

SILK PROTEIN: A BOON TO COSMETICS

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Abstract: Silk is the fibrous protein of animal origin. Silk extract obtained from the cocoon of caterpillar consists of two proteins viz, fibroin and sericin. Fibroin is the structural center of silk and sericin sticks the silk cocoons together. Silk proteins are beneficial for skin, hair and nails having a vast application in cosmetics because of its numerous biological functions such as UV resistance, antioxidant, antimicrobial, antibacterial, absorbs and release moisture, inhibition of tyrosinase and kinase's activity, aids in wound healing, facilitates in hair growth and makes it softer and silkier and also prevents nails from chapping and brittleness. It works on skin for cellular and dermal matrix regeneration, moisturization and skin brightening with UVB protection by forming an active topical nanomatrix. It easily penetrates into the individual strand of hair because of its low molecular weight, thereby binding the keratin present in hair, forming a layer that protects against the moisture loss.

Index Terms – Silk Protein, Sericin, Fibroin, Cosmetic Applications, Skin, Hair.

Introduction

Silk is a fibrous protein of animal origin.¹ Silk is a natural fiber which is produced by silk worms and spiders is among the most important silks. The most widely used silks are from the domesticated silkworm, *Bombyx mori*, and from spiders *Nephila clavipes* and *Araneus diadematus*. The essential constituent of cocoon filament is the silk protein. The cells of silk glands produce the silk proteins, and these proteins are stored in the lumen of the silk glands which are further converted into silk fibers. When the liquid silk is secreted by the silkworms, it passes through the anterior gland and it is expelled out through the spinneret opening at the time of spinning.

Silk extract, prepared from the cocoon of the silk caterpillar consists primarily of two proteins, fibroin and sericin.² Fibroin is fibrous in nature, whereas sericin is an amorphous glue-like substance.¹ Both the silk proteins provide the benefits for hair and skin care, and sericin is currently the most widely utilized.



Fig. 1 - Silk Worms³

1. FIBROIN- It is one of the proteins produced by the silkworm. Being a structural center of the silk, it also contributes to its rigid structure and tensile strength. Most of the skin care products use fibroin because this protein has a high percentage of glycine and alanine. The combination of both gives silk a remarkable effect on the skin.

A. GLYCINE- It is the simplest form of an amino acid which is capable of being manufactured in the body from diet. This amino acid produces a protein that has high collagen concentration. Therefore, glycine can help in repairing the damaged tissue and also speed up the healing processes much better than common collagen.

B. ALANINE- It is another amino acid which the body is capable of manufacturing through the diet. It has been discovered that the use of alanine in the skin care purposes like skin conditioning agent and masking ingredient, is because of its ability to combine with the epidermal cells which fill up the creases, giving a smooth surface to the skin appearance.⁴

2. SERICIN- It is the protein that sticks the silk cocoons together.⁴ Sericin contains 18 amino acids where serine, aspartic acid, and glycine are the most significant compound. This protein is composed of 45.8% of hydroxy amino acids, 42.3% of polar amino acids, and 12.2% of non-polar amino acids. Sericin can be copolymerized and blended along with other polymers to produce biodegradable materials which are possible since sericin possesses a strong polar side chains such as hydroxyl, carboxyl and amino allowing the easy cross linking. Therefore, sericin is most widely used.⁵ The attributes of sericin and fibroin are given are shown in the figure-1 below-

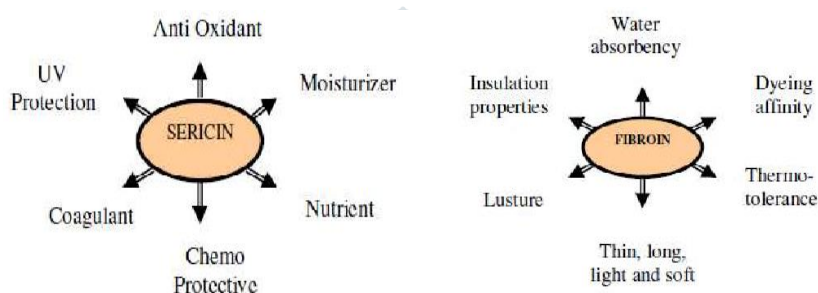


Fig. 3- Diagrammatic representation of attributes of 1. Sericin 2. Fibroin.⁶

Composition of Silk Protein

The average percentage of amino acids contained in silk protein is given in Table-1

Table 1- Composition of silk protein^{7,9}

Amino Acid	Average percentage of amino acid
Alanine	26.8
Arginine	1.7
Asparagine	5.6
Cysteine	0.1
Glutamine	4.4
Glycine	32.8
Histidine	1.1
Isoleucine	0.8
Leucine	1.2
Lysine	1.7
Methionine	0.2
Phenylalanine	0.9
Proline	1.2
Serine	11.6
Threonine	2.1
Tyrosine	1.0
Valine	2.1

The amino acid composition in fibroin and sericin expressed as percentage of amino acid N/ total N on moisture free basis are given in Table-2.

