Preparation and characterization of sericin powder extracted with deep sea water

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Abstract

In this study, we developed an effective technology for the extraction of sericin from silk cocoons by deep sea water (DSW). We focused on extraction of sericin in the absence of chemical additives to obtain a safe, effective, inexpensive sericin powder. Sericin was extracted using a simple high-temperature process involving heating, condensation with *Molus alba*, filtering with cotton cloth, cold storage, and lyophilization. The results showed that the yield of sericin (26%) extracted by DSW was approximately 2% higher than that obtained using a chemical buffer (0.2 M Na₂CO₃, 24%). The marine mineral sericin *M. alba* (MSM) showed a size distribution of 15–250 kDa, with major peaks at 75–250 kDa with a galactose chain. Additionally, this MSM product had high antioxidant, whitening, and antibiosis effects and could be safely stored for a long time. Thus, our findings supported the use of a DSW extraction method, which was ecofriendly and yielded a proteinous, biodegradable biopolymer, for preparation of sericin.

Keywords Silk · Sericin · Ecofriendly extraction · Biomaterial · Antibiosis

Introduction

In addition to mineral salts and coloring matter, fibroin and sericin proteins, accounting for about 70–75% and 25–30% of total silk weight, respectively, are the main constituents of silk. Silk products are a major part of the textile industrial sector, in which intensive water consumption cannot be avoided; thus, silk production results in large volumes of wastewater.

Sericin envelops the fibroin fiber with successive sticky layers that act as a gum binder to maintain the structural integrity of the cocoon (Mashhiro et al. 2000). Several processes, including extraction with water at high temperature and high pressure (HTHP), boiling-off in soap, alkalis, acidic

solutions, enzymes, and biosurfactants have been used for degumming of silk (Freddi et al. 2003; Gulrajani et al. 1992, 1996; Bianchi and Colonna 1992; Rangam et al. 2010). Until recently, sericin had been considered a waste by-product and was usually discarded. However, sericin has recently been found to possess various biological functions, such as antioxidant, antityrosinase, ultraviolet-absorbing, and moisture-absorbing effects (Zhang 2002; Sarovar et al. 2003; Yu-Qing et al. 2006; Abhilasha and Lalit 2015). Additionally, sericin may be a valuable natural ingredient in the cosmetic and food industries and may have biomedical applications.

Conventional degumming processes using soap and alkalis are effective to remove sericin. However, these promote the hydrolysis of the sericin chain structure, losing potential properties, whereas soap removal from the sericin solution is difficult and expensive (Mahmoodi et al. 2010). Accordingly, studies of alternative degumming methods to remove sericin from cocoons and methods for the recovery and recycling of sericin by-products from the degumming stage could have substantial economic and social benefits.

Deep sea water (DSW) is pumped up from a depth of over 200 m and is associated with low temperature, high purity, and beneficial elements, including magnesium (Mg), calcium (Ca), potassium (K), chromium (Cr), selenium (Se), and zinc (Zn) (Samihah et al. 2016). Moreover, DSW contains ions of

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sodium (Na^+), chloride (Cl^-), sulfate (SO_4^{2-}), magnesium (Mg^{2+}), calcium (Ca^{2+}), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}) (Li and Gregory 1974). The long distance from solar radiation results in minimal to no bacterial activities and the depth from the surface seawater results in a high abundance of inorganic material. Due to the high mineral and low bacterial contamination compared with other sources of water, DSW can be applied as an extraction buffer for sericin for cosmetics, foods, and biomedical materials.

In this study, we evaluated sericin extraction from silkworm cocoons using natural carbonate ions in DSW in the absence of chemical additives under high temperatures. The extracted sericin and DSW buffer were subjected to simple filtering and lyophilization to promote the fractionation of sericin protein and utilized marine mineral and *Molus alba* extracts to obtain a retentate with various functional properties.

Materials and methods

Materials

The experimental silk cocoons and roots of *M. alba* were procured and supplied by the Gyeongsangbuk-do and Kangwon-do Foundation Original Seed Production Center (Sericulture and Entomology Experiment Station). DSW was supplied and pumped up from the Ulleungdo of South Korea.

