Review Article

Silk sericin: From silk waste to high-value product

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ABSTRACT

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| Silk sericin, a water-soluble globular protein traditionally discarded during silk processing, has recently emerged as a sustainable and bioactive ingredient for cosmeceutical applications. Rich in hydrophilic amino acids, it demonstrates moisturizing, antioxidant, anti-inflammatory, and wound-healing properties, making it well-suited for skin and hair care formulations. This review summarizes its origin, structure, and multifunctionality, emphasizing its potential as a natural and biodegradable alternative to synthetic cosmetic agents. Extraction techniques such as hot water, enzymatic, and advanced physical methods are discussed in relation to their influence on sericin’s bioactivity and applicability in skincare. The paper also highlights its role in promoting sustainability through zero-waste utilization of silk industry byproducts. Key challenges including scalability, stability, and regulatory compliance are considered alongside future opportunities in nanotechnology, protein engineering, and personalized skincare. Overall, sericin stands out among biomaterials for its unique combination of bioactivity, sustainability, and compatibility with cosmetic formulations, making it superior to many other natural and synthetic counterparts. |

*Keywords:* Silk sericin, Cosmeceuticals, Biomaterials, Silk waste

1. INTRODUCTION

Silk is a natural fibrous protein renowned for its luster, softness, tensile strength, and biocompatibility, and has been highly valued in textile applications for thousands of years. Beyond its mechanical and aesthetic appeal, silk's biological functionality is attributed to its two primary protein components: fibroin and sericin. Fibroin forms the structural core of the silk fiber, providing its signature strength and elasticity, while sericin acts as a natural adhesive, binding fibroin fibers together. Historically, sericin has been removed and discarded during the degumming process due to its gummy nature. Extensive research, both historical and contemporary, has highlighted its significant bioactive potential, particularly in cosmetic, pharmaceutical, and biomedical applications. (Kato *et al.,* 1998; Zhaorigetu *et al.,* 2001; Altman *et al.,* 2003; Munir *et al.,* 2023). Sericin comprises 18 amino acids, with serine (32%), glycine (19%), aspartic acid (16%), and alanine (11%) being the most abundant. This composition enables properties such as film formation, moisture retention, antioxidant activity, and biodegradability, which make sericin a versatile material across industries (Deb *et al.,* 2024). In particular, sericin-based hydrogels have demonstrated excellent wound healing performance, anti-inflammatory activity, and accelerated tissue regeneration, outperforming conventional treatments in animal studies (Munir *et al.,* 2023). Studies on sericin’s biocompatibility and antioxidant potential, both in vitro and in vivo, show that it is immunologically safe and versatile, enabling applications in biomedicine, cosmetics, food, culture media supplementation, cryopreservation, wound healing, antitumor activity, metabolic regulation, tissue engineering, and drug delivery (Sen *et al.,* 2025). These features, along with its skin affinity and bioactivity, have aligned sericin with the principles of green chemistry and the circular economy, especially as the silk industry shifts toward zero-waste valorization strategies. This approach transforms what was once a byproduct into a high-value functional biomaterial.

Recent clinical evaluations have demonstrated that silk sericin-based electrospun nanofiber films significantly enhance skin hydration, elasticity, and smoothness. These films, developed from sericin extracted from *Bombyx mori* silkworms, were tested in a clinical trial. The results indicated notable improvements in skin moisture retention and texture, supporting the potential of sericin as a functional ingredient in cosmetic formulations (Dragojlov *et al.,* 2025). This review provides a comprehensive overview of silk sericin, a protein byproduct of the silk industry with emerging cosmeceutical and biomedical applications, highlighting its extraction methods, biological activities, potential uses, and the associated economic and regulatory challenges.

1. **Origin and Structure of Sericin**

Sericin is a globular, water-soluble protein produced by the middle silk gland of the domesticated silkworm *Bombyx mori*. It functions as a natural adhesive, surrounding and binding the two fibroin filaments within silk fibers, thereby playing a vital structural and protective role in the formation of the silk cocoon (Padamwar and Pawar, 2004; Zhaorigetu *et al.,* 2001). Sericin makes up approximately 20-30% of the silk cocoon by weight and is typically removed during the degumming process in textile production. However, due to its biofunctional properties including antioxidant, anti-inflammatory, and regenerative effects, it is now being increasingly recovered for use in biomedical, pharmaceutical, and cosmetic applications (Aramwit *et al.,* 2012; Kunz *et al.,* 2016).

