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The Biopolymer Sericin: Extraction and Applications

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Abstract

The sericin is natural, eco-friendly, proteinous and biodegradable biopolymer which is obtained as byproduct from silk industries. The gummy sericin material has to be removed from raw silk in degumming procedure to give luster to silk. The sericin has number of useful application in various fields such as cosmetics, food, medical, membranes, biomaterials, etc. Hence, it is recovered as by product from silk waste or effluent of silk industries by various extraction methods. The present paper emphasize on sericin, especially on its chemical composition, sources, properties and extraction methods. Further sericin characteristics and applications have been also discussed one by one.

Keywords: Silk; Sericin; Antioxidant activity; Biomaterial

Introduction

Considerable contribution of the commercial silk rendering in the world is of mulberry silk produced by *Bombyx mori L* silk worm. Silk is a proteinous fiber nature and is produced by silkworms in the form of cocoon. Silk consists of 70-80% of crystalline and insoluble in water fibrous protein called fibroin and 20-30% of an amorphous matrix of a water-soluble globular protein called sericin. Sericin acts like a gum to hold the fibroin filaments together. Sericin has non-filamentous while fibroin has filamentous character [1]. Sericin gives strident and creaky feel to the fiber and conceals the luster and pallidity of silk.

Composition of silk

In its natural formation silk comprise natural impurities like fat, wax, inorganic salt and colouring matter. Composition of silk is given in Table 1 [2].

Aplenty of Fibroin and Sericin present in layers of cocoon are listed in Table 2 [3]. It is clear from the Table that each layer of cocoon has different amount of sericin. Content of Sericin is higher in the outlying layer of cocoon, to award more stickiness.

Sericin

Chemically sericin and fibroin two together have amino acids but in disparate balance. Table 3 tabulates the different amino acid percentage in fibroin and sericin [4,5]. Fibroin is well off in glycine and alanine acids where as sericin is well heeled in serine and aspartic acids. By reason of dissimilarity in the percentage of amino acids, both proteins put on view different features.

Component	%
Fibroin	70-80
Sericin	20-30
Carbohydrates	1.2-1.6
Inorganic matter	0.7
Wax matter	0.4-0.8
Pigment	0.2
Total	100

Table 1: Composition of silk.

Layer	Fibroin (%)	Sericin (%)
1	64.94	32.41
2	74.92	23.15
3	78.34	19.79
4	79.69	17.86
5	79.09	17.78

Table 2: Distribution of Fibroin and Sericin in cocoon layers.

Assets of sericin

Sericin is offshoot of Silk Corporation and was ordinarily discarded as waste but now in subsequential years of exploration it is ascribed with numerous substantial properties. Numerous researchers have reported several valuable characteristics of sericin such as exemplary moisture absorption and dispensation properties [6], UV resistance [7], anticoagulant [8], antioxidant and anti-bacterial activity [9] and inhibitory action of tyrosinase [10].

Symbol	Amino acid	Fibroin	Sericin
G	Glycine	45	14
A	Alanine	29	5
S	Serine	12	33
Y	Tyrosine	5	3
V	Valine	2	3
D	Aspartic acid	1	15
R	Arginine	1	3
E	Glutamic acid	1	8
I	Isoleucine	1	1
L	Leucine	1	1
F	Phenylalanine	1	1
T	Threonine	1	8
C	Cystine	0	0
H	Histidine	0	1
K	Lysine	0	4
M	Methionine	0	0
P	Proline	0	1
W	Tryptophan	0	0

Table 3: Amino acid composition of Fibroin and Sericin.

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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. Across the world overall yearly cocoon production is around 400,000 metric tons and so from the degumming process only, 50,000 metric tons of sericin is junked in effluent every year [11]. Now a day's most of the sericin is retrieved from silk degumming process [12,13]. Large amount of sericin can be attained from cocoon waste or silk waste as compared to silk degumming liquor [14]. However very less consideration was given to it, but now sericin is becoming the centre of attraction to researchers.

