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Silk Sericin: Transforming Silk Industry Waste into a Powerful Antibacterial Biomaterial

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Silk sericin, a natural protein derived from the cocoon of *Bombyx mori L.*, has emerged as a sustainable biomaterial with significant biomedical potential. Once discarded as a by-product of silk processing, sericin is now recognized for its antibacterial, antioxidant, anti-inflammatory and biocompatible properties. Its ability to be fabricated into films, hydrogels, nanoparticles and composite materials has expanded its applications in wound healing, tissue engineering and drug delivery. Recent advances in nanotechnology have further enhanced the antibacterial efficacy and functional performance of sericin-based biomaterials, highlighting their promise for next-generation healthcare and sustainable biomedical applications.

Keywords: Silk sericin, Antibacterial biomaterials, Wound healing, Tissue engineering, Drug delivery, Nanotechnology, Sustainable biomaterials.

Introduction

Every year, millions of silk cocoons are processed to produce the luxurious silk fibers used in textiles. During this process, a natural protein called sericin is removed from the cocoon and traditionally discarded as industrial waste. For decades, this valuable protein was considered an unwanted by-product. Today, however, scientists have discovered that sericin is far more than waste- it is a remarkable natural biomaterial with enormous potential in medicine, biotechnology and sustainable healthcare (Aramwit *et al*., 2012; Wang *et al*., 2024). Derived from the cocoon of the silkworm *B. mori*, sericin accounts for nearly one-fourth of the total silk protein (Hata *et al*., 1998; Wei *et al*., 2005). Worldwide silk processing generates thousands of tonnes of sericin annually, much of which enters wastewater and contributes to environmental pollution (Fabiani *et al*., 1996) Instead of allowing this valuable resource to go to waste, researchers are now exploring innovative ways to convert sericin into high-value biomedical products.

A Natural Protein with Extraordinary Properties

Sericin is rich in hydrophilic amino acids such as serine, glycine and aspartic acid. These amino acids make the protein highly water-attracting, biocompatible and biodegradable. Unlike many synthetic materials, sericin is naturally compatible with living tissues and causes minimal adverse reactions. Research has shown that sericin possesses several important biological properties. It functions as a powerful antioxidant by neutralizing harmful free radicals that damage cells and tissues (Li *et al*. (2021). It also exhibits anti-inflammatory activity, helping reduce excessive inflammation while promoting tissue repair and collagen formation (Dash *et al*., 2008). Another remarkable characteristic is its natural antimicrobial activity, which enables it to inhibit the growth of disease-causing microorganisms (Zhao *et al*., 2014; Rony *et al*., 2024). In addition to these biological functions, sericin has excellent film-forming ability (Dash *et al*., 2008; Rony *et al*., 2024). It can easily be fabricated into films, hydrogels, nanofibers, scaffolds and nanoparticles, making it an ideal material for developing advanced biomedical products.

How Does Sericin Fight Harmful Bacteria?

One of the most exciting discoveries about sericin is its ability to combat bacterial infections. Scientists have found that sericin attacks bacteria through multiple mechanisms rather than relying on a single mode of action (Dash *et al*., 2008; Doakhan *et al*., 2013; Wang *et al*., 2024). Initially, sericin molecules attach to the negatively charged bacterial cell surface. This interaction destabilizes the bacterial membrane and weakens its structural integrity. As the membrane becomes damaged, essential cellular contents begin to leak out, ultimately causing bacterial death. Sericin also interferes with important metabolic enzymes inside bacterial cells, disrupting vital biological processes required for bacterial growth and reproduction. Furthermore, it prevents bacteria from forming biofilms - protective communities that make infections difficult to treat and resistant to antibiotics (Silva *et al*., 2022). Another important antibacterial mechanism involves the generation of reactive oxygen species (ROS) (Wang *et al*.,2024). These highly reactive molecules damage bacterial proteins, lipids and DNA, leading to irreversible cellular injury and death. Because sericin attacks bacteria through several different pathways simultaneously, it has attracted considerable attention as a natural alternative or supplement to conventional antimicrobial agents.

Effective Against Disease-Causing Microorganisms

Laboratory studies have demonstrated that sericin exhibits antibacterial activity against several medically important pathogens. Among Gram-positive bacteria, *Staphylococcus aureus* is particularly susceptible to sericin treatment. Studies have shown that sericin damages the bacterial cell membrane, resulting in leakage of intracellular components and inhibition of bacterial growth. Sericin is equally effective against several Gram-negative bacteria, including *Escherichia coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* (Doakhan *et al*., 2013; Sapru et al., 2021 *et al*., 2022; Wang *et al*., 2024). Although Gram-negative bacteria possess an additional outer membrane that often protects them from antibiotics, sericin can penetrate this barrier, increase membrane permeability and disrupt normal cellular functions. The antibacterial effectiveness of sericin depends on factors such as extraction method, molecular weight, concentration and formulation. Researchers have consistently reported measurable inhibition of bacterial growth, demonstrating its broad-spectrum antimicrobial potential.