Table 2- Percentage of amino acid N/ total N on moisture free basis in fibroin and sericin. ⁸

Amino acid	Fibroin	Sericin
Glycine	43.75	9.85
Alanine	29.05	3.21
Valine	1.85	2.20
Leucine	0.42	1.2
Isoleucine	0.53	0.67
Serine	10.0	19.31
Threonine	0.90	5.90
Aspartic acid	1.51	10.30
Glutamic acid	1.07	2.34
Phenylalanine	0.50	0.27
Tyrosine	5.42	1.51
Lysine	0.60	26.83
Histidine	0.36	5.97
Arginine	1.90	1.21
Proline	0.50	2.02
Tryptophan	0.39	0.24
Cystine	0.08	0.01

Properties

1. Solubility-Sericin is classified into three fractions depending upon its solubility, as sericin A, sericin B, and sericin C. Sericin A is the outermost layer which is insoluble in hot water, which consists of about 17.2% of nitrogen and amino acids such as serine, threonine, glycine and aspartic acid. Sericin B constitutes the middle layer, which on acid hydrolysis yields the amino acids of sericin A in addition to tryptophan, it consists 16.8% of nitrogen. Sericin C is the innermost layer adjacent to fibroin, insoluble in hot water but can be separated or removed from fibroin by the treatment with hot dilute acid or alkali. The solubility of sericin in water decreases when its molecules are transformed from a random coil to the β -sheet structure.¹⁰

2. Gelling Property- Sericin consists of random coil and β -sheet structure where the random coil is soluble in hot water and with the lowering in temperature the random coil structure gets converted to β -structure leading to the gel formation.¹⁰ This phenomenon is reversible when the sample is heated in water to 50-60°C which can be gelled again.¹¹ Sericin's gelation phenomenon, occurs faster at low temperatures (10°C) and pH about 6-7.¹² The gel strength of sericin increases with the decrease in surface tension and the gelation time decreases with the addition of high concentrations of poloxamer gel. This is because the latter gel absorbs the water that surrounds sericin.⁵

3. Isoelectric Point-The isoelectric point of sericin is about 4 because there are more acidic amino acids than basic amino acid residues.¹³

4. Sericin also exhibits the properties such as biocompatibility, biodegradability, and wettability that allow the development of cosmetic products for skin, hairs, and nails.¹⁰

The detailed description of sericin and fibroin are given in Table-2 below-

Table 3- Properties of Silk Proteins

Protein	Property	Value	Information	References
Sericin	Form	Gelatinous, sol-gel	Easily dissolves in water at 50-60°C; returns to gel form on cooling Gelation is rapid at 108°C and pH $\approx$ 6-7.	14
		Powder, amorphous structure	Transforms into β - structure in the presence of water.	14
	Molecular weight	10 to >400kDa	Depending on extraction method, temperature, pH, and processing time.	14
		35 to 150 kDa	Heat and acid extraction.	14
		15 to 75 kDa	Alkaline solution extraction.	14
		10 to >225 kDa	Urea extraction.	14
		<20 kDa	Recovered during early stages of raw silk production.	14
		>20 kDa	Obtained from later stages of raw silk production.	14
	Solubility	Highly soluble in water	Decreases when molecules are transformed from random coil into the β -sheet structure.	14
	Isoelectric Point	$\approx$ 4.	Because there are more acidic than basic amino acids in sericin.	14
Fibroin	Form	Pale Yellow Mass		14
	Molecular Weight	300 to 420 kDa		14
	Solubility	Soluble in concentrated alkalis, concentrated mineral acids, and in ammonical nickel oxide solution. Insoluble in water, alcohol, ether, and diluted alkalis.		14
	Isoelectric Point	5.1		7,9

