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CHEMICAL ENGINEERING - MATERIALS ENGINEERING

Sericin applications: a globular silk protein

INGENIERÍA QUÍMICA - INGENIERÍA DE MATERIALES

Aplicaciones de la sericina: una proteina globular proveniente de la seda

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Abstract

Sericin is a protein found in silk. This one has different biological functions such as oxidation resistance, antibacterial and antimicrobial activity, and solar ultraviolet radiation (UV) protection, easy absorption and moisture release, inhibition of tyrosine and kinase's activity and cellular additivity, anticoagulants and anticancer properties, and also promotes cell growth and wound healing.

In this scientific review article will be reviewed general characteristics of both the fiber of silksilk worm *Bombyx mori*, and specifically of silk sericin (physico-chemical composition, structural properties and extraction methods). The potential use of sericin in food, drug and cosmetics applications will be also detailed, due to its valuable bioactive properties.

Keywords: Applications, protein, sericin, sericulture, silk.

Resumen

La sericina es una proteína que se encuentra en la seda. Esta posee diferentes funciones biológicas tales como resistencia a la oxidación, actividad antibacterial y antimicrobiana, protección a la radiación solar ultravioleta (UV), fácil absorción y liberación de humedad, inhibición de la actividad de la tirosina y de la cinasa, aditividad celular, propiedades anticoagulantes y anticancerígenas, además, promueve el crecimiento celular y la cicatrización de heridas.

En este artículo de revisión científica se examinarán las características generales de la fibra de gusano de seda *Bombyx mori* y específicamente de la proteína de sericina (composición fisicoquímica, sus propiedades estructurales y los métodos de extracción). También se detallará el uso potencial de la sericina en aplicaciones alimenticias, farmacológicas y cosméticos, principalmente por el interés que despierta sus valiosas propiedades bioactivas.

Palabras clave: *Aplicaciones, proteína, seda, sericina, sericultura.*

1. Introduction

Silk is a natural fibre that is produced by silk worms such as *Bombycidae, Saturnidae* and *Lasiocampidae* (Nagaraju, 2008) and spiders (Humenik et al., 2011). Mulberry silk, so named due to they are only fed with mulberry leaves, is obtained from *Bombyx mori* (*Bombycidae* family). This silk worm needs human care to growth and reproduction mainly because the way they were domesticated many years ago.

Sericulture is a labor-intensive industry in which mulberry tree (*Moraceae* family, *Morus* genus) is grown and silk worms are reproduced. The aim of this industry is to obtain both yarn and textile products. This activity includes: egg conservation, silk worm breeding, prevention of diseases, feed using mulberry leaves, collection of mature larvae and transfer to the cocoons formation area (Takeda, 2009). Around de world, 100 thousand tons/years of silk are produced. China contributes with 70% of it, followed by Brazil, Japan, India, Thailand and Vietnam. In Colombia, the silk production is low, and La Corporación para el Desarrollo de la Sericultura del Cauca (CORSEDA) is the only producer (20.5 ton/year) in the country (Pescio et al., 2008).

Silkworm needs an especial diet to produce high quality cocoons and white mulberry leaves (*Morus alba*) has a nutritional value that meets this requirement. These leaves are composed by water (81.72%), fat (0.57%), protein (1.55%), fibre (1.47%), carbohydrates (14.21%) and other minor compounds (0.48%), such as minerals (Capsadel, 1883; Imran et al., 2010). Leaf proteins are synthetized by cocoon´s gland cells silk, and right after they are stored into the lumen, where they are transformed in silk fibre. During the pinning process, this silk passes through the anterior gland and thereafter it is ejected through the die opening. The result is a delicate double fibroin filament, which is coated by a gum called sericin. This last one, helps to form the silk cocoon because it acts as a binder that maintains the structural integrity of this one. The obtained structure, which has an oval-shaped, is a safe haven during the larva metamorphosis, process in which it becomes pupa (Patel & Modasiya, 2011; Takeda, 2009).

2. Silksilk worm life cycle - Bombyx mori

Bombyx mori is a lepidopteran insect that has been domesticated for more than seven thousand years. The physiology of these species has been widely studied due to the economic importance of silk production throughout the centuries (Nagata & Nagasawa, 2006). The silkworm life cycle includes four different stages of metamorphosis: egg, larva, pupa or chrysalis, and adult (moths). Larval stage consists of five stages or ages (Kundu et al., 2008; Red Andina de la Seda, 2009). The production of eggs is the first stage of the metamorphosis. The female silk worm lays between 300 to 400 eggs at the same time, and right after she dies; the male silk worm, on the other hand, lives a bit longer after this event (Ude et al., 2014). In the second stage, eggs are incubated for about ten days until they have hatched into larvae (caterpillars). Larvae are fed with mulberry leaves in order for them to store enough nutrients and also be able to shed their skin five times. This period lasts for about four to six weeks until a caterpillar is formed. The third stage, called pupa or chrysalis, begins by building the silkworm cocoons, right after the feeding period is completed (Zhao et al., 2005). The aim of this cocoon is to protect the pupa from microbial degradation, natural drying during metamorphosis, and from potential predators (Kirshboim & Ishay, 2000).