Chemically, sericin is composed of 18 amino acids, with serine being the most abundant (30-33%), followed by aspartic acid, glycine, threonine, and glutamic acid (Deb *et al.,* 2024). The high content of polar amino acids particularly serine accounts for sericin’s excellent water-binding ability and hydrophilicity, making it particularly effective in skin and hair hydration formulations (Zhaorigetu *et al.,* 2001). Recent studies confirm that sericin’s amino acid composition varies by extraction method and cocoon layer, which significantly influences its physicochemical behavior and performance in functional products. The molecular weight of sericin can range from <20 kDa to >400 kDa depending on silkworm strain, cocoon layer, and extraction technique, such as hot water, alkaline, enzymatic, or microwave-assisted methods (Aramwit *et al.,* 2012; Kunz *et al.,* 2016; Munir *et al.,* 2023). This variability directly affects its biological activity, including film-forming ability and cellular interaction.

Genetically, sericin proteins are encoded primarily by the Ser1, Ser2, and Ser3 genes, which produce distinct sericin isoforms via alternative splicing (Gulrajani *et al.,* 2008). Emerging genomic studies have also proposed the existence of additional sericin genes (e.g., Ser4, Ser5) and post-translational modifications such as glycosylation and phosphorylation, which enhance the heterogeneity and bioactivity of sericin (Zhaorigetu *et al.,* 2001; Kunz *et al.,* 2016; Wang *et al.,* 2024). This structural diversity underpins sericin’s multifunctional nature, enabling its applications in wound healing, moisturization, antioxidant therapy, and anti-aging cosmetics.

1. **Extraction Techniques**

The method used to extract sericin plays a crucial role in determining its structural integrity, molecular weight, and biological activity. Selection of the appropriate technique is essential for ensuring its suitability for cosmeceutical, pharmaceutical, and biomedical applications. Several extraction techniques have been explored, each with its own advantages and limitations.

* 1. **Hot Water Extraction**

Hot water extraction is still one of the most eco-friendly and widely used methods for isolating sericin from silk cocoons or silk waste. It typically involves boiling the material in water under controlled temperature and pressure, without any harsh chemicals making it a popular choice for green cosmetic formulations (Padamwar and Pawar, 2004). Recent studies have enhanced sericin extraction by employing autoclaving at 120 °C, resulting in higher protein yield and purity, along with preserved bioactivity (Baht *et al.,* 2024). However, keeping sericin exposed to high heat for too long can cause it to break down. This means the proteins become smaller and lose some of their beneficial properties, like antioxidant activity (Aramwit *et al.,* 2010). Another promising method is ultrasonic-assisted extraction, which uses sound waves to help separate the sericin at lower temperatures, saving energy and water while still keeping the protein mostly intact (Wang *et al.,* 2024).

* 1. **Alkaline and Acid Hydrolysis**

Alkaline (such as sodium carbonate or sodium hydroxide) and acid (such as citric acid) hydrolysis methods are still widely used for extracting sericin, mainly because they offer high yields and effectively break down the silk structure (Gulrajani *et al.,* 2008). Acid extraction, using mild organic acids like citric acid, has been proposed as a greener alternative. While it also provides good yields, it tends to degrade sericin into even smaller fragments than enzymatic or urea-based methods. Another issue is that both alkaline and acid extractions leave behind residual chemicals that must be thoroughly removed before the sericin can be used safely in cosmetics. Without proper purification such as dialysis or freeze-drying these residues can cause skin irritation or formulation instability (Wang *et al.,* 2024).

