Transformation of Waste Sericin into Value Added Resources and Its Application in Food Industry

Shubhajit Shaw

Department of Sericulture, Raiganj University,

Raiganj, Uttar Dinajpur, India

**ABSTRACT**

Sericin, a silk protein that is typically discarded in substantial amounts during the time of cocoon boiling of silk reeling process may be a valuable source to be used as a functional food of food items in food packaging as well as other food sectors. Sericin derived from silk cocoon contains a variety of important amino acids, including aspartic acid, glycine, and serine. Similarly, sericin is very hydrophilic, which imparts beneficial biological and biocompatible qualities such as antibacterial, antioxidant, anticancer, and anti-tyrosinase activity. Sericin when combined with other biomaterials, it has proven to be successful in the production of films, coatings, and packaging materials. The features of sericin materials and their possible application in food-sector enterprises are reviewed critically in this paper.

Keywords: application, food, preservation, sericin.

**I. INTRODUCTION**

Silk fibres which are widely recognized as the queen of textiles play an important role in the global textile market due to their unique lustre and elegance. The process of silk reeling involves cocoon boiling, reeling, re-reeling, silk processing and finally making excellent silk garments. The boiling of the cocoon facilitates the degumming of sericin, the gluey substance present in the cocoon, thus helping to unwind the silk filament in the silk reeling wheel. Generally, a cocoon consists of 80% fibroin and 20% of sericin content. It is estimated that 50,000 MT of such sericin being generated as silk-industrial waste annually by the global silk industry cause serious environmental pollution and health hazards. (Seo et al., 2023) However, sericin is a highly proteinous substance, therefore, it can be applied to make several highly value-added products, particularly to the food, cosmetic and biomedical industrial sectors. The present study provides a critical review of the utilization of waste sericin and its various application, particularly to the food industry sector (Kunz et al., 2016).

**II. PROPERTIES OF SERICIN**

Sericin mainly has three types of properties that include biophysical, biochemical, and biological characteristics (Figure 1).

**Biophysical properties**

**Water Solubility:** Sericin, a protein found in both mulberry and non-mulberry silk, possesses substantial hydrophilicity and water solubility, primarily because of its amino acid composition. It has random coils, a ß sheet, and a low α helix content as secondary structures. The structure is influenced by temperature as well; whereas high water temperatures lead to insoluble development, low temperatures allow it to change from random coil to ß sheet, which is advantageous for gel formation followed by biomaterial uses (Reddy and Aramwit, 2021).

**Thermal Stability:** The thermogravimetric study evaluates sericin's mass stability with changes in temperature and time. A study has been done on the stability of sericins at different temperatures in both mulberry (B. mori) and non-mulberry (A. mylitta, A. assamensis, and S. ricini) silkworms (Dash et al., 2008). It has been claimed that non-mulberry sericins exhibit greater stability than mulberry sericin. S. ricini sericin has the highest level of stability. This characteristic shows that the structures and characteristics of sericins of various species vary (Reddy and Aramwit, 2021).

**UV protection:** Sericin has proven to be able to protect cells against UV radiation. Sericin is effective in reducing skin oxidative stress, inhibiting UVB-induced apoptosis, and absorbing UVC rays in investigations of the photoprotective properties of B. mori (Reddy and Aramwit, 2021, Dash et al., 2008). Non-mulberry sericin was observed from A. assamensis and S. ricini to improve cell viability against UVA and UVB more than B. mori sericin. The sericin from B. mori boosted UVA protection alone, but the sericin from A. assamensis promoted collagen production from UVA and UVB exposure. This information suggests that non-mulberry sericins are more photoprotective than mulberry sericin (Kumar et al., 2018)

**Adhesion Properties:** During the phases of development, particularly the cocoon phase, the adhesive property has significance for silkworms. The adhesive characteristic is useful for cementing the cocoon scaffolding and connecting the cocoon to a tree limb through floss or a peduncle (Reddy and Aramwit, 2021).

**Biochemical Properties:**

**Antioxidant:** Sericin has been extracted, and tests utilising chemiluminescence, 1, 1-diphenyl-2-picrylhydrazyl, electron spin resonance, O2 radical absorbance capacity, and other procedures have revealed its antioxidant characteristics [28, 29]. Compared to white cocoons, sericin isolated from yellow-green cocoons demonstrated better antioxidative activity. The sericin protein extracts have varying diameters for the cocoons of different colour strains, according to earlier research. The sericin from *B. mori* with the highest antioxidant activity was demonstrated using the autoclaving method, while the sericin with the lowest antioxidant activity was obtained using the acid approach. Furthermore, the antioxidant activity of sericin derived from waste materials produced by *Antheraea* spp. (Takechi et al., 2014).