Extraction of sericin

Degumming was carried out in tap water, DSW, and 0.2 M Na_2CO_3 medium using a heating mantle (GLHMD-F, Global LAB, Korea) at 98 °C for 120 min in 1:50 (w/v) buffer. Dried cocoon shells were cut into small pieces, washed with boiling distilled water for 10 min, removed water by squeezing, and then extracted. Extraction was carried out for different times and with varying temperatures, buffer volumes, and buffer concentrations. The extracted sericin (marine mineral sericin [MS]) was incubated at 98 °C after removing fibroin fiber or other debris. The other portion was condensed with 1:50 (w/v) air-dried *M. alba* for 1 h at 98 °C (marine mineral sericin *M. alba* [MSM]). The sericin liquor concentrated using optimized conditions was converted into powder using a freeze dryer (PVTFD20R; Ilsin Ltd., Korea). Sericin yield, which represents a quantitative evaluation of the extraction efficiency, indicates the weight loss of the fabric after extraction. Before weight measurement, fibroin fabric was kept at 30–37 °C in an incubator for 24 h:

$$\text{Extraction yield (\%)} = \frac{[\text{Initial weight of silk cocoon} - \text{weight of silk fibroin recovered}]}{\text{Initial weight of silk cocoon}} \times 100.$$

Protein analysis

The concentration of sericin was determined using the bicinchoninic acid method with bovine serum albumin as a standard (Smith et al. 1985). The samples were denatured in 4×Laemmli sample buffer and resolved by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) on 10%, 12%, and 15% gels. After electrophoresis, the gels were stained with Coomassie Brilliant Blue R-250 and a glycoprotein staining kit (Pierce, USA) using the periodic acid-Schiff (PAS) method. Then, proteins were transferred onto polyvinylidene difluoride membranes for western blotting (Millipore, USA), and the membranes were blocked for 1 h at room temperature in TBS-0.1% Tween 20 (TBST), washed with TBST, and then incubated at room temperature for 1 h using anti-lectin antibodies (Rochland, USA). The membranes were then washed five times with TBST and incubated with concanavalin A (ConA), *Dolichos biflorus* agglutinin (DBA), and *Ricinus communis* agglutinin 120 (RCA120) for detection of lectin for 1 h (Hong et al. 2014). After extensive washing with TBST, the membranes were incubated with horseradish peroxidase-conjugated streptavidin (Thermo Scientific Pierce, USA) for 1 h at room temperature, washed, and detected using 3,3'-diaminobenzidine solution (Thermo Scientific Pierce). The glycoprotein carbohydrate content was estimated using a Glycoprotein Carbohydrate Estimation Kit (Thermo Scientific Pierce) according to the manufacturer's instructions.

Amino acid analysis

Sericin powder was hydrolyzed with 6 M hydrochloric acid at 110 °C for 24 h under vacuum. Tryptophan was determined following alkaline hydrolysis. The hydrolysate was submitted to automated online derivatization with *o*-phthalaldehyde and reversed-phase high-performance liquid chromatography analysis on an Agilent 1100 system (Agilent Technology, USA) using a Zorbax 80A C18 column, running at 0.5 mL/min. The results were analyzed with the aid of a ChemStation for LC3D software (Agilent Technology).

Mineral element analysis

For mineral element analysis, 1% of each sample was analyzed for trace minerals using an inductively coupled plasma mass spectrometer (Agilent Technologies). The results were analyzed with the aid of a VistaChip II CCD detector (Agilent Technology).

Confirmation of health index bacteria

The safety of extracted sericin was assayed by a 3 M biofilm for *Escherichia coli*, *Staphylococcus aureus*, *Listeria*, yeast,

fungi, and other bacteria. For this analysis, 1% of each sample was analyzed at 37 °C for 24 and 48 h. All experiments were performed in triplicate.

Antimicrobial assay

The inhibitory effects of sericin on bacteria were investigated by the disc diffusion assay method using *S. aureus*, *Bacillus megaterium*, and *B. cereus* as Gram-positive bacteria; *Pseudomonas fluorescens*, *E. coli*, *Salmonella enteritidis*, *Vibrio parahaemolyticus*, and *Propionibacterium acnes* as Gram-negative bacteria; and *Malassezia furfur* as a representative fungus. Sericin extracts were redissolved in 1 mL distilled water. The agar medium was spread or inoculated with bacterial suspension (1 mL of 10^7 CFU). The plates were kept in an incubator at 30 °C for 1 h to permit sericin extract diffusion and then incubated at 30 °C for 24 h. At the end of incubation, the inhibition zone (IZ) that formed around the disc was measured in millimeters with a transparent ruler. All experiments were performed in triplicate.