* 1. **Enzymatic Extraction**

Enzymatic extraction uses gentle, protein-digesting enzymes like papain or trypsin to break down the silk structure and release sericin without damaging its important functional groups. Unlike other chemical methods, this approach preserves sericin’s natural properties, including its antioxidant, anti-inflammatory, and moisturizing effects, making it especially suitable for skin-care and pharmaceutical applications (Li *et al.,* 2024; Sun and Hu, 2024). Recent studies have shown that using enzymes like papain under mild conditions (around pH 6-7 and 50-60 °C) can effectively separate sericin while keeping its bioactive structure largely intact (Sun and Hu, 2024). Another major advantage is that enzymatic extraction leaves behind very little chemical residue. This makes it a safer choice for products that come into direct contact with the skin, like creams, masks, or wound dressings (Wang *et al.,* 2023). However, it is worth noting that enzymatic extraction can be slower and more expensive, which may be a limitation for large-scale industrial use (Wang *et al.,* 2023).

* 1. **Ultrasound and Microwave Assisted Extraction**

Emerging physical extraction methods such as ultrasound-assisted extraction (UAE) and microwave-assisted extraction (MAE) have gained increasing attention in recent years due to their high efficiency, reduced environmental impact, and suitability for industrial-scale applications. These techniques facilitate the breakdown of silk fibers through mechanisms like acoustic cavitation (UAE) and dielectric heating (MAE), which enhance the release of sericin while preserving its structural and functional integrity, an important factor for biomedical and cosmetic uses. Recent studies have demonstrated that UAE improves protein recovery by disrupting fiber structures through mechanical vibration, while MAE accelerates solvent penetration and heating, significantly reducing processing time and energy consumption (Rashid *et al.,* 2023; Cai *et al.,* 2024). Moreover, both methods minimize solvent use compared to conventional extraction approaches, aligning with green chemistry principles. The gentle yet effective nature of these techniques makes them promising alternatives for sustainable sericin extraction, supporting cleaner production without compromising product quality (Li *et al.,* 2023; Zhang *et al.,* 2024).

1. **Applications in Cosmeceuticals**

Sericin, a natural protein derived from silk, has been drawing attention across the cosmetic, medical, and pharmaceutical industries not just recently, but for decades. Known for its remarkable moisture-retention capacity and gentle gelling properties, sericin forms a soft, protective film on the skin that enhances hydration and elasticity, making it a popular ingredient in moisturizers, serums, and hair care products (Kato *et al.,* 1998; Li *et al.,* 2023; Zhao *et al.,* 2024). Its ability to soothe and soften the skin lends well to anti-aging and anti-wrinkle formulations, especially for sensitive or irritation-prone skin (Padamwar and Pawar, 2004).

* 1. **Moisturizing Agent**

Sericin’s natural moisture-binding ability has long made it a compelling ingredient in skincare, even before the current wave of clean and bio-based beauty trends. As early as the late 1990s, researchers recognized sericin's hydrophilic nature and its capacity to form a lightweight, semi-occlusive film over the skin, effectively reducing transepidermal water loss while locking in hydration (Kato *et al.,* 1998). This breathable film not only reinforces the skin’s barrier function but also smooths and softens the surface, improving elasticity and overall texture (Padamwar and Pawar, 2004).

In recent years, sericin has gained renewed attention for its moisturizing properties, especially as consumer demand has shifted toward naturally derived, multifunctional ingredients. Newer studies confirm that sericin-enriched creams and gels significantly increase skin hydration and firmness, both in vitro and in clinical trials (Zhang *et al.,* 2023). Test subjects often report noticeably smoother, more supple skin after several weeks of use. Silk sericin has been shown to enhance skin hydration by promoting the production of proteins that strengthen the skin's moisture barrier, thereby improving its ability to retain key amino acids. This effect is particularly beneficial for dry skin or conditions like atopic dermatitis, leading to improved overall skin hydration and appearance (Okamoto *et al.,* 2011). Because of this powerful blend of hydration, protection, and compatibility with the skin's natural structure, sericin is now widely incorporated into moisturizers, serums, and anti-aging formulations designed to combat dryness and promote youthful skin (Wang *et al.,* 2023; Zhao *et al.,* 2024).