Extraction of sericin

Sericin can be extracted from silk by detaching it from the fibroin part. Only fibroin part is demanded in the silk industry so removal of sericin is needed and is done by degumming process which later on is discarded in the effluent. Restoration of sericin from the degumming liquor can lighten the load in effluent, thus lowering the environmental impression and we get a biopolymer having untold profitable properties.

Miscellaneous means for separating sericin from fibroin have been worked upon; from which primeval method was use of alkali at particular conditions for removing sericin from silk [15]. Presently, several methods are given by researchers to extract sericin. Separation of sericin is established looking upon its solubility in hot aqueous solutions. The solubility escalates significantly in the augmented alkaline or acidic solutions [16]. Customary fibroin was of more concern so for the complete removal of sericin effective degumming process using soap and alkali [17-20] were preferably used. But when sericin is of more significance this method is not generally used because separation of soap from sericin is very complex process and after all if small traces of soap are left, application of sericin becomes complicated. Sericin can also be extracted using certain acids like citric, tartaric or succinic acid etc. Temperature should be kept at boiling while using acidic conditions [21,22]. Acids and alkalis have a degrading effect on proteins and sericin being proteinous nature can get damaged while extraction. So extraction in urea solution with 2-mercaptoethanol becomes useful having lesser degrading effect on sericin and damage can be downplayed. Using this process around 95% of the total sericin present can be separated out without any damage [23]. But in this is costly and time consuming because before application, purification of sericin is required and is done by dialysis procedure. In biotech age, enzymatic schemes for sericin extraction have also been proposed [24,25]. But the huge expenses and sensitivity to working conditions of enzyme confines the use of this method for extraction purpose [26].

Due to above given constraints hot-water extraction is the most widely used method for sericin extraction. In this method silk is heated in hot distilled water adding no other chemical. Time and temperature of extraction play a key role in the amount of sericin extracted. Though, this method also causes the degradation of sericin but yet degradation is to an extent that sericin still retains its important properties. So many researchers considering the easiness of the procedure prefer to use hot-water extraction. It has been reported in papers that temperature can be applied to the system either by boiling at atmospheric pressure [27,28], HTHP (high temperature high pressure) [29-31], IR (infrared radiations) [32] or microwaves [33,34].

After extraction sericin is reformed to powder form. In different studies researchers have tried various processes like membrane filtration [35-37], ethanol precipitation [38,39] freeze drying/tray drying [40] and spray drying [41] to isolate sericin from the degumming solution. The membrane process is a technique that concentrates the amount of sericin in liquor without the use of heat. The advantage of the spray drying process over others is that it includes minimal possibility of degradation of proteinous molecules which are sensitive to heat. Dried powder of sericin from solution is obtained very rapidly in one-step.

Characteristics of Sericin

The structure and molecular weight affects functional properties of sericin. The chemical structure and molecular weight of sericin mainly depends on two factors: method of separation of sericin and fibroin and method of recovering sericin from degumming liquor. And as mentioned earlier the addition of chemicals or exposure to heat (high temperature) causes the degradation of sericin polypeptides during degumming and its recovery process, so methods are chosen very carefully to get maximum benefits from sericin. Characteristics of sericin are next given to have a better understanding about this biopolymer.

Various contents

Different characteristics of sericin like moisture content [42], nitrogen content, ash content, colour [43] and solubility are reported in literature and are given in Table 4.

Morphology

The surface morphology of the spray dried sericin powder was reported [36] to be like wrinkled particles which can be due to the collapse of hollow spherical structures when rapidly evaporated [6]. Sericin by virtue of its hydrophilic nature gets agglomerated by immediate picking of moisture when exposed to atmosphere.

Molecular weight

Sericin extracted by different methods has different molecular weights. It has been reported that molecular weight of sericin analysed using non reducing SDS-PAGE analysis lies in the range of 90-125 kDa. Sericin extracted without any heat treatments show three distinct bands. Heat treatments attack on the peptides linkage and the samples showed broader bands due to mixture of different molecular weight peptides [44].

