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Keio University

Thesis Abstract

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Thesis Title

Controlling Physical Properties of Artificial Spider Silk through Sequence-Property Relationships

Thesis Summary

Spiders utilize up to eight types of silk throughout their lifecycles, tailoring each physical properties of silks to specific functions. Among these, major ampullate silk (MA-silk) has attracted extensive research interest due to its extraordinary tensile strength and toughness, prompting continuous efforts to artificially reconstruct MA-silk. With the growing demand for environmentally sustainable alternatives to man made and natural fibers, recombinant based artificial spider silk has drawn considerable attention in the textile industry. To facilitate broader applications, controlling physical properties of the fiber is essential. This thesis aims to establish the design methodology by engineering protein sequences. A comparative analysis was conducted on the physical properties and protein composition of MA-silk and minor ampullate silk (MI-silk). The results indicate that differences in protein composition and sequences explain the distinct physical properties of these two silk types. To demonstrate the feasibility of manipulating these properties, fibers were produced and evaluated from recombinant mini-spidroins. MaSp1- and MiSp-based fibers exhibited higher tensile strength than those made from MaSp2, whereas MaSp2 fibers showed greater shrinkage in water (supercontraction) than both MaSp1 and MiSp. These findings suggest that the properties of artificial spider silk can be controlled through amino acid sequence designs reflective of those found in natural spidroins (Chapter 2). Building on these observations, motifs correlated with specific physical and structural properties were extracted from 1,000 spiders spidroins and applied to motif-based sequence modifications of artificial spider silk. Incorporating a positively correlated motif increased the tensile strength of the recombinant mini-spidroin fibers by 9.3%, while substituting a negatively correlated motif decreased it by 5.1% (Chapter 3). These outcomes demonstrate that motif-based sequence modifications can be employed to tailor the mechanical properties of artificial spider silk, thereby broadening its potential industrial applications.

Keywords: biomaterial, structural protein, protein design, artificial spider silk, mechanical property