Cell culture and viability assays

B16F10 *Mus musculus* skin melanoma cells (ATCC 6475; American Type Culture Collection [ATCC], Manassas, VA, USA) and hs895sk human skin fibroblasts (ATCC 7637; ATCC) were maintained in 25-cm³ flasks containing Dulbecco's modified Eagle's medium (Thermo Fisher, USA) supplemented with 10% fetal bovine serum (Gibco, USA) and antibiotics (100 µg/mL streptomycin, 100 µg/mL penicillin; Gibco) at 37 °C in a humidified atmosphere containing 5% CO₂. For growth assays, cells were cultured in octoplicate using 96-well microplates at 2×10^4 cells/well.

Cell viability was analyzed using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) colorimetric assays, as described previously (Mosmann 1993). Briefly, cells were seeded in 96-well plates at 2×10^4 cells/well and incubated for 24 h. The cells were treated with different concentrations of sericin, and control cells were treated with phosphate-buffered saline. Plates were then incubated at 37 °C in the presence of 5% CO₂ for 24 or 48 h. After treatment, the supernatants were removed, 100 µL of 5 mg/mL MTT solution (Dojindo, Japan) was added to each well, and the plates were incubated for 3 h. The precipitated formazan crystals were dissolved in dimethyl sulfoxide, and absorbance was measured at 570 nm using a microplate reader (PerkinElmer, USA). Cell viability was defined as the percentage of cells relative to the number of control cells.

Antioxidant and melanin content assays

Total free radical-scavenging molecules were evaluated by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method, as previously reported (Delogu et al. 2016). For free radical analysis, 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox; Abcam, USA) was used as a standard reference. The concentration range of the extracts used for the antioxidant tests was 0–10 mg/mL. The activity was expressed as the concentration of sample necessary to give a 50% reduction in the original absorbance (IC₅₀).

The melanin content in B16F10 cells was analyzed as previously described (Pintus et al. 2015). B16F10 cells were seeded in 6-well plates (10^5 cells/mL). After 24 h, the medium was substituted with fresh medium supplemented with 100 nM α -melanocyte-stimulating hormone (α -MSH) and different concentrations of sericin extract (0–1 mg/mL) and incubated for 24, 48, or 72 h. Cells treated with α -MSH and kojic acid were used as positive controls for comparison of the inhibitory strengths of the extracts. Melanin contents were measured at 405 nm using a microplate reader (PerkinElmer).

Results and discussion

Characterization of sericin extracted by DSW

To obtain fibroin or sericin from silkworm cocoons for silk fibers, cosmetics, foods, and pharmaceutical applications, chemical materials, such as soaps and alkalis, are commonly used. However, these degumming processes using chemical materials are not efficient, are expensive, and damage the protein. To maximize the recovery of sericin and minimize the damage to the protein, extraction by DSW may be the best solution. Accordingly, in this study, heating in DSW for 90–120 min was used for extraction of sericin from cocoons (Supplemental Data 1), and the results were compared with tap water and sodium carbonate.

Table 1 shows the yield, pH, and salinity of sericin obtained from extraction using different methods. Sericin extracted in tap water (TW), sodium carbonate (CS), MS, and MSM showed yields of 20.7–26.3%. Additionally, the pH values of MS and MSM were 6.8 and 6.4, respectively, and the salinities in 1% solution were 0.87 and 0.73, respectively. The extraction yield obtained with DSW was higher than that obtained with TW and CS, consistent with the amount of sericin present in silkworm cocoons, as previously described (Zhang 2002). Increases in the CS concentration and boiling time also improve sericin yield but lower the quality of the product. The optimum temperature and time for extraction of sericin and silk fibroin were 98 °C and 90–120 min, respectively. From a chemical point of view,

Table 1 Comparison of sericin extracted by various buffers

Extraction process	Temperature (°C)	Time (min)	Ext yield (%)	pH in 1% solution	Salinity in 1% solution (%)
TW	98	120	20.7	7.1	–
Na ₂ CO ₃ (0.02 M)	98	120	24.5	7.91	0.02
MS	98	120	26	6.82	0.87
MSM	98	120	26.3	6.46	0.73

