International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 14-11-2024, Accepted: 15-12-2024, Published: 30-12-2024
Volume 9, Issue 12, 2024, Page No. 202-206

Exploring the role of silk-producing moths (*Bombyx mori*) in cosmetic industry: An overview of taxonomy, composition, extraction methods, applications, and challenges and future prospects

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Abstract
Silk-producing moths (*Bombyx mori*) are traditionally known for their capacity to deliver high-quality silk fibers, but later research has uncovered their potential in the cosmetic and therapeutic businesses. The two essential proteins found in silk, fibroin and sericin, have various bioactive properties, counting antioxidant, anti-inflammatory, antimicrobial, and moisturizing effects. These properties make silk proteins important in the advancement of skincare items, wound healing medications, and drug delivery systems. Fibroin, due to its great biocompatibility and biodegradability, is especially suited for applications in tissue engineering, whereas sericin is broadly utilized for its moisturizing and skin-soothing benefits. As consumers progressively request natural and sustainable ingredients, silk-derived compounds offer an eco-friendly elective to synthetic items. This review investigates the bioactive properties of fibroin and sericin, their applications in cosmetics and therapeutics, and the methods of silk protein extraction. It moreover discusses the challenges of silk production, showcase patterns, and future directions for the advancement of silk-based products. The developing interest in *Bombyx mori* silk highlights its potential as a versatile and sustainable resource, with the capacity to revolutionize industries centered on progressing human wellbeing and wellness.

Keywords: *Bombyx mori*, taxonomy, bioactive compounds, extraction, cosmetic, therapeutic applications

Introduction
Silk-producing moths, especially *Bombyx mori*, have long been recognized for their contribution to the textile industry, creating silk fibers that have been prized for centuries due to their quality, luster, and luxurious feel. In any case, the restorative and cosmetic potential of these silks has as it were recently started to capture the attention of researchers and industries, growing the applications of silk beyond conventional fabrics. The two fundamental bioactive compounds found in *Bombyx mori* silk fibroin and sericin have shown promising restorative, cosmetic, and therapeutic properties, making them important resources in areas such as regenerative medicine, wound healing, drug delivery systems, and cosmetics.

Silk proteins are basically composed of fibroin, which shapes the central core of the silk fiber, and sericin, a water-soluble protein that coats the fibroin fibers. These proteins have one of a kind bioactive property, counting antioxidant, anti-inflammatory, antimicrobial, and moisturizing effects, all of which have gathered consideration in the advancement of novel cosmetic and therapeutic products. Fibroin, due to its fabulous biocompatibility and biodegradability, has been considered broadly for its potential in tissue engineering, drug delivery, and wound healing applications. Sericin, on the other hand, has moisturizing, antioxidant, and skin-soothing properties, making it an amazing ingredient for skincare formulations [1, 2].

The expanding worldwide demand for natural, economical, and eco-friendly items has further supported the request of silk proteins. *Bombyx mori* silk is biodegradable, non-toxic, and effortlessly sourced, making it an ecologically friendly elective to synthetic compounds commonly utilized in different industries. As consumers ended up more conscious of the ingredients in their cosmetic and therapeutic items, the drift towards utilizing natural resources like silk proteins aligns with broader shifts toward sustainability and ethical production [3].

The restorative and cosmetic potential of *Bombyx mori* silk extends across a range of applications. In the cosmetic industry, silk proteins are being consolidated into skincare products, offering benefits such as improved hydration, progressed skin elasticity, and assurance from natural damage. These proteins are moreover utilized in anti-aging formulations, advancing collagen production and decreasing the appearance of fine lines and wrinkles. Moreover, silk-based products are utilized in hair care, where they give nourishment, shine, and assurance to the hair strands [4].

In pharmaceutical, the bioactive properties of silk fibroin have opened up modern frontiers for tissue engineering and regenerative medicine. Silk fibroin scaffolds have appeared guarantee in advancing the recovery of damaged tissues, such as skin, bone, and cartilage, due to their capacity to back cell attachment and growth. Silk proteins too have potential in controlled drug delivery systems, where they can be utilized to encapsulate and slowly release drugs to targeted sites, progressing the adequacy of medicines whereas minimizing side effects [5].