Silk caterpillar weaves cocoon around itself continually moving its head as 8 or S, which is achieved by cyclic bending and stretching their body. Cocoons are lightweights (only several grams) and compacts, and they are made of a single continuous filament silk with a length between 700-1500 m. These are constructed in 3 days approx. and right after, the silk worm sheds its skin for the last time and then it becomes pupa. The cocoon has an ellipsoidal form with the smallest thickness at its two ends. These points are pierced with an alkaline substance secreted by the silk worm, allowing that the invertebrate emerges as moth to complete the metamorphosis (Zhao et al., 2005; Ude et al., 2014; Pescio et al., 2008).

3. Silk

Silk is the only natural fiber available commercially as a continuous filament. It has a wide range of textile properties that have made it commendable to be used in this industry. Some examples are its finesse, strength, elasticity, dyeability, softness, flexibility, gloss, elegance, and high properties (Khan et al., 2010; Ude et al., 2014).

3.1 Silk fibre structure

Silk fiber is mainly composed of two proteins: fibroin (70-80%) and sericin (20-30%), and other minor components such as carbohydrates, waxes and ash (1.0-2.0%) (Takasu et al., 2002; Mondal et al., 2007). Moreover, fibroin is a fibrillar protein, which has a semicrystalline structure that provides stiffness and resistance to fiber, while sericin is an amorphous protein that operates as a binder to maintain structural integrity of the cocoon (Humenik et al., 2011; Vepari & Kaplan, 2007; Zhang, 2002).

3.2 Silk transformation

Silk transformation involves different steps to obtain a silky material, which is characterized by its softness, length, fine gauge, affinity dyes, capacity brightness and thermal tolerance (Burkinshaw & Paraskevas, 2010; Mondal et al., 2007). This steps are: 1) hot air drying, 2) “fluff” process, 3) cooking, 4) raw silk winding, 5) spool process and 6) degumming. In the first step, freshly harvested cocoons are dried at a temperature of 110-115 °C in order to avoid the metamorphosis of the silk worm. After this process, it is recommended to store cocoons for a period no longer that 40 days, and protect them from moisture to prevent fungus growth. Before constructing cocoons, the silkworm produces a loose woven known as "fluff", with the intention of keeping the cocoon attached to a supporting structure. This woven, which is 1.5% of the weight of cocoon is removed in the second step. This process can be conducted either manually or using a specialized machine. In the third step, cocoons are cooked in hot water to expand them and soften the outer layers of sericin. This process allows filaments being detached easily from them. Later on, in fourth step, bundles of raw silk are produced through the merge of several filaments that are twisted to form yarns. These yarns may have both different thicknesses and twists depending on the end use. This procedure is done using a spinning machine. During spool process, the samples called spinning yarn, are transferred from ring bobbin or hanks into a package such as cone and spool, where yarns have the longest length. This length is achieved by joining several yarns through small knots (Pescio et al., 2008).

Finally, degumming step is conducted to achieve high quality dyeing, and to improve both silk appearance and its application in the textile industry. This process consists in removing the sericin from yarns (Martínez & Del Val, 2010). Traditionally, the degumming procedure not only is performed with soap in a strongly alkaline medium, but also alternative procedures are being studied using other chemical compounds. For example, some researchers are doing studies on hot water at high pressures, synthetic detergents, mineral acids, alkalis and enzymes (Riva et al., 2001).

4. Sericin

Sericin is a cold water insoluble protein, highly hydrophilic, with adhesive characteristics such as gelatine. This protein, which has a globular structure, allows the adhesion of silk filaments to maintain the structural integrity of the cocoon during its formation (Dash et al., 2007; Hoa et al., 2012). Furthermore, sericin contains 18 amino acids where serine (32%), aspartic acid (18%), and glycine (16%) are the more significant compounds. Additionally, this protein is composed of 45.8% of hydroxy amino acids (serine and threonine), 42.3% of polar amino acid, and 12.2% of non-polar amino acids (Shaw & Smith, 1951; Voegeli et al., 1993; Zhang, 2002). In order to produce biodegradable materials, sericin can be copolymerized and blended along with other polymers. This is possible as the sericin possesses a strong polar side chains such as hydroxyl, carboxyl and amino that allow an easy crosslinking (Nagura et al., 2001).