Antioxidant activity

DPPH (2, 2-diphenyl-1-picrylhydrazyl) is a stable free radical which absorbs at 517 nm and is normally used to study the radical scavenging effect. As antioxidants donate protons to this radical, the absorption decreases. Antioxidant activity of sericin is assayed by calculating the decrease in absorption. In another research it has been found that sericin completely inhibits lipid peroxidation showing sericin have antioxidant activity.

Spectra

In many studies UV spectrum is used to evaluate the quality of proteins as they absorb near-ultraviolet region due to the

Parameters	(%)
Moisture content	10-17
Nitrogen Content	9-16
Ash content	0.8-6
Colour	Cream to light yellow
Soilubility	Insoluble in cold water; soluble in hot water

Table 4: Various characteristics of sericin.

electron transfer of aromatic amino acid, tryptophan, tyrosine, and phenylalanine [32,45]. It has been reported that the IR spectra of sericin samples extracted by different methods show peaks in the region of 3000-3500 cm^{-1} which are associated with N-H stretching vibrations of amide bonds and peaks between 1600 and 1700 cm^{-1} are because of the C=O stretching vibration and is the most useful for determining proteins structure. The peak at 1540 cm^{-1} arises because of the random coil structure of the sericin and belonged to amide II. Signature peak of sericin at 1400 cm^{-1} has been observed in case of all the samples. Same results have been reported in literature by other researchers [46,47]. The conformation change in sericin can be assessed through CD spectroscopy. The CD spectrum of sericin powder sample has strong negative band at 198 nm suggesting a random coil structure. A slight negative band at 218 nm reveals the presence of β sheet. These results seemed to be in good agreement with the results reported by others [48].

Application Areas of Sericin

In recent years sericin having many important, valuable properties like gelling, moisture absorption, antioxidant, anti-bacterial, etc has emerged as a commercial resource in various industries and has got wide applications in many industries such as cosmetics, food, medical, pharmaceuticals, etc. The sericin sources, extraction methods, properties, characterization and applications are represented in Figure 1.

