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Sericin: A Natural Biopolymer and Its Applications

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Abstract

Sericin, a protein derived from silkworms, has gained increasing attention due to its promising properties and potential applications in various fields. This article explores the composition, sources, and extraction methods of sericin. It then highlights the diverse applications of sericin, including its use as an anti-frosting agent, biomaterial, coating, and functional material in the food, film, and membrane industries. Furthermore, the article discusses the potential of sericin in moisture absorption, medical textiles, and cosmetics. Overall, sericin presents itself as a versatile and valuable material with significant contributions to various sectors.

Keywords: Amino acids, Degumming, Fibroin, Sericin, Silkworm, Silk industry

Introduction

Silk, a natural fiber, originates from various sources, including silkworms and spiders. Among these, the most extensively studied is the silk produced by the Bombyx mori worm (Gonzalez *et al*., 2014). This protein-based fiber consists of two main components: fibroin and sericin. Fibroin constitutes approximately 70% to 80% of the silk fiber and possesses both amorphous and crystalline domains. These short amino acid chains contribute to its compact structure (Koh *et al*., 2015). Sericin, on the other hand, makes up about 20% to 30% of the silk fiber. It contains 18 amino acids including essential amino acids and is characterized by the presence of 32 per cent of serine. The total amount of hydroxy amino acids in sericin is 45.8 per cent. There are 42.3 per cent of polar amino acid and 12.2 per cent of nonpolar amino acid residues. Its role involves coating and linking the fibroin filaments within the silkworm cocoons (Aghaz *et al*., 2015). Additionally, sericin provides protection against UV radiation, wind, rain, and low temperatures (Cao and Zhang, 2016). Although the silk industry typically discards sericin during processing, recent research has revealed intriguing properties that could lead to its application in various fields.

Amino acid composition of Sericin

Amino acid	Composition (%)	Amino acid	Composition (%)
Serine	33	Arginine	3
Aspartic acid	15	Isoleucine	1
Glycine	14	Phenylalanine	1
Glutamic acid	8	Leucine	1
Threonine	8	Proline	1
Alanine	5	Histidine	1
Lysine	4	Cystine	0
Valine	3	Methionine	0
Tyrosine	3	Tryptophan	0

Sources of sericin

Silkworm is the only source generating sericin; hence sericin is attained from cocoons, silk fabric, and silk waste or from the degumming liquor of silk industry. As per the data statistics, published by the International Sericulture commission, in the year 2019 and 2020, 1,09,111.10 and 91,771.00 MT of silk cocoons respectively was produced globally (ISC, 2020). So from the degumming process a large amount of sericin can be extracted. Large amount of sericin can be attained from cocoon waste or silk waste as compared to silk degumming liquor.

Extraction methods

Extraction method	Condition of extraction	Outcome	References
Denaturing agents (boiling with detergents, alkaline compounds and chaotropic agents)	Urea (8M) for 30 min	10 to > 225 kDa sericin size, 18% to 20% yield.	Aramwit *et al.* (2010a)
	Sodium carbonate (0.5%) for 30 min.	5 to 75 kDa sericin size, 6% to 12% yield	Aramwit *et al.* (2010b)
	Sodium oleate (0.3%) and sodium carbonate (0.2%) for 60 min	High-purity sericin was recovered with calcium chloride	Yang *et al.* (2013)
	Neutral soap (0.2%)	Longer processing time.	Wang *et al.* (2015)
	Calcium hydroxide (0.025%) for 40 min and neutralization with acids	< 20 kDa sericin size, more than 85% recovery	Zhao *et al.* (2018)
Infrared rays	IR heating extraction from silk wastewater	21% to 26% yield, a clean sericin is obtained, eco-friendly process	Gupta *et al.* (2013)
Steam (Autoclave)	120 °C for 60 min. The liquor ratio was 1:25. Sericin was concentrated by rotavapor.	A film made of glycerol/sericin was satisfactorily carried out to assess its use as a polymeric material	Yun *et al.* (2016)
	70-65 °C for 60 min	Total phenolic compound correlated with amount of sericin extracted.	Prasong (2011)
	82-120 °C (above 105 °C using autoclave) and time in the range of 10-60 min. Separation by hydraulic pressing at 2.5 MPa for 1 min and drying.	Extracted sericin exhibited mainly serine (18.24%) and 132 kDa molecular size. Effective to film formation.	Sothornvit *et al.* (2010)
	Autoclaved 120 °C for 60 min and dried by spray-drying	Sericin microparticles with an average diameter < 10 μm were obtained.	Chlapanidas *et al.* (2013)

