Sericin, a dietary additive: Mini review
Snehashish Ghosh, Roopa S. Rao, K. Shwetha Nambiar, Vanishri C. Haragannavar, Dominic Augustine, S. V. Sowmya

Department of Oral Pathology and Microbiology, Faculty of Dental Sciences, M. S. Ramaiah University of Applied Sciences, Bengaluru, Karnataka, India

Abstract
Realization of the nutritive value of silk and silk protein sericin is essential to exploit its compatibility and value added potential. Sericin, a globular protein, obtained from cocoons, as a part of the refining process. It has a wide array of applications in food industry, pharmaceuticals, molecular biology, cosmetics, and textile industry. Dietary intake of sericin reduces the levels of serum cholesterols and triglyceride. Furthermore, exhibits antioxidant activity by inhibiting tyrosinase enzyme. The nutritive value of sericin is explored in countries such as Japan and China. Although sericin is exploited in India in cosmetic industry, textiles, and pharmaceutical industry, it has not been explored in the food industry. Sericin is a unique protein; its rate of production is high, as enormous amount of silk is generated in India and most goes for waste. Instead, it can be utilized into a dietary additive in the food industry. The aim of this review article is to highlight the nutritional benefits of sericin and how best it can be utilized in food industry as a dietary additive for the health benefits.

Keywords
Food, nutrition, sericin

Introduction
The word sericin is derived from a Latin word “sericum” meaning silk. Silk is obtained from silkworm Bombyx mori, comprising two proteins sericin and fibroin. In Sanskrit, silk is popularly known as “Kitta-Sutram.” The word “kitta” means worm, and “sutram” means thread. About 1 million tons of fresh weight cocoons produced worldwide and approximately 4,000,000 tons of dry cocoons are generated, that produce around 50,000 tons of recoverable sericin. India produces around 1600 tons of silk every year, leaving behind approximately 250-300 tons of sericin. The glue-like protein secreted from the mid-region of the silk gland, functions as a binder of the fiber. Presently, sericin is underutilized and mostly discarded as a degumming solution causing environmental hazard due to its soaring oxygen demand for degeneration of microorganisms.

Forms of Sericin
Sericin can be classified into three forms based on their solubility as Sericin A, Sericin B, and Sericin C.

Sericin A
Consists of the outermost layer and insoluble in hot water. It contains 17.2% nitrogen and amino acids such as threonine, glycine, serine, and aspartic acid.

Sericin B
Consists of the middle layer, which on hydrolysis with acid yields the same amino acid of Sericin A, and tryptophan. It contains about 16.8% of nitrogen.
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Table 1: Applications of sericin\textsuperscript{[7,21]}

| Skin                              | Hair                              | Food industry                        | Fabrics                        | Medicinal uses                        | Other uses                                      |
|-----------------------------------|-----------------------------------|--------------------------------------|--------------------------------|---------------------------------------|------------------------------------------------|
| Combat melanin, and whiten skin   | Repair damaged hair by providing basic nutrients | Combat constipation and obesity      | In fabrics to absorb moisture   | Biomaterial to contradict cold        | Treating industrial wastewater with adsorptive pollutants |
| Protect skin and increases skin elasticity | Protect hair | In porridge, to improve its taste and touch | Cleaning fabrics |          |                                                |
| Preserves and maintains moisture of skin can be used in foundation creams and eyeliners | Hair conditioner | Beverage rich in amino acids | Improved antibacterial activity | |                                                |
| Prevents wrinkles and aging of skin | Shampoo containing sericin and pelarogenic acid of pH<6 are useful for hair cleaning | Edible antioxidant used in greasy food. Prevents browning reactions of various foods | To develop durable and bioactive finish on polyester for use in medical and sports garments | Suppresses development of bowel cancer and colon tumors has antitumor properties |                                                |
| Antioxidant used in cosmetics     | Antioxidant applied in dairy products | Accelerates the absorption of minerals | | |                                                |
| Additive applied in cosmetics to ameliorate its guarantee period | | Additive as nourishment | | |                                                |
| In nail cosmetics, prevents nail from chapping and brittleness | | | | |                                                |

**Sericin C**

Consists of the deepest layer, which lies adjacent to fibroin and is insoluble in warm water. It is separated from fibroin by treating with hot dilute acid or alkali. On acid hydrolysis it yields proline and amino acids present in sericin B. It also contains about 16.6% of nitrogen.\textsuperscript{[5,7]}

Sericin can also be classified based on the color of cocoons from which it is obtained. White sericin is the low viscosity sericin. Yellow sericin, is the one which is medium viscosity sericin, used in salad dressing. Yellow-green sericin, is the high viscosity sericin, contains flavonol pigments, which has antioxidative property, which is mostly incorporated in baking of bread.\textsuperscript{[5,7,8]} The properties of sericin are mentioned in Table 2.