* 1. **Anti-Aging Effects**

Sericin has gained recognition as a powerful anti-aging ingredient, largely due to its strong antioxidant activity that helps neutralize reactive oxygen species (ROS), the unstable molecules responsible for oxidative stress and premature skin aging. This activity plays a key role in preventing the development of fine lines, wrinkles, and uneven pigmentation (Li *et al.,* 2024). Recent studies have shown that sericin boosts antioxidant enzyme levels like superoxide dismutase and glutathione peroxidase, which support the skin’s natural defenses and reduce cellular damage caused by environmental stressors (Mumtaz *et al.,* 2023). In addition to its antioxidant benefits, sericin also stimulates collagen synthesis, the protein responsible for maintaining skin firmness and elasticity. Increased collagen production helps improve skin texture, reduce wrinkle depth, and promote a more youthful appearance (Wang *et al.,* 2023). These combined effects make sericin a valuable component in modern anti-aging skincare, offering both protective and restorative benefits.

* 1. **Skin Soothing and Healing**

Sericin has shown great promise in skincare, particularly for soothing and healing irritated or damaged skin. Its natural anti-inflammatory properties help reduce redness, swelling, and discomfort by downregulating pro-inflammatory cytokines such as IL-6 and TNF-α (Munir *et al.,* 2023). In addition to calming inflammation, sericin plays an active role in accelerating skin repair by promoting keratinocyte migration and enhancing fibroblast proliferation key processes involved in wound closure and tissue regeneration (Qi *et al.,* 2023). Due to these therapeutic effects, sericin is increasingly incorporated into creams, gels, and hydrogel dressings formulated to support sensitive skin, facilitate post-procedural recovery, and improve overall skin integrity.

* 1. **Sunscreen and UV Protection**

Sericin’s ability to absorb ultraviolet light has been recognized since early foundational studies, which demonstrated its potential to attenuate UVB-induced oxidative stress and minimize photoaging signs like pigmentation and fine lines. Kumar and Mandal(2018) showed that sericin from *Antheraea assamensis* and *Philosamia ricini* significantly improves keratinocyte survival and reduces ROS, DNA fragmentation, and inflammatory cytokines (IL‑6, IL‑8) following UVA and UVB exposure. Additionally, combining sericin with traditional UV filters has been shown to enhance sunscreen photostability and antioxidant protection, offering dual-action defense, physical UV absorption paired with ROS neutralization. Functional textile studies also support sericin’s practical UV shielding: fabrics treated with sericin and chitosan achieved a UPF of ~16.8, demonstrating effective UV resistance in a bio-based system (Mondal and Sarkar, 2024). Together, these classic and modern findings highlight sericin as a multifunctional natural ingredient that adds both UV-blocking and photoprotective antioxidant activity to sun-care formulations.

* 1. **Hair care products**

Sericin is increasingly used in hair care products like shampoos, conditioners, and masks due to its ability to form a thin, protective coating around hair fibers. This coating helps reduce mechanical damage and split ends by strengthening the hair shaft and preventing protein loss. Silk sericin's affinity for keratin enables it to adhere to the hair surface, improving resilience and imparting a smoothing effect that reduces friction between strands (Das *et al.,* 2021). These multifunctional benefits make sericin a valuable active ingredient in modern hair care formulations aimed at both repair and protection.

1. **Sustainability and Economic Impact**

Sericin represents a strong example of how natural byproducts can be transformed into high-value, sustainable materials. Commonly obtained during the silk degumming process, sericin was historically discarded, contributing to waste water rich in organic matter and posing environmental challenges (Padamwar and Pawar, 2004; Gulrajani *et al.,* 2008). With growing interest in circular economy practices, this protein is now being actively repurposed, supporting zero-waste goals and enhancing the overall sustainability of silk production (Kunz *et al.,* 2016). This integrated approach supports full utilization of cocoon biomass, aligning with modern demands for clean, traceable, and biodegradable raw materials especially within the cosmetic and personal care sectors (Zhao *et al.,* 2024).

A circular economy emphasizes reusing by-products rather than discarding them, reducing environmental impact and conserving resources. Advancing research on sericin and its diverse applications is key to promoting sustainability, tackling resource depletion, and driving innovation across industries (Aad *et al.,* 2024). Through sustainable sourcing and innovative reuse, sericin has evolved from a waste material into a key component of eco-conscious production strategies.