	Autoclaved at 121 °C for 30 min/45 min/ 60 min.	16 to 44 kDa molecular size. Clean product. Lower yield compared to alkaline extraction	Srnivas *et al.* (2014)
	Steam 120 °C for 60 min and precipitation with ethanol at various ratios.	Precipitation of hydrophobic SS and removal of low molecular weight SS, enhanced mechanical stability	Oh *et al.* (2011)
	Autoclaved 120 °C for 60 min	Higher thermal stability compared with urea and alkaline extraction methods	Aramwit *et al.* (2010b)
	Autoclaved at 121 °C for 30 min, and a liquor ratio 1:30 (w/v), filtered and lyophilized	Source of sericin extraction (cocoons or yarns) affects the final product.	Martínez *et al.* (2017)
Enzymatic digestion	Commercial proteolytic enzymes for 5-240 min at 50-65 °C	5 to 20 kDa sericin size with a weight-average molecular weight of about 12 kDa	Freddi *et al.* (2003)
	Alcalase and Savinase at 55 °C	Efficient degumming, sericin was not characterized	Arami *et al.* (2007)
	Alcalase/Savinase and ultrasound		Mahmoodi *et al.* (2010)
	Novel protease isolated from *Bacillus* sp.		Suwannaphan *et al.* (2017)
Polymeric membranes	Membrane of polysulfone in by phase inversion with polydioxolane and polyethylene glycol	10 kDa - 250 kDa sericin size recovered from silk wastewater	Sonjui *et al.* (2009)
Ultrailtration-Nanofiltration	Silk wastewater was centrifuged, crystallized and ultrafiltered with polyethersulfone membranes	Sericin is separated from fatty acids derived from soaps added during industrial degumming.	Capar *et al.* (2009)
	Hollow fiber nanofiltration membrane integrated with ultrafiltration	86% sericin from cocoon silk wastewater could be recovered. Isolated sericin was not characterized.	Li *et al.* (2015)
	Autoclaved and recovery by ultrafiltration with hollow fiber membrane of polyethersulfone	High molecular sericin is obtained	Silva *et al.* (2012)

Application of Sericin

1. Anti-frosting agent: The anti-frosting property of sericin can be harnessed by applying a film to the surfaces of refrigeration equipment. This film effectively prevents frost buildup. It can be widely used on refrigerators, deep freezers, refrigerated trucks, and ships. Additionally, applying sericin-coated films on roads and roofs can help prevent frost damage. Researchers have also reported that sericin coatings enhance the functionality of various durable materials (Nagura *et al*., 2001).

2. Biomaterials: Sericin has been identified as a valuable biodegradable biomaterial and can serve as a polymer for creating functional membranes and other articles. By blending sericin with other resins, it is possible to produce environmentally friendly biodegradable polymers (Padamwar *et al*., 2005).

3. Coating: Sericin can be utilized in the preparation of art pigments and for protecting antique surfaces. When applied as a coating, sericin enhances the material's weather resistance and overall functionality (Yamada *et al*., 2001).

4. Food industry: Kato et al. (1998) conducted research that revealed the antioxidant properties of silk protein, specifically sericin. They demonstrated that sericin effectively inhibits lipid peroxidation in vitro. When applied as a layer on fruit, sericin protects it from aging, thanks to its antioxidant activity. Additionally, sericin has the ability to inhibit tyrosinase activity. These valuable properties make sericin a natural ingredient with great potential for the food industry.

5. Films: Acrylonitrile, commonly used in the production of synthetic polymers, can be copolymerized with sericin to create a protein-containing synthetic polymer film. This film serves the purpose of separating water from organic substances (Zhaorigetu *et al*., 2001).

6. Membranes: Pure sericin alone is not easily converted into membranes, but when cross-linked, blended, or copolymerized with other substances, it readily forms membranes. Additionally, alternative methods have been explored for creating sericin-containing polyurethane with impressive mechanical and thermal characteristics (Fujikawa *et al*., 1987).

7. Moisture absorbents: A blended hydrogel composed of sericin, fibroin, and PVA exhibits remarkable properties, including excellent moisture absorption and desorption capabilities as well as elasticity. Additionally, the moisture absorption/desorption rate of polyurethane foam containing sericin is reported to be very high (Rangi *et al*., 2015).

8. Medical textiles: Sericin hydrogel can serve as a soil conditioner and be utilized in medical materials and wound dressings. Additionally, sericin plays a role in bone regeneration (Kim *et al*., 2023).

9. Cosmetics: Sericin, with an amino acid composition closely resembling the skin's natural moisturizing factor (NMF), serves as an ideal substance for maintaining skin moisture. It contributes to skin elasticity, smoothness, and softness. Due to its high hygroscopic function, adding a small amount of sericin to cosmetics can yield effective moisturizing and hydrating results (Sheng *et al*., 2013).

Conclusion

Sericin's biocompatibility and natural properties make it an attractive option for sustainable and eco-friendly materials in various sectors. As research into sericin's potential continues, we can expect even more innovative applications for this remarkable protein in the future.

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