**Sericin-extraction**

**Extraction with the aid of heat**

Sericin belongs to the category of structural glue proteins synthesized within the silk gland cells and secreted into the lumen of the gland. Presently, sericin is obtained from cocoon when the raw silk is processed into fibers. Sericin in the cocoon layers is extracted with hot water or mildly alkaline solution. Apart from the proteins, many other constituents such as carbohydrates, wax, pigments, and minerals are also present in layers. Of these constituents, the lower molecular weight accumulates along with sericin layers and emerges when sericin is extracted. Sericin sample is prepared by dialysis of this extract fluid which removes the low molecular weight components, except the pigments, followed by freeze-drying.\textsuperscript{[7]}

**Extraction of sericin with enzymes**

Extraction is carried out using enzyme alkylase or alkaline protease at 60°C for 90 min, at a pH 10. Following which, hydrolysis is done with trypsin for the retrieval of sericin.\textsuperscript{[9]}

**Proteins and its Importance**

Proteins are the biomolecules or macromolecules comprising a chain of amino acids. It has wide spectrum of functions ranging from catalyzing various biochemical reactions, transport of biomolecules, DNA replication and many more. The recommended dietary allowance (RDA) for proteins is 0.8 mg/kg of body weight. If protein is consumed more than

\textsuperscript{[7]}

\textsuperscript{[9]}

\textsuperscript{[7,21]}

\textsuperscript{[7,8]}

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\textsuperscript{[5,7,8]}
1.5 mg/kg of body weight, which is almost the twice of RDA for proteins causes oxidative stress on the kidney, increases glomerular filtration rate, hypertrophy of the contralateral kidney and can lead to formation of renal calculi.\textsuperscript{[10,11]}

Whereas, decreased protein intake can lead to growth retardation, reduced osmotic pressure causing extravasation of fluid to the interstitium, leading to edema. Decreased protein intake can lead to malnutrition in children and can affect the growth, intelligence and several other functions in children. Sericin is a treasure, as it is generated free of cost and if utilized properly can combat the protein-energy malnutrition in India.\textsuperscript{[12,13]}

In oral cancer, the requirement of protein increases, and it becomes difficult for the patients of low socioeconomic class to combat with the needs. In such a scenario, sericin, which is readily available, if integrated with the bread, can serve as a milestone for the dietary requirement of such patients.\textsuperscript{[12,13]}

### Sericin-nutritional Component

Silk protein has been used as diet for Control Ecological Life Support System, the Japanese Aerospace Exploration Agency. They have devised a recipe on using silk protein for astronaut food. Moreover, dried cocoon powder when used to feed poultry and fish has reported better growth rate, improved quality of egg and prolonged survival of hens.\textsuperscript{12} Sericin is hydrophilic in nature and has a strong affinity for other proteins. In general, silk fiber is nontoxic to degradation, as its amino acid composition is similar to that found in humans. The high concentration of these amino acids in sericin causes chelation with different metal ions, with interpositioning of hydroxyl groups resulting in increased capacity for water retention. Furthermore, it is resistant to degradation by proteases. In the year 1998, the Japanese Association for Dietary Fiber Research stated that “food ingredients that are hardly digestible or absorbable within the human small intestine and exhibit a physiological effect that is useful for the maintenance of good health via the digestive tract” should be collectively termed as “luminacoids,” which means the substances which possesses variable physiologic properties. Proteolytic enzymes play an important role in research labs from food industries to pharmaceuticals.\textsuperscript{14} Sericin is a scalable protein, can be manipulated to a greater extent without altering its physical and chemical properties and nutritional value.\textsuperscript{15}

Various studies have reported that dietary sericin reduces the level of serum cholesterol and triglyceride in rats. The reduction in serum triglyceride also causes reduction in very low-density lipoprotein (VLDL) without affecting the serum high-density lipoprotein levels.\textsuperscript{16} As high level of triglyceride and VLDL increases the chance of atherosclerosis, consumption of sericin can be helpful in the prevention of atherosclerosis. Sericin also exerts an inhibitory effect on the accumulation of lipids in the liver and causes decreased release of triglycerides to the serum. The free fatty acids in the serum are reduced with sericin intake, without affecting the activity of carnitine palmitoyltransferase I (CPT I) which is a rate limiting enzyme for the oxidation of fatty acids. The suppressive effect of sericin on free fatty acids is associated with increased peripheral glucose uptake, bringing about a better glucose tolerance. It has been reported that a dietary addition of 2% sericin, significantly reduces the oxidative stress in rats. Recently, it has been found that sericin increases the antioxidant activity in rats by inhibiting tyrosinase.\textsuperscript{13,15} It has an anti-constipative effects, as it causes increased excretion of fecal nitrogen, thereby causing increased evacuation in rats.\textsuperscript{16,17} Furthermore, sericin increases intestinal absorption of various trace elements such as zinc, magnesium, and iron, and the resultant is increase in bioavailability of these substances.\textsuperscript{16} Sericin is also an anti-frosting agent, and coating of it if applied on raw fruits and vegetables can prevent them from freezing.\textsuperscript{18} The composition of sericin food grade powder is mentioned in Table 3. The merits of using sericin in food industry are mentioned in Table 4.