TW tap water, *MS* marine mineral sericin extracted using DSW, *MSM* marine mineral sericin *Molus alba* extract extracted using DSW and then condensed with *Molus alba*

Table 2 Composition of mineral of sericin extracted by different buffers

	Na ₂ CO ₃	MS	MSM
Na	17,000	39,500	40,400
Mg	1730	28,740	28,600
Ca	4980	3841	6470
K	362	8145	12,700
B	0	51	98.6
Sr	26.3	101	171
Al	102	8	9
Si	257	101	114
Zn	80.4	7	8
As, Ba, Be, Cd, Co, Cr, Cu, Ga, Ge, In, Li, Mn, Mo, Nb, Ni, Pb, Rb, Re, Sb, Sc, Se, Sn, Ta, Ti, Tl, V, W, Y, Zr	Not detected	Not detected	Not detected
Total (ppm)	24,648	80,502	88,580

sericin is a soluble protein that has many hydrophilic groups (with high polarity) as side chains. As described, the solubility increased significantly in alkaline or acidic solution. Thus, extraction in DSW, including natural alkali and acid ions, became useful for reducing yield loss, cost, and time and increasing effectiveness. Thus, due to the salinity and weak acidity of the products, MS and MSM could be used as effective biomaterials. Sericin recycling by DSW could have significant economic and social benefits without the need for costly chemical materials, ultrafiltration, enzymes, or dialysis and without the generation of effluent.

The mineral compositions of CS, MS, and MSM are given in Table 2, and the results showed that the products contained high Na, Mg, K, and Ca, although other components were not detected. The mineral composition of CS was lower than those of MS and MSM. Thus, we developed a novel and simple approach for the preparation of sericin as a biomaterial.

A comparison of the amino acid compositions of sericin prepared using different methods is shown in Table 3. The results showed that the main components of sericin protein were aspartic acid, serine, and glycine, with concentrations of 55.7%, 56.3%, and 59% for TS, CS, and MSM, respectively. Of the identified amino acids, serine had strongly polar hydroxyl groups and may be related to the functional and physiochemical properties of sericin. The amino acid

Table 3 Amino acid composition for sericin extracted by different buffers

Amino acid (mg/g)	Review	TW	2CO ₃	MSM
Asp	15	20.5	23.4	20.0
Thr	8	6.7	5.2	7.4
Ser	33	23.9	21.3	28.1
Glu	8	9.2	7.9	6.3
Pro	1	1.2	1.1	1.3
Gly	14	11.3	11.6	11.4
Ala	5	4.5	5.2	3.5
Cys	–	–	–	–
Val	3	3.2	4.4	2.9
Met	–	–	–	–
Ile	1	0.9	1.3	0.8
Leu	1	1.5	2	1.3
Tyr	3	2.8	3.4	4.5
Phe	1	0.8	0.9	0.5
Lys	4	5.9	4.3	4.0
His	1	1.8	2.3	2.4
Arg	3	4.8	5.2	4.9
Total	101	99	99.5	99.3

TW tap water, *MS* marine mineral sericin extracted using DSW, *MSM* marine mineral sericin *Molus alba* extract extracted using DSW and then condensed with *Molus alba*

composition ratios of the sericin extracts obtained in this study were similar. However, the overall contents of amino acids, except serine, glycine, threonine, glutamic acid, alanine, isoleucine, and phenylalanine were higher than those reported by Rangi and Jaipura (2015).

Overall, these mineral and amino acid composition analyses showed that MS and MSM had high proportions of sericin and active substances, enabling their use as biomaterials.

Protein analysis of sericin extracted by DSW

The molecular weight (MW) distribution of sericin samples was determined using CBB and PAS staining and immunoblotting for lectin by SDS-PAGE (Fig. 1). CS showed a diffused band at a MW range of 15–250 kDa, whereas MS and MSM showed bands in the high MW range (20–250 kDa). As indicated by PAS staining, the MW of CS showed diffused bands at MWs of 15–25 and over 100 kDa, whereas MS and MSM contained a band at over 75 kDa, suggesting that these products retained other sugar chains. The PAS staining differences found in the sericin protein were most likely due to the degree and type of sugar chain-linked protein. A lectin affinity analysis using ConA, DBA, and RCA120 was performed to confirm this hypothesis. ConA and DBA bind to molecules that contain the exposed mannose of *N*-glycan and *N*-acetyl galactose of *O*-glycan, respectively, whereas RCA120 recognizes the terminal galactose of *N*- or *O*-glycan. As shown in Fig. 1, whereas proteins in MS and MSM recognized ConA, DBA, and RCA120 lectins, CS only reacted with ConA binding to mannose of *N*-glycan, suggesting the scarcity of sugar chains in the terminal carbohydrates of CS. Thus, extraction with chemicals indicated the presence of oligosaccharide hydrolysis of sericin,