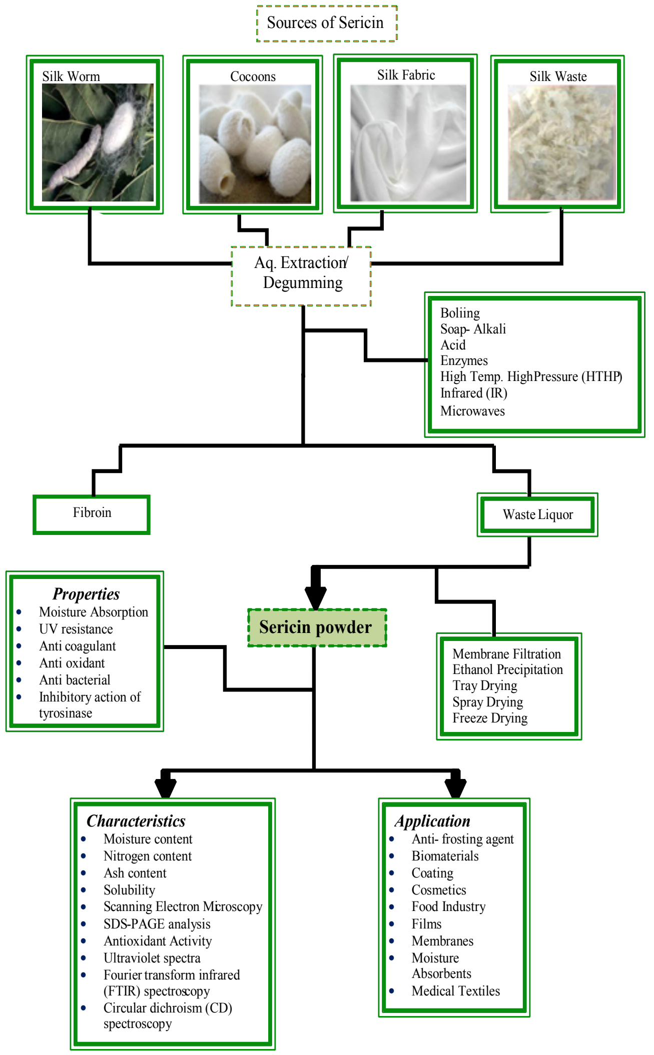

Figure 1: Schematic diagram of sericin sources, extraction, properties, characterization and applications.

Anti-frosting agent

Anti-frosting property of sericin can be utilized to coat a film on the surface of refrigeration equipment because of its anti-frosting action [49]. Use of sericin film is an effective anti-frosting method that can be widely applied to refrigerators, deep freezers and refrigerated trucks and ships. Moreover use of the coated film on roads and roof can prevent frost damage. Sericin coating on surfaces of various durable materials has also been reported to enhance functionality [50].

Biomaterials

Moreover, sericin has also been found to be useful as a degradable biomaterial and to be used as polymer for forming articles and functional membranes. Environment friendly biodegradable polymers can be produced by blending sericin with other resins [51].

Coating

Sericin can be used in preparation of art pigments and for the protection of surface antique articles. When the material is coated with sericin its weather ability increases. Sericin coatings enhance the functionality of materials [52].

Cosmetics

Sericin has emerged as a valuable commercial resource in making cosmetics [53]; the biopolymer sericin has a strong affinity to keratin. Excessive trans-epidermal water loss (TEWL) is one of the causes of dry skin and skin moisturizers have been used to overcome it. Serine is the main component of sericin which gives it resemblance to the natural moisturizing factor (NMR) in human skin making sericin a good moisturizer [54]. Sericin gel is prepared to prevent water loss from the upper layer of the skin. It forms a moisturizing, protective, anti-wrinkle film on the skin surface imparting an immediate, long lasting, smooth, silky feeling [55]. Nail cosmetics, containing 0.02-20% sericin are reported to prevent nail from chapping, brittleness, and impart inherent gloss to nails [56]. Sericin with average molecular weight is added to bath preparations as well as skin and hair conditioners [57].

Food industry

Kato et al. provided the first evidence of antioxidant action of the silk protein by showing that sericin suppressed in vitro lipid per-oxidation. Sericin layer when deposited on fruit protects it from ageing dues to its antioxidant activity. Furthermore, sericin also inhibits tyrosinase activity. These properties suggest that sericin is a valuable natural ingredient for food industry.

Films

Acrylonitrile used in making certain synthetic polymers can be copolymerized with sericin to prepare a protein containing synthetic polymer film for separating water from organics [58,59].

Membranes

Pure sericin cannot be easily made into membranes, but membranes of sericin cross-linked, blended, or copolymerized with other substance are readily made. Other procedures have also been reported for producing sericin-containing polyurethane with excellent mechanical and thermal properties [60].

Moisture absorbents

A blended hydrogel made of sericin, fibroin and PVA is said to have excellent moisture absorbing and desorbing properties and elasticity. The moister absorption/desorption rate of the sericin containing polyurethane foam is reported to be very high.

Medical textiles

Use of Sericin as a biomaterial has been reported. Sericin hydro-gel can be used as a soil conditioner and in medical materials and wound dressing.

Conclusion

Sericin with its several valuable properties has emerged as a commercial resource in many industries, such as those making cosmetics, pharmaceuticals and food; as well as in the production of many functional biomaterials. It can be observed that due to numerous valuable applications and ecological friendly properties sericin becomes precious biopolymer. Due to unawareness many silk producers and processors are still discarding this valuable sericin as it is in the effluent. Many a researchers are working in this field to explore possibilities for the efficient extraction of sericin and its further applications. The future of sericin is promising and exploration in this field will definitely strengthen the silk and their associated industries.

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