Applications and Benefits

Silk Proteins exhibits the properties of biocompatibility, biodegradability and wettability which allows the development of cosmetic products for skin, nails, and hair.⁵

Benefits

1. For Skin-

- Stimulates collagen production which improves the appearance of lines, wrinkles, sagging skin and other signs of ageing.¹⁵
- Promotes healthy barrier function and skin hydration as amino acids are the primary components of the skin's natural moisturizing factor (NMF).¹⁶
- Aiding the skin's wound healing process, which helps to prevent the scars.¹⁵
- Provides protection against harmful free radicals as many amino acids possess strong antioxidant qualities.¹⁵
- Resistant to ultraviolet (UV) rays and also inhibits the development of harmful bacteria.¹⁷
- It is also used to make biodegradable products which could help to reduce the environmental impact of manufacturing.¹⁷

2. For Hairs-

- a. Silk proteins contains amino acids that helps to facilitate hair growth and make softer, because silk protein has low molecular weight that is able to penetrate individual strands of hair, helping to improve elasticity and increase shine.¹⁷
- b. It prevents direct contact between hair and chemicals which will prevent the hair damage from harsh chemicals or radical from environment.⁴
- d. Hair and bath preparations, containing sericin and 0.01-1% olive oil, fatty acids or their salts show reducing damage of hair surface by binding of sericin to hairs.¹⁸
- e. Sericin hydrolysates with average molecular weight 300-3000 are used as conditioners for skin and hair.¹⁹
- f. Shampoo containing sericin and palarogenic acid of pH less than six are useful for the care and cleaning of hairs.²⁰

3. For Nails-

Nail cosmetics containing silk protein are reported to prevent nail from chapping, brittleness, and imparting the inherent gloss to nails.²¹

Application

Wetting properties of sericin have been evaluated in different cosmetic formulations such as creams and lotions. It has been found that a powder mixture of silk fibroin (70-95%) and sericin (5-30%) has antistatic characteristics and capacity to absorb moisture²² and both detection and UV filtration are enhanced.²³ The application of silk protein in some cosmetic product formulations are given in Table-3 below.

Table 3-Available Cosmetic product formulations including silk sericin

Product	Effects	Reference No
Gel using 1.5% (p/p) and 2.0% (p/p) of sericin, 2.5-10% (p/p) of pluronic acid and 0.05-0.2% (p/p) of carbopol	Prevents water loss from the skin top layer. Forms a proactive and moisturizing surface that gives to the skin a silky, smooth feeling. ⁵	[10]
1% (p/p) sericin and 4% (p/p) D-glucose lotion.	Moisturizer. ¹⁶	[21]
Creams containing 0.001-30% (p/p) of sericin	Improves cleaning properties with less skin irritation. ¹⁷	[24]
Nail Cosmetics with 0.02-20% (p/p) of sericin	Helps to prevent brittleness and provides shine to the nails. ¹⁶	[21]
Hair cosmetics containing sericin between 0.02-2% (w/w), and bath preparation with 0.01-1% (w/w) of fatty acids from olive oil	Reduces surface hair damage. ¹³	[18]
Hydrolyzed sericin with low molecular weight	Hair and skin conditioner. ¹⁴	[19]
Shampoo with sericin and palarogenic acid	Helps with hair cleaning. ¹⁵	[20]

Working of Silk Protein

A. On Skin-

Silk extracts are used cosmetically creating an active topical nano-matrix promoting the moisturization, sebum absorption and skin tightening. The bioactive proteins and peptides present in silk extracts increase cellular activity of epidermal cells and growth rates of collagen that produce dermal fibroblasts.

Silk proteins also aids in wound healing for skin cells and non-cellular skin components. Silk protein also demonstrate potent antioxidant, UVB photo protective and anti-tyrosinase melanin inhibitive effects that help promote a brighter, protected and less inflamed complexion. While the skin care benefits of silk proteins include cellular and dermal matrix regeneration, moisturization with cosmeceutical delivery and skin brightening with UVB protection.²

1. Cellular and dermal matrix regeneration

Silk proteins have been shown to increase the growth and survival of human dermal fibroblasts that is the collagen producing cells, by up to 250 percent compared to control groups. Also, studies have shown a measurable increase in epidermal thickness with the application of silk proteins. The body of scientific evidence that supports the silk protein's role in improving the skin's cellular regeneration is large and still growing. The bioactive peptides appear to be responsible for some of the beneficial effects where the ability of silk to form a tightly adherent microenvironment- controlling nanofilm may also play a role, regardless of mechanism, improved dermal fibroblast survival and growth from silk proteins correlating with better dermal function. This is essential because improved dermal function has the potential to enhance the skin thickness and elasticity.²