Despite the promising applications, the broad utilize of silk proteins in these industries faces a few challenges. The generation of silk proteins can be resource-intensive, and the prepare of silk extraction requires cautious optimization to keep up the bioactivity of the compounds. Additionally, whereas there is expanding interest in the restorative potential of silk, regulatory approval and quality control for pharmaceutical and therapeutic applications remain critical hurdles [6].

This review points to give a comprehensive overview of the therapeutic and cosmetic applications of *Bombyx mori* silk, centering on the bioactive compound's fibroin and sericin extracted from silk and their different parts in various businesses. The review will cover the methods of silk protein extraction, the bioactivity of these compounds, their applications in cosmetics and therapeutics, the market trends encompassing silk-based products, and the future directions of research in this field. Through this detailed investigation, the objective is to highlight the immense potential of silk proteins in improving human wellbeing and wellness whereas advancing sustainability in industrial applications.

Taxonomy of *Bombyx mori*:

Silk-producing moths, *Bombyx mori*, are subdued insects from the family Bombycidae, popular for their generation of silk, a common fiber that has been prized for thousands of a long time. The basic bioactive compounds, sericin and fibroin, extricated from silk, are broadly utilized in the cosmetics industry for their hydrating, anti-aging, and skin-repairing properties. Nearby to China and by and large related with the ancient Silk Street, *Bombyx mori* is directly created in silk-producing countries such as India, Japan, and Brazil for the large-scale production of both textiles and cosmetics-grade silk proteins [7, 8].

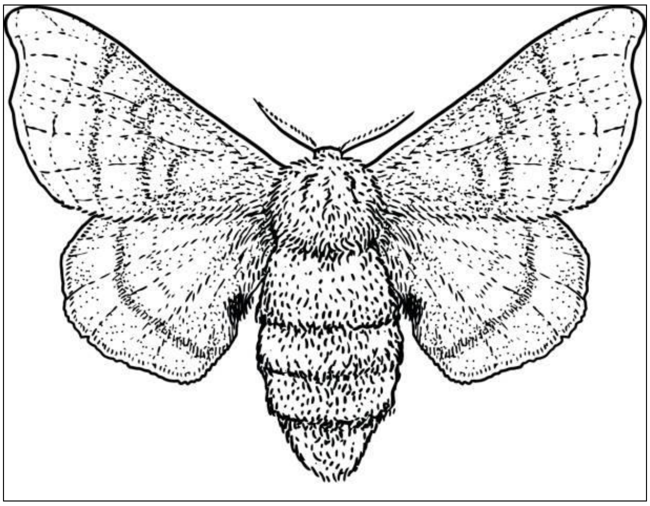

Fig 1: *Bombyx mori*

- **Kingdom:** Animalia
- **Phylum:** Arthropoda
- **Class:** Insecta
- **Order:** Lepidoptera
- **Family:** Bombycidae
- **Genus:** Bombyx
- **Species:** *Bombyx mori*
- **Common name:** Domesticated silk moth

Life cycle of *Bombyx mori*

The life cycle of *Bombyx mori* incorporates four particular stages: egg, larva, pupa, and adult moth. The larval stage is especially noteworthy due to its production of silk, comprising two key proteins—sericin and fibroin—along with other important metabolites.

1. **Egg stage:** Tiny, circular eggs are laid by adult moths and require controlled natural conditions to hatch.
2. **Larval stage:** The silkworms feed solely on mulberry leaves, collecting supplements that contribute to silk production. During this stage, the silk organs discharge fibroin (inner basic protein) and sericin (external defensive protein) to shape cocoons.
3. **Pupal stage:** The cocoon, fundamentally made of silk, encases the pupa. This stage is pivotal for collecting silk and related bioactives.
4. **Adult stage:** The moth rises from the cocoon but does not nourish or produce silk, as its essential part is reproduction [9].

Bioactive compounds in *Bombyx mori*:

Bombyx mori, the mulberry silkworm, is not only significant for silk production but too a critical source of different bioactive compounds that have earned consideration for their potential wellbeing benefits. The essential bioactive components found in *Bombyx mori* incorporate fibroin and sericin, along with a variety of other supplements and metabolites.

Key bioactive compounds

Fibroin: Comprising around 75-83% of the silk, fibroin is the basic protein that shapes the centers of silk fibers. It is known for its great biocompatibility and has been considered for applications in tissue engineering and drug delivery systems.