whereas extraction by DSW preserved the primary structure and composition. This difference in the presence or absence of sugar chains can have significant effects on the properties and applications of sericin. Due to its proteinaceous nature, sericin is susceptible to the activities of proteolytic enzymes present in the environment. However, because of the stability of sericin due to sugar chains in MS or MSM, this molecule could have wide applications in cosmetics and pharmaceutical materials.

Antioxidant activity of sericin

DPPH radical-scavenging activity is one of the most widely used methods for analysis of antioxidant activity because it is a quick, reliable, reproducible method. Figure 2 shows the antioxidant activities of CS, MS, and MSM, as assessed using DPPH assays. The highest DPPH activity was observed for 1% MSM (88.4%) followed by 3% MS (71.2%) and 3% CS (61.2%). The IC_{50} was calculated (Fig. 2b); lower IC_{50} values indicated higher antioxidant activities. The antioxidant effects of our sericin, as determined using DPPH scavenging assays and ascorbic acid as a standard decreased in the following order: vitamin C > MSM > MS > CS. Generally, the antioxidant properties of sericins in this study were found to be concentration dependent.

To obtain information regarding the potency of sericin in the cellular model, we examined the ability of sericin to affect the viabilities of B16F10 melanoma cells and hs294T cells (Fig. 3). Cells were treated with sericin at concentrations ranging from 1 to 5% for 48 h at 37 °C and then examined cell viability using MTT assays. The results showed that most samples did not have significant cytotoxic effects until reaching a concentration of 5% (w/v, viability of over 100%, Fig. 3a, b), whereas 5% CS in B16F10 cells at 48 h

Fig. 1 Detection of sericin protein extracted in each buffer. Sample was analyzed by Coomassie Brilliant Blue (CBB) staining, glycoprotein staining (periodic acid-Schiff staining [PAS]) and immunoblotting for detection of lectin, ConA, DBA, and RCA120. *M* molecular

weight standard marker (Bio-Rad), CS sericin extracted by sodium carbonate buffer (Na_2CO_3), MS marine mineral sericin extracted by DSW, MSM marine mineral sericin *M. alba* extracted by DSW and then condensed with *Molu alba*

Fig. 2 Antioxidant activities of sericin extracts as determined by DPPH assays. **a** Antioxidant effects of sericin at different concentrations. **b** IC_{50} s according to antioxidant assay results. *Vit C* ascorbic acid (positive control); *CS* sericin extracted by sodium carbonate

buffer (Na_2CO_3), *MS* marine mineral sericin extracted by DSW, *MSM* marine mineral sericin *M. alba* extracted by DSW and then condensed with *M. alba*

Fig. 3 Effects of sericin extracts in B16F10 and hs895.sk cells. **a** and **b** Cytotoxicity of CS, MS, and MSM extracts in both cells. Cells were incubated with various concentrations (0.1%, 1%, and 5%) of sericin extracts for 48 h. Red line: basic growth line of cells. **c** Effects of

sericin extracts on melanin production in B16F10 mouse melanoma cells. **d** Antioxidant effects of sericin extracts on conversion of Cu^{2+} ion to Cu^+

resulted in a loss of viability of 64% (Fig. 3a). Thus, our results showed that sericin enhanced cell viability. Similarly, Cao and Zhang (2017) reported that sericin promoted cell viability and proliferation. However, sericin prepared by

various methods may have different biological and physical characteristics.