**Anti tyrosinase:** The tyrosinase protein catalyses an oxidation process in monophenols, transforming them into diphenols and quinones. Browning is a common side effect of this procedure in fruits and vegetables. Cancer and disorders such as Parkinson's are affected by tyrosinase (Xing et al., 2016). Sericin from casings has been shown to have anti-tyrosinase activity in several investigations, and the activity varies depending on the strain and extraction technique. A study shows that the method for the extraction of sericin through Bombyx mori was compared using various techniques, including urea, temperature, acid, and alkaline chemicals, which contribute to the inhibition of tyrosinase. Sericin's strongest antityrosinase activity was seen when it was extracted with urea. This is due to the abundance of valine and arginine, both of which have a strong affinity for tyrosinase (Reddy and Aramwit, 2021).

**Anti elastase:** A proteolytic enzyme called elastase works to break down elastin, which causes the skin to lose its elasticity. UV light can stimulate the production of elastase protein. *B. mori* sericin was isolated from several strains. A study identified the anti-elastase action of cocoons for the first time. Sericin from *Antheraea spp*. (tasar), a non-mulberry showed anti-elastase action. Interestingly, tasar sericin isolated from silk industry waste preserved anti-elastase action. Sericin's antielastase activity is useful for sun protection. As a result, it was advocated that sericin be used in cosmetic items (Reddy and Aramwit, 2021).

**Anti-lipid-peroxidase:** Kato et al. studied the sericin protein for its anti-lipid peroxidation action for the first time in 1998Cocoon sericin extracted by heating prevented lipid peroxidation by thiobarbituric acid reactive substances (TBARS) and was associated with diene assays in an in vitro test using rat brain homogenization [34]. Non-mulberry sericins have also been found to decrease lipid peroxidation.The activity against lipid peroxidation was found to be 75-90% depending on the amount of sericin used. (Kumar and Mandal, 2019). However, the anti-lipid peroxidation activity was unaffected by the extraction procedures, including autoclaving and alkali. The action is sustained by a variety of sericin sources, including cocoons and waste products from the silk industry. However, the extraction procedure had an impact on its activity (Reddy and Aramwit, 2021).

**Biological Activities**

**Antibacterial activity:** Sericin, a protein present in both mulberry and non-mulberry silk, has been investigated for antibacterial response against *E. coli*, *S. aureus*, and *P. aeruginosa*. The quality and manner of extraction of sericin have an impact on its antibacterial capabilities. Pure sericin has antibiotic-like action against S. aureus despite having extremely little activity against *P. aeruginosa* and *S. aureus*. Sericin from the autoclaving preparation had little effect on *S. aureus* but did not affect *E. coli* or *P. aeruginosa*. Sericin has been shown to reduce biofilm development; however, the technique of extraction influences its efficacy. In terms of inhibitory and disruption effects, urea-extracted sericin had the greatest potential anti-biofilm action for Streptococcus mutants. Heat- and acid-extracted sericins inhibited biofilm development in a dose-dependent manner, but alkaline-extracted sericin had no inhibitory or disruptive effects on the bacterial biofilm. Sericin's changed structure may destabilize the bacterial cell wall, resulting in membrane breakdown and cell death. The kind of silkworm and the technique of processing are important variables in sericin selection (Aramwit et al., 2020). Antibacterial activity may not be the most important attribute, but it exhibits a wide range of bioactivity qualities for medicinal purposes. Combining sericin with other antibacterial bioactive compounds can boost its activity and increase the quality of biomaterials. Sericin-derived biomaterials have been coupled with biopolymers, and chemical agents, to improve their antibacterial and biological capabilities (Reddy and Aramwit, 2021).

**Anti-inflammatory properties:** Several investigations have found that B. mori sericin has anti-inflammatory properties. In a study of sericin therapy in rat wounds, it was shown that sericin initially increased the activity of pro-inflammatory cytokines such as tumour necrosis factor- α (TNF-α) and interleukin-1 (IL-1) (Aramwit et al., 2013). However, after seven days of long-term medication, the inflammation did not worsen. Sericin produced inflammation at the initial phase of therapy in this trial, but it did not speed up the course of wound inflammation. Sericin's anti-inflammatory effect might be employed for a variety of applications, including wound healing, nano micelles for tumour therapy, and drug delivery nanoparticles (Reddy and Aramwit, 2021).

