above protein synthesis can be done to obtain the culture and the isolation process is carried out to bring out the spider silk.

16. E.COLI (BL21-DE) STRAIN

The Competent Cell BL21 (DE3) pLysS is a chemically competent E. coli BL21 (DE3)pLysS cell. The BL21 (DE3) pLysS strain contains the T7 RNA polymerase gene controlled by the lacUV5 promoter in its chromosomal DNA1) and the T7 lysozyme gene in the pLysS plasmid. T7 RNA polymerase is expressed upon addition of isopropyl-1-thio-β-D-galactopyranoside (IPTG) which induces a high-level protein expression from T7 promoter driven expression vectors (e.g., pET). The T7 lysozyme suppresses the activity of T7 RNA polymerase2), which reduces the basal level protein expression from the gene of interest. It is important if the protein is toxic to the E. coli cells. The presence of T7 lysozyme increases the tolerance of the E. coli cells against the toxicity. The pLysS plasmid contains a chloramphenicol resistant gene and a p15A replication origin which is compatible with those found in pBR322 and pUC derived plasmids. E. coli BL21 (DE3) pLysS strain is a derivative of E. coli B strain and lacks both the lon protease and the ompT membrane protease which may degrade expressed proteins.

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