Sericin: This water-soluble protein accounts for 17-25% of the silk and serves as a defensive coating for fibroin. Sericin shows moisturizing, antioxidant, and anti-inflammatory properties, making it advantageous for restorative applications.

Nutritional content: Silkworm pupae are wealthy in protein (51-55%) and lipids (25-32%), containing basic amino acids, fatty acids, and different vitamins (C, E, K, D, and B12) which contribute to their dietary value.

Phenolic compounds: A range of phenolic acids (e.g., ferulic acid, cinnamic acid) and flavonoids (e.g., quercetin, luteolin) have been distinguished in silkworm pupae. These compounds have antioxidant properties that may have restorative implications.

Other metabolites: The silk cocoon too contains secondary metabolites such as alkaloids and coumarin subordinates, which are famous for their potential wellbeing benefits [10, 11].

Extraction techniques of bioactive compounds from *Bombyx mori*:

The extraction of bioactive compounds from *Bombyx mori* has picked up expanding importance due to the developing request for natural and sustainable ingredients in the cosmetic and pharmaceutical businesses. Silk proteins such as fibroin and sericin, as well as other bioactive metabolites, require proficient and inventive extraction techniques to protect their properties and maximize their therapeutic potential.

Extraction of silk Proteins: Sericin and fibroin:
In addition to water extraction, sericin can too be extracted utilizing alkaline or acidic solutions. Alkaline extraction, frequently utilizing sodium hydroxide, makes a difference break down the protein structure, whereas acidic extraction (utilizing acids such as citric acid) can further improve the discharge of sericin. For fibroin extraction, the sericin is expelled utilizing these strategies, leaving behind the insoluble fibroin [12, 13].

Extraction of chitin and chitosan:
To extract chitin, the exoskeleton is to begin with treated with an acidic solution (ordinarily hydrochloric acid) to evacuate minerals, taken after by a fundamental treatment (such as sodium hydroxide) to eliminate proteins. The remaining chitin can at that point be further prepared into chitosan
Chitosan is created by deacetylating chitin utilizing an alkaline solution, ordinarily sodium hydroxide, at raised temperatures. This process decreases the acetyl group content in chitin, changing over it into chitosan [14].

Extraction of fatty acids and lipids:
Solvent extraction, utilizing solvents like hexane, ethanol, or chloroform, is one of the most common strategies for extricating lipids from *Bombyx mori*. The fat body is to begin with ground and at that point drenched in the solvent, which breaks up the lipids. The solvent is at that point evaporated, clearing out behind the concentrated lipids [15].

Therapeutic potential of silk-producing Moths (*Bombyx mori*) in cosmetics and skincare:
Silk-producing moths, especially *Bombyx mori*, have long been recognized for their profitable commitment to the textile industry, but later research has highlighted their promising part in the cosmetic and skincare businesses. The bioactive compounds determined from these moths, particularly the silk proteins (fibroin and sericin), have a wide extend of restorative properties that make them important ingredients in skincare formulations. These properties incorporate moisturization, wound healing, anti-aging, and anti-inflammatory effects.

Skin hydration and moisturization
One of the key benefits of *Bombyx mori* silk proteins, particularly sericin, is their capacity to hydrate and moisturize the skin. Sericin has amazing water-retaining properties, making it a characteristic humectant in corrective formulations. When applied to the skin, sericin shapes a lean, defensive layer that locks moisture in, keeping the skin hydrated for longer periods.
Sericin's hydrophilic nature permits it to absorb and retain water molecules, giving profound moisturization. It makes a difference in reestablishing the skin’s natural moisture balance, which is especially useful for people with dry or sensitive skin [16].

Anti-aging effects
The anti-aging properties of *Bombyx mori* silk proteins are credited to their capacity to advance skin elasticity, collagen generation, and skin regeneration. Fibroin, the essential protein in silk, has been appeared to have antioxidant properties that can offer assistance combat free radical harm, a major donor to skin aging [17].

Wound healing and skin regeneration
Another momentous therapeutic potential of *Bombyx mori* silk is its capacity to promote wound healing and skin regeneration. Silk proteins, especially fibroin, have been found to back tissue repair by advancing cell development and encouraging the healing process. This makes silk-based items effective for treating minor cuts, burns, and other skin wounds [18].