**Collagen Production:** Sericin has been documented to stimulate fibroblast cell proliferation as well as collagen synthesis. It has been shown to stimulate fibroblast cell growth. Sericin obtained using four different extraction procedures (heat, urea, acid, and alkali) promoted collagen synthesis at different concentrations (Aramwit et al., 2013). On the other hand, the heat extraction approach showed the maximum stimulation of collagen production. Sericin's amino acid content influences collagen synthesis's efficacy. The amino acid contents of several silkworm strains were discovered. The great amount of methionine and cysteine residues in sericin protein promotes collagen synthesis (Reddy and Aramwit, 2021).

**III. APPLICATION OF SERICIN IN FOOD-SECTOR INDUSTRIES**

**Food-Packaging and Food-Coating Material:** Research suggests that over 800 million people globally suffer from malnutrition, and roughly 40% of newly harvested and domestically produced goods end up wasted. If we can increase the shelf life of food by even just one week, it would be a significant benefit to food production and agricultural industries. This would also have a positive impact on reducing the amount of waste in the world, especially as 30% of food purchased in stores goes uneaten. (Seo et al., 2023). Plastic pollution is a growing concern, and researchers have identified natural and biodegradable food packaging solutions as an alternative to synthetic polymers. Synthetic polymers are harmful to the environment as they are nonrenewable and nonbiodegradable. The use of biodegradable polymers can help mitigate these concerns (Low et al., 2022). Biopolymers are a favourable option as they are not only biodegradable but also readily available, renewable, nontoxic, and can be derived from various natural sources. Therefore, scientists are conducting research on different types of biopolymers to characterize, understand their properties, and create food packaging materials from raw materials like proteins, lipids, and polysaccharides to replace synthetic polymers. Protein-based products, for example, can improve food quality and shelf life while also being environmentally friendly (Seo et al., 2023). The affinity and hydrophobicity/hydrophilicity of sericin films are influenced by the polarity of sericin. The use of higher-polarity sericin leads to the formation of a sericin layer with higher moisture content (Meerasri et al., 2022). Conversely, the addition of sericin hydrolysate to sericin film reduces both moisture content and molecular weight, which increases water-vapour permeability (Meerasri et al., 2022). Moreover, the addition of sericin hydrolysate results in increased antioxidant activity, polyphenols, and alkaloids production, as well as overall phenolic content, due to strong acid hydrolysis (Meerasri et al., 2022). The physical properties of sericin film can also be improved by reinforcing it with nanocelluloses, such as bamboo-derived cellulose nanofibrils (Kwak et al., 2018). The combination of the antioxidant activity of sericin film with bamboo-derived cellulose nanofibrils shows promise (Kwak et al., 2018). Another researcher discovered that utilising a sericin-based edible covering material containing chitosan, aloe vera, and glycerol has the potential to increase tomato storage life at 25 degrees Celsius and 70% relative humidity. In postharvest situations, it is possible to preserve the same amount of fruits and avoid ageing when compared to uncoated fruits. Additionally, ATR-FTIR analysis demonstrates that the coating material has no effect on the fruit's structure (Tarangini et al., 2022). Another study found that using glycine as a plasticizer resulted in sericin films with elongation properties. Glycine acts synergistically with water molecules on the sericin film, increasing its elasticity, and as the amount of glycine in the sericin film increased, the moisture level and -sheet structure also increased moderately, so enhancing its elasticity.