### Sericin in the Making of Bread

Sericin was incorporated in the baking of bread to promote the nutritive benefits of sericin. Diabetics can use bread integrated with sericin, because it is rich in fibers. Takechi and Takamura stated that incorporating sericin, in a calculated dose of

| Table 3: Composition of sericin food grade powder\textsuperscript{[10]}
| --- | --- |
| Attributes | Properties |
| Water content | 2.64% |
| Protein | 96.4% |
| Fat | 0% |
| Nitrogen | 9-16% |
| Arsenic | 0.9 ppm |
| Lead | 0.08 ppm |
| Ash | 0.8-6% |
| Sodium | 280 mg/100 g |
| Calories | 400/100 g |
| PER | 95 |
| Biological value | 96 |

PER: Protein efficiency rating

| Table 4: Merits of using sericin in food industry\textsuperscript{[8,10,14,15,20]}
| --- |
| Readily available |
| Nontoxic |
| Economical |
| Excellent moisture retaining capacity |
| Increased fiber content |
| Antioxidant |
| Good emulsifying agent |
| Good anti-frosting agent |
| Reduces serum cholesterol and free fatty acids |
2-4/1000 g of flour while baking bread, tends to lower the height and the specific volume of the bread, while maintaining a uniform internal surface texture.\(^\text{[18]}\) Whereas, adding sericin in excessive amount >10/1000 g of flour causes significant changes in the color, hardness and palatability of the bread. It is reported that the color becomes darker, the consistency becomes harder and it becomes difficult to swallow the bread.\(^\text{[18]}\) Scanning electron microscopic studies were used to assess the internal structure and surface volume of the bread slices baked using varying amount of sericin. The authors stated that up to 330 mg of sericin can be consumed in 1 slice of bread. The final conclusion of the authors was that sericin if added in calculated amount to the bread can be an ideal processed food which is effective in digestion and absorption.\(^\text{[18]}\) The standardized formulation for preparation of bread using sericin is mentioned in Table 5.

**Regulatory Bodies\(^\text{[12]}\)**

In India, not much of research has been done with sericin in the food industry. Food Safety and Standards Authority of India (FSSAI) is the apex body that enforces the regulations on food as prescribed in the Food Safety and Standards Act, 2006 (FSS Act). As per FSSAI regulations, food products fall into two categories—standardized and non-standardized. The standardized food products are those for which standards are set and do not require prior approval to manufacture, sale, distribution, or import.

Non-standardized food products are those, which do not have standards pertaining to the safety parameters. Non-standardized food products, awaiting product approval, are evaluated for safety. To facilitate product approval, a 90-day outer limit is given for completion of the application and review process. Furthermore, if the product is further referred to the Scientific Panel for scrutiny, the time limit could be extended for another 30 days. The applicants can track the application status at any stage of the approval process, and on approval they can continue with the research process.

**Sericin in Salad Dressing\(^\text{[19]}\)**

Salad dressing can be grouped into three types, namely, vinaigrettes, emulsified dressings, and creamy dressings, and each contains a different mix of ingredients.\(^\text{[19]}\) Vinaigrettes blends an acid and oil, with or without herbs, and need to be mixed vigorously just before serving to ensure that they are well mixed and balanced. For optimal vinaigrette quality, it is mandatory to assimilate additives to maintain emulsion after vigorous whisking as well as to prevent lipid peroxidation. Emulsified dressings are made by blending oil and vinegar with a third ingredient (usually a naturally occurring emulsifier, i.e., egg yolk), which helps the dressing become a non-separable emulsion. Creamy dressings can be prepared from a wide range of ingredients which includes sour cream, yogurt, heavy cream, and buttermilk. The antioxidant action of sericin together with a wide range of emulsifying activity makes it a promising ingredient in salad dressing.\(^\text{[20,21]}\)

**Conclusion**

The silk-derived protein sericin is not an ecofriendly product, but it has proved to be a key ingredient in food industry, it also finds application in cosmetic and biomedical fields. Yet, limitations are there in devising appropriate protocols and equipment to extract, purify and use sericin in a right way. Considering the biochemical functions, it possesses, it is worth to undergo extensive research to incorporate sericin as a routine additive in the greasy food, beverage, and dairy products.

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**Table 5: Standardized formulation for prepared bread\(^\text{[19]}\)**

| Ingredient    | Amount   |
|---------------|----------|
| Wheat flour   | 250 mg   |
| Sericin       | 2-8 mg   |
| Sugar         | 17 mg    |
| Salt          | 4 mg     |
| Dry yeast     | 2.8 mg   |
| Butter        | 10 mg    |
| Water         | 180 ml   |
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