Next, we investigated the effects of antioxidant and melanin inhibition. The melanin contents of α -MSH-stimulated

Table 4 Antibacterial activities of different extracts of sericin

Extraction process	Conc. (mg/mL)	Inhibition zones (mm)					
		<i>B. cereus</i>	<i>B. megaterium</i>	<i>S. aureus</i>	<i>P. acnes</i>	<i>M. furfur</i>	
CS	1.0	na	na	na	na	na	
MS	1.0	na	na	na	na	11.1 ± 0.2	
MSM	1.0	11.1 ± 0.1	11.3 ± 0.2	11.3 ± 0.2	13.2 ± 0.1	12.2 ± 0.1	
Negative control	–	na	na	na	na	Na	

Negative control, distilled water dissolved sericin. Data are means of three replicates ($n=3$) ± standard errors

na not active

B16F10 cells in the presence of sericin were also evaluated for 72 h (Fig. 3c). The samples slightly reduced cellular melanin in a concentration-dependent manner. When comparing the results obtained with sericin and arbutin at the same concentration of 1% (w/v), we found that the cellular antimelanogenesis effects of MSM showed inhibition of 86% versus 64% for the standard inhibitor at 72 h.

To confirm the antioxidant capacity of sericin in the cellular model, the ability of sericin to affect the antioxidant activities of B16F10 melanoma cells and hs294T cells was evaluated using Cu^+ ion specific changes (Fig. 3d). Reducing power was investigated based on the reduction of the cupric (Cu^{2+}) form to the cuprous (Cu^+) form. As shown in Fig. 3d, the reducing powers of the three sericin extracts (1% w/v) showed slight decreases in the following order: Arbutin > MSM > MS > CS.

Antibacterial activity of sericin

Sericin extracts were then investigated to evaluate their antibacterial activities against food poisoning, skin, and scalp bacteria, including four strains of Gram-positive bacteria (*B. cereus*, *B. megaterium*, *S. aureus*, and *Propionibacterium acnes*), three strains of Gram-negative bacteria (*E. coli*, *Pseudomonas fluorescens*, and *Salmonella enteritidis*), and one strain of fungus (*M. furfur*) using the disc diffusion method. Evaluation of the antibacterial activities of these sericin extracts is shown in Table 4. The results revealed that MSM was potentially effective for suppressing four strains of Gram-positive bacteria as well as *M. furfur*, but not strains of Gram-negative bacteria used this study (Supplemental Data 2). The other sericin extract, CS, did not show antimicrobial activity against all bacterial strains used this study, whereas MS was just effective against *M. furfur*, which causes dandruff.

The results of antimicrobial activity analysis of sericin extracts suggested that MSM and MS extracted by DSW were resistant to *M. furfur* and that MSM was also effective against *P. acnes*. Moreover, MSM extracts were the most effective materials and showed antibacterial activities against the food-poisoning, skin, and scalp bacteria used

this study. *Molus alba* has been reported to have antioxidant, antibacterial, antiviral, and anti-inflammatory properties (El-Beshbishy et al. 2006; Chung et al. 2003). The addition of *M. alba* increased the antioxidant and antibacterial effects and could have great value in the cosmetic and biomedical industries. We also investigated the stability of *E. coli*, *S. aureus*, *L. monocytogenes*, yeast, and fungi using 3 M Petrifilm after storage of sericin extract powder at 4 °C for 6 months (Supplemental Data 3). The results showed that MS and MSM did not permit the growth of microorganisms, whereas CS permitted the growth of *E. coli* (1.5×10 CFU/mg) and general bacteria (7.5×10 CFU/mg) after incubation at 37 °C for 24 h. Therefore, MSM and MS were found to be stable at 4 °C for 6 months. The reason for this discrepancy is thought to be related to salinity (Table 1); indeed, the salt in MSM and MS is expected to enhance their storage stability. Sericin extracted from chemical, physical, or enzymatic hydrolysis is not an ecofriendly product, but has been used commercially in cosmetic, biomedical, and food industries. According to currently available results, we suggest that MSM and MS can be used safely as cosmetics, dietary additives, or biomedical materials. Thus, further detailed studies are needed.

In summary, in this study, we developed a novel extraction process to recover sericin or fibroin from silkworm cocoons or silk fabrics using heating with DSW. Our results showed that this method was effective and simple. We also characterized the yields, physiochemical activities, and biological activities of sericin powders, including antioxidant, antimelanogenesis, and antibacterial activities as well as cell viability and innocuous effects, highlighting the important potential applications of sericin as cosmetics or dietary additives. Future studies are still needed to evaluate the biomedical or clinical applications of sericin extracted by DSW, which is expected to be more suitable for the development of functional materials than sericin isolated by conventional methods.

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Compliance with ethical standards

Conflict of interest There are no financial/commercial or any other conflicts of interest among authors.

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