Tarangini et al., 2022 evaluated the effect of sericin-based edible coatings on the quality and shelf-life of tomatoes held for 40 days at a temperature of 25°C and relative humidity of 70%. The results showed that using a sericin-based coating material reduced weight and firmness deficits in the tomatoes, as shown in Figure 2 A-C. Furthermore, as storage time increased, the titratable acid level increased, while the pH, total antioxidant content, total phenol content, total soluble solid content, and lycopene concentration kept being lower relative to untreated tomatoes (Tarangini et al., 2022). Oh et al., 2021 carried out another study that indicated the feasibility of using sericin in food packaging. Sericin films containing strong crosslinks were employed to make glucose and heat treatment, boosting sericin's restricted physicochemical capabilities by triggering the sericin-glucose Maillard reaction (Oh et al., 2021). The author studied the hydrophilicity of the sericin film layer using the contact angle, which is utilised to assess the hydrophilic properties of the polymer layer (Oh et al., 2021). The inherent deficiencies of the sericin film, such as mechanical characteristics and waterproofing, had been substantially enhanced as the chemical crosslinking responses depend on the Maillard reaction developed, according to the author, and the sericin film was additionally equipped with protection from UV rays and antioxidant characteristics (Oh et al., 2021). So, by using glucose to form a sericin coating, food oxidation is reduced. Food oxidation is therefore decreased by employing glucose to generate a sericin coating. Another study by Me et al., 2022 demonstrates that when a mixture of silk, chitosan, and carbon dots is used for storing food (post-harvest litchi preservation), it appears to prevent nutrient loss during storage and retain the higher quality of the litchi fruit. A film was formed via the combination of sericin with agarose, to increase its mechanical characteristics. After being coated with polydopamine, which has high adhesive properties independent of surface features, Ag/ZnO nanoparticles were collected (Li et al., 2020). As a result, the coating developed displayed exceptional antibacterial activity against *E. coli* (+*ve*) and *S. aureus* (-*ve*). As a result, linking the sericin/agarose film with Ag/ZnO increases the mechanical characteristics and exceptional antibacterial activity. Polymeric films with similar qualities might be utilised to cover different surfaces to kill bacteria (Seo et al., 2023).

**Other Food Applications of Sericin:** Sericin has numerous applications in the food industry, including as a bread additive. Studies have shown that sericin can be added to bread at a dose of 2-4 grams per kilogram of flour to maintain its texture and taste while reducing its height, specific volume, and colour. Additionally, sericin can be used as an emulsifying agent in salad dressings, as it has no immunogenic properties and can be a suitable alternative to natural emulsifiers such as egg yolk and casein. (Takechi and Takamura, 2014, Seo et al., 2023)

**IV. LIMITATIONS AND PROSPECTS OF USING SILK SERICIN**

Sericin has a few limitations that make it unsuitable for future use in food-related industries. This also applies to its use in food packaging, which is impeded by its poor mechanical properties due to sericin self-aggregation, which causes weak mechanical strength. Furthermore, due to its hydrophilic nature, it is inappropriate for use in a water environment, which is a key constraint that prohibits its application in a variety of industries. Furthermore, the powder sericin's limited solubility in a solvent and the terrible scent of silkworm chrysalises are barriers to its widespread use in nutritious and functional foods and supplements. (Table 1).

**V. CONCLUSIONS AND FUTURE PROSPECTS**

Sericin is a protein generated spontaneously by the B. mori silkworm insect. It is a water-soluble glycoprotein that makes up around 25-30% of a silk cocoon. Sericin's characteristics vary depending on the technique of extraction, and it has a wide molecular weight range of 10-400 kDa. Sericin comprises both hydrophobic or hydrophilic amino acids, which confer antibacterial, antioxidant, anticancer, antitityrosinase, anti-inflammatory, and anti-ageing properties. When coupled with other biomaterials, sericin has a wide range of uses, notably in the food sector. According to studies, sericin protein has few side effects and allergies, making it a promising functional protein for further investigation in a variety of fields.

**Table 1: Prospects and limitations of sericin-based food-packaging materials**

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| Prospects and Major findings | Limitation Addressed | Reference |
| The shelf life of tomato extended significantly by applying sericin-based edible coating supplemented with including chitosan, aloe vera, and glycerol compared to uncoated one. | Low hydrophobicity of sericin in a water-based environment. | Tarangini et al. (2022) |
| The shelf life of food is extended by the combination of glucose and sericin | Oh et al. (2021) |
| The physical properties of sericin film can also be improved by reinforcing it with nanocelluloses, such as bamboo-derived cellulose nanofibrils | Sericin is prone towards self-aggregation due to poor mechanical properties. | Kwak et al. (2018) |
| Linking the sericin/agarose film with Ag/ZnO increases the mechanical characteristics and exceptional antibacterial activity. | Li et al. (2018) |
| A mixture of silk, chitosan, and carbon dots is used for storing food (post-harvest litchi preservation), it appears to prevent nutrient loss during storage and retain the higher quality of the litchi fruit. | The particle size of extracted sericin is large in size and uneven in nature. | Me et al. (2022) |

**Figure 1: Properties of Sericin**



**Figure 2: (A) Effect of sericin-based edible coating on weight loss; and (B) Effect of sericin-based edible coating on firmness for a period of 45 days of storage at 25°C. (C) Photos of the tomatoes with and without the sericin-based edible coating**

**Source: Tarangini et al. (2022)**

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