Anti-inflammatory and soothing effects
Silk proteins, especially sericin, show anti-inflammatory properties that can offer assistance relieve irritated or inflamed skin. This makes them valuable in formulations for sensitive skin conditions, such as dermatitis, psoriasis, or rosacea. The calming impact of sericin makes a difference diminish redness and swelling whereas reestablishing the skin's natural barrier function [19].

Antimicrobial and antioxidant properties
Silk proteins too illustrate antimicrobial and antioxidant properties, which are useful for avoiding infections and ensuring the skin from oxidative stress. The antioxidant action of *Bombyx mori* silk can offer assistance neutralize free radicals that harm skin cells and quicken the aging process. Additionally, the antimicrobial properties of sericin offer assistance secure the skin from bacterial diseases, making it an amazing choice for acne treatment and overall skin wellbeing [20].

Cosmetic formulations using silk proteins
Given the flexibility and therapeutic potential of silk proteins, *Bombyx mori* has gotten to be a critical ingredient in a wide extend of cosmetic formulations. These formulations can target different skin concerns, from anti-aging to acne treatment, and offer a more natural and economical elective to synthetic chemicals. Sericin is regularly utilized in formulations pointed at moisturizing, relieving, and protecting the skin. It is especially effective in hydrating masks, serums, and creams designed for dry or sensitive skin. Fibroin, with its antioxidant and anti-aging properties, is commonly consolidated into products like anti-aging serums, skin regeneration creams, and firming medicines [21, 22].

Challenges and future prospects of *Bombyx mori* silk proteins in the cosmetic and therapeutic Industries
The challenges and future prospects of *Bombyx mori* silk proteins in the cosmetic and therapeutic businesses are multifaceted, reflecting both the potential and restrictions of silk production. One major challenge is sustainability concerns, as conventional silk production includes the death of billions of silkworms every year, raising ethical issues. This has driven to expanded interest in elective strategies, such as Ahimsa silk, which claims to be more sympathetic but yields less silk and is less commercially viable.
Additionally, *Bombyx mori* is exceedingly sensitive to climatic variables like temperature and humidity, which can altogether influence silk quality and yield. Inconstancy in natural conditions postures a challenge for reliable production. Current industrial extraction forms for silk

fibroin moreover have restrictions related to sustainability and product quality, requiring more proficient strategies that minimize natural affect whereas maintaining high-quality yield. Moreover, the utilize of silk proteins in cosmetics and therapeutics faces regulatory challenges, particularly concerning safety assessments and approval forms for modern formulations determined from animal products.

Looking to the future, biotechnological progresses such as recombinant DNA technology hold guarantee for creating fibroin sustainably without depending on silkworms. This may lead to standardized production forms that diminish ethical concerns whereas keeping up the desirable properties of silk proteins. Research proceeds to investigate the differing applications of silk proteins in cosmetics and medicine, counting their parts in wound healing, anti-aging treatments, and as natural moisturizers. The developing demand for natural ingredients in cosmetics may drive assist interest in silk proteins [23, 24, 25, 26].

Conclusion

Bombyx mori silk proteins, especially sericin and fibroin, speak to a momentous resource with broad applications in the cosmetic and therapeutic businesses. Their one-of-a-kind properties, counting amazing moisturizing, anti-aging, antioxidant, and antimicrobial impacts, make them valuable ingredients for tending to a wide extend of skin concerns, from hydration to wound healing. The developing customer demand for natural and economical items encourage enhances the request of silk proteins as options to synthetic chemicals.

However, the industry faces noteworthy challenges related to sustainability, ethical production hones, and regulatory obstacles. Conventional silk production raises concern approximately the welfare of silkworms and environmental impacts. As mindfulness of these issues increments, there is a squeezing need for inventive approaches that prioritize humane hones and decrease ecological footprints.

Future prospects for *Bombyx mori* silk proteins are promising, driven by headways in biotechnology that might empower sustainable production strategies and improve the quality of silk-derived products. Moreover, continuous research into the therapeutic potential of silk proteins may lead to modern formulations that tackle their benefits in inventive ways. As the market evolves, grasping these opportunities whereas tending to existing challenges will be pivotal for maximizing the potential of *Bombyx mori* in advancing skin wellbeing and wellness economically and ethically.

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