1. **Challenges**

Sericin is showing great promise across industries from skincare to wound healing but turning that promise into widespread, everyday use still comes with a few hurdles. To truly unlock its potential, there are some practical challenges that need thoughtful solutions.

One of the biggest challenges is scaling up production. Extracting sericin consistently, with high purity and functional stability is not easy. The quality can vary quite a bit depending on the silk cocoon source, how it is processed, and the method used for extraction (Aramwit *et al.,* 2010; Kunz *et al.,* 2016). There is also the issue of stability. Sericin tends to degrade when exposed to air, light, or certain pH conditions, which can reduce its effectiveness over time. Researchers have explored ways to overcome this, like encapsulating sericin in protective carriers or adjusting formulation conditions to keep it stable (Padamwar and Pawar, 2004; Wang *et al.,* 2023). These solutions are promising, but they can also make the final product more complex and costly to produce.

From a regulatory standpoint, things are still a bit fragmented. While sericin is generally considered safe, there is no unified global framework for how cosmeceutical ingredients like this should be approved. Different countries have different rules, testing requirements, and documentation standards, which can slow down international rollout and increase development costs (Gulrajani *et al.,* 2008; Zhao *et al.,* 2024). Another obstacle is awareness or rather, the lack of it. Despite its impressive benefits for skin hydration, elasticity, and repair, sericin is not yet as well-known as ingredients like collagen or hyaluronic acid. Consumers rarely recognize sericin on a label or understand its benefits at a glance. Success will depend on collaborative efforts between researchers, formulators, silk producers, and brands. With better production methods, clearer regulations, and smarter communication, sericin can move from niche ingredient to everyday essential in both skincare and health-related applications.

1. **Future Prospects**

The growing interest in sericin is driving innovation on multiple fronts, as researchers and formulators look for ways to enhance its functionality and expand its applications. Several emerging strategies show great promise in addressing current limitations and pushing sericin-based products into the next generation of skincare and biomedical solutions.

One promising area of exploration is when combined with other beneficial ingredients, sericin-loaded nanocarriers may offer synergistic effects, enhancing product performance and stability (Wang *et al.,* 2023).

Another exciting direction is the bioengineering of sericin to fine-tune its structure and function. By applying recombinant DNA techniques or protein design, scientists are working on creating sericin variants with more predictable molecular weights, enhanced solubility,andtailored bioactivities (Kunz *et al.,* 2016). These modifications can help address inconsistencies in natural extraction and improve compatibility across various formulations. To move from lab to market, rigorous clinical testing is essential. While sericin has shown strong results in vitro and in animal models, more human trials are needed to confirm its long-term safety and effectiveness, especially in sensitive skin or therapeutic contexts. Well-designed studies will not only support regulatory approvals but also help distinguish scientifically backed sericin-based products in a market where consumers increasingly seek evidence-based skincare (Aramwit *et al.,* 2010).

Looking ahead, the integration of artificial intelligence (AI) with formulation science opens the door to personalized sericin-based skincare. AI tools can analyze vast datasets, including skin type, lifestyle, environment, and user feedback, to help chemists design customized sericin formulations that match individual needs and preferences (Zhao *et al.,* 2024). This technology-driven approach aligns perfectly with the shift toward personalized beauty and could make sericin a standout ingredient in customized skin solutions. Altogether, these future directions reflect a dynamic and evolving field. With continued research, cross-disciplinary collaboration, and smart use of emerging technologies, sericin has the potential to play a key role in the next generation of high-performance, sustainable, and personalized skincare.

1. **Conclusion**

Sericin is a promising, eco-friendly biomaterial with proven moisturizing, antioxidant, and healing properties, making it highly suitable for cosmeceutical applications. Its valorization not only reduces silk industry waste but also supports sustainable innovation. The transition of sericin from silk waste to a functional skincare ingredient marks a paradigm shift in natural resource utilization. While challenges like scalability, scaling and regulatory hurdles remain, advancements in extraction methods, formulation technologies, and clinical validation are paving the way for broader adoption. With growing consumer demand for sustainable and biologically active ingredients, sericin stands out as a high-performance, natural alternative for next-generation skincare products.

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