Making Sericin Even More Powerful

Although sericin naturally possesses antibacterial properties, scientists have discovered that its effectiveness can be significantly enhanced by combining it with other antimicrobial materials. One of the most successful approaches involves incorporating silver nanoparticles into sericin (Shah et al., 2019 *et al*., 2020). These composites exhibit much stronger antibacterial activity because silver nanoparticles further damage bacterial membranes and stimulate the production of reactive oxygen species (Kaewkod *et al*., 2024). Researchers have also developed sericin composites containing zinc oxide nanoparticles and gold nanoparticles to improve both antibacterial performance and biocompatibility. Natural antimicrobial substances such as plant extracts, essential oils and chitosan have also been successfully incorporated into sericin-based materials. These combinations provide synergistic antibacterial effects while maintaining excellent safety and biodegradability. Another promising strategy is the use of sericin as a carrier for antibiotics. Drugs such as moxifloxacin, tetracycline, gentamicin and ciprofloxacin can be incorporated into sericin hydrogels and films, allowing controlled drug release directly at the infection site while reducing systemic side effects (Shah *et al*., 2019; Silva *et al*., 2022).

Revolutionizing Modern Healthcare

The unique biological and physical properties of sericin have opened exciting opportunities in modern medicine. One of its most important applications is in wound dressing. Sericin-based films and hydrogels maintain a moist environment that promotes faster wound healing while simultaneously preventing bacterial infection (Aramwit *et al*., 2012; Zhang *et al*., 2021).

These materials also support fibroblast growth, collagen synthesis and tissue regeneration, accelerating the healing process. In tissue engineering, sericin-based scaffolds provide a supportive framework for cell attachment and growth. Their porous structure allows efficient nutrient transport, making them suitable for regenerating damaged skin and soft tissues. Sericin has also emerged as an excellent material for drug delivery. Nanoparticles, hydrogels and nanofibers prepared from sericin can encapsulate therapeutic compounds and release them gradually, improving drug stability, bioavailability and treatment efficiency (Wang *et al*., 2024). Beyond medicine, sericin has found applications in cosmetic and pharmaceutical industries. Its moisturizing, antioxidant and anti-inflammatory properties make it a valuable ingredient in creams, lotions and other skin-care products.

Nanotechnology Opens New Possibilities

Recent advances in nanotechnology have dramatically expanded the biomedical potential of sericin. Researchers have successfully developed sericin nanoparticles capable of delivering drugs more efficiently while enhancing antibacterial activity. These nanoparticles improve cellular uptake and provide sustained release of therapeutic agents. Sericin hydrogels have also attracted considerable attention because they retain large amounts of water, creating an ideal environment for wound healing (Aramwit *et al*., 2012; Zhang *et al*., 2021; Silva *et al*., 2022). These hydrogels promote fibroblast proliferation, collagen production and rapid tissue regeneration. Even more impressive are sericin-based nanocomposites that combine sericin with antimicrobial nanoparticles. These advanced materials exhibit superior antibacterial activity and have shown promising results against multidrug-resistant bacteria. Scientists are also developing smart wound dressings that integrate sericin with antibiotics, nanoparticles and growth factors. These multifunctional dressings not only prevent infection but also monitor wound conditions and promote faster healing.

Looking Ahead

The future of sericin research is extremely promising. Advances in biomaterials science and nanotechnology are expected to overcome current limitations such as relatively low mechanical strength and moderate antibacterial activity. Future research is likely to focus on developing stronger nano-sericin materials, advanced tissue engineering scaffolds, implantable biomaterials and targeted drug delivery systems. Perhaps the greatest advantage of sericin lies in its sustainability. By converting a discarded silk industry by-product into valuable biomedical materials, researchers are creating environmentally friendly technologies that reduce industrial waste while improving healthcare. This approach supports the growing global demand for sustainable, biodegradable and eco-friendly biomaterials capable of replacing synthetic alternatives.

Conclusion

Silk sericin has undergone an extraordinary transformation from an unwanted waste product of the silk industry to one of the most promising natural biomaterials in modern biomedical science. Its antioxidant, anti-inflammatory, antimicrobial and biocompatible properties make it suitable for numerous applications, including wound healing, tissue engineering, drug delivery and smart medical devices. Although further research is needed to improve its mechanical properties and long-term stability, the rapid progress in nanotechnology and biomaterial engineering suggests that sericin will play an increasingly important role in future healthcare. By combining sustainability with advanced biomedical functionality, silk sericin represents an excellent example of how nature's resources can be transformed into innovative solutions for global health challenges.

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