2. Moisturization with cosmeceutical delivery

A recent study for skin hydration of 47 renal patients with dry itchy skin found that the addition of silk protein to moisturizing cream base greatly improved the skin hydration compared to base cream alone. Silk proteins provides an improved deliver of cosmeceutical actives. Silk proteins or silk extracts resembles a micro-sponge when studies under the microscope. When the silk proteins mixed in with other ingredients is applied on the skin, the active agents leech out of silk over time and the toxins from the skin leech in. The active compounds within the silk protein matrix gets slowly absorbed into skin while silk slowly absorbs the things that can be detrimental to the skin such as sebum and keratinaceous debris. Silk is used to deliver moisture and active compounds to skin where moisturizers and sleep masks are traditional ways. The innovative silk-based spa-focused facial masks are increasingly popular new way to obtain these benefits.²

3. Skin brightening with UVB protection

Silk proteins promote brightness while at the same time offers broad anti-inflammatory properties that are comparable to aspirin like compounds, in laboratories. In addition to calming the skin brightening, silk proteins have shown to greatly reduce the risk of two common American problems UVB- induced skin damage and tumor development.

A study of more than 40 patients applying a moisturizer with and without silk proteins demonstrated significant reductions of skin pigmentation levels on both arms and legs. The results were both clinically and statistically significant. The potency of silk protein anti- tyrosinase brightening activity was found to be variable, in large part depending upon the finer aspect of silk extraction technique and initial silk quality.²

B. On Hair-

Hair is mostly made up of protein called keratin which is responsible for strengthening it and protecting it from damage. If the hair gets damaged or gets low in keratin, using the hair care products containing the silk proteins replenish that supply and make the locks healthier. In addition, the products containing the silk proteins can also reinforce weakened strands.²⁵

Silk protein contains amino acids that help facilitate hair growth and make strands softer. The silk protein has the ability to easily penetrate the individual strand of hair because of its low molecular weight.¹⁷

When applied to hair the silk proteins bind to the keratin that are present in hair creates a layer to protect against moisture loss.²⁶ Silk proteins penetrate into the hair bulb and nourish it from the roots up. It moisturizes and nourishes each strand of hair, forming a protective shield around the scalp thus rejuvenating the damaged locks and keeping them shiny. It also makes hair stronger enough to retain moisture that is required to remain lustrous and soft. Hair care products containing this essential ingredient are known for reducing the dryness, repairing split ends and making the hair silkier.²⁵

Everyone has different hair but those who have had their hairs treated or colored a number of times need more protein than others. Chemical treatments break the natural protein bonds which can result in irreparable hair damage if damaged scalp is not treated on time.

Hydrolyzed silk protein can replenish the hair with cysteine which is an essential amino acid that boosts the keratin production. Having lower molecular weight, silk protein which is hydrolyzed can easily penetrate

into hair strands at the molecular level. Once it does, it improves its elasticity and makes it strong enough to prevent it from breaking. The natural shield provided also ensures a full head of hair remains shiny and retains moisture.

According to several clinical studies, silk proteins also have anti-oxidant properties indicating that they have anti-aging and anti-wrinkling properties which when applied to hair care products will give a shinier and thicker hair. It also makes the strands silkier which spells good news for those who have frizzy, damaged or unmanageable hair.²⁵

Conclusion

Silk Proteins provides a variety of benefits to be used in cosmetics such as biocompatibility, biodegradability, wettability, stimulates collagen production, promotes skin hydration, antioxidant property, resistance to UV rays, wound healing, conditioning and improvement in elasticity of hairs. On skin they work by forming an active topical nano-matrix which promotes moisturization and skin tightening. The bioactive peptides are responsible for the ability of silk to form a tightly adherent microenvironment-controlling nanofilm, having an important role in dermal fibroblast survival and better dermal function leading to cellular and dermal matrix regeneration and moisturization. Hair is mostly made up of protein called keratin responsible for strength and protection from damage. Silk protein binds to keratin forming a layer providing protection from moisture loss. It penetrates into hair bulb and nourish the hairs from root and also locks the cuticle thereby improving the shine and soft feel of hair.

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