The molecular weight of sericin depends on its extraction method. For instance, there is a range of 40-400 kDa when this is recovered from cocoons and a range of 80-310 kDa when it is extracted directly from the gland worm (Wei et al., 2005). These ranges will depend on their extraction conditions as the reactive type (acidic, alkaline, enzymes), and other factors such as temperature, pressure, pH and the processing time (Zhang, 2002).

4.1 Properties

Solubility. Sericin is a partial soluble protein in hot water. It can be classified according to its relative solubility, using different designations such as: A and B, or sericin I, II, III, and IV; also S1, S2, S3, S4, and S5; and α, β, γ modification (Komatsu, 1996; Voegeli et al., 1993). Depending on the sericin position within the layer of the cocoon, other researchers define two subunits: α-sericin and β-sericin. The first one is located in the outermost layer and it has a high solubility in hot water. The second one is in the inner layer and it keeps a low solubility when is compared with the α-sericin. This difference between these two subunits can be explained by the presence of a smaller amount of carbon atoms and hydrogen, and a greater presence of nitrogen and oxygen in β-sericin (Bose et al., 1989).

Solubility is also related to the amorphous and crystalline structure of sericin. The amorphous region is formed of a random coil structure, which is the main molecular conformation of the readily soluble sericin. The crystalline region, called β-sheet, is more difficult to dissolve (Dash et al., 2007).

Gel properties. Sericin's gelation phenomenon, which was first investigated in 1994, occurs faster at low temperatures (10 °C) and pHs about 6-7 (Zhu et al., 1995). An aqueous solution of sericin forms a gel when random coil structure of the protein changes to β-given sheet (Aramwit et al., 2012). This phenomenon is reversible when the sample is heated into water to 50-60 °C and it can be gelled again on cooling (Komatsu, 1980). According with Kweon et al. (2000), gel strength of sericin increases with decreasing surface tension and the gelation time decreases with the addition of high concentrations of poloxamer gel. The reason behind this is that the hydrophilic parts of latter gel absorb the water that surrounding sericin.

Isoelectric point. It is referred to the pH at which a molecule carries no net electrical charge. It is also defined as the reference concentration of hydrogen ions, or other ion in which this condition can be found. Therefore, it has become customary to define the isoelectric point in terms of the pH scale. The isoelectric point of sericin has been reported between 3.5 and 4.0. It is due to greater amount of acids amino-acid that basics (Voegeli et al., 1993).

4.2 Methods for sericin extracting

As mentioned above, sericin is removed during degumming process of silk (Capar et al., 2008). This procedure is based on the protein hydrolysis by using chemical, thermal or physical processes (Gupta et al., 2013). Detergents (Vaithanomsat & Kitpreechavanich, 2008; Capar et al., 2008), alkalis, acids and hot water (Sothornvit et al., 2010; Padamwar & Pawar, 2004; Khan et al., 2010) can also be used.

Wastewaters from the degumming process can contribute to increase the deposited organic load in aqueous effluents, leading to water pollution. This is due to the solubilized sericin during process, which increases the BOD and COD (Takasu et al., 2002; Capar et al., 2008; Mondal et al., 2007). It has been reported a production of about 1 million ton of cocoons (fresh weight) worldwide, this is equivalent to 400.000 ton of dry cocoon, and 50.000 ton of sericin (Zhang, 2002).

Due to the increasing global attention on the processes of cleaner production, sericin is being studied as a bioactive compound, which can be used in the food, biomedical, pharmaceutical and cosmetic industries.

Along with the cleaner production, some methods are being studied about extraction and recovery of this protein. This last topic includes the use of alkaline proteolytic enzymes (Freddi et al., 2003), filtration membranes for recovery (Capar et al., 2008), and also technologies such as infrared (Gupta et al., 2013). These new methods bring with them both positive and negative characteristics. For example, the use of enzymes requires less water, energy and chemicals, but it is expensive and generates the degradation of sericin (Arami et al., 2007). With respect to infrared technology, this is associated with cost reduction and higher efficiency in the heating cycle; however, it is still an expensive technology.

The sericin extraction process in hot water using both high temperatures and pressures is an example of an environmentally friendly technology (Zhang, 2002; Padamwar & Pawar, 2004; Sothornvit et al., 2010). Recovering and using sericin via this method can represent a significant economic, social and environmental benefit. This methodology does not need to use any harmful solvent (water is sufficient), and therefore protein recuperation is achieved easily by dehydration sample. Nevertheless, it must be especially careful during the process conditions, because they are associated not only with the extraction yield, but also with characteristics of the obtained sericin and the quality of the resulting fibre (Aramwit et al., 2010; Sothornvit et al., 2010).

5. Applications of silk sericin

Recent studies have shown the potential use of sericin in biomedical, pharmaceutical and food industries. Cancer drugs, blood thinners, and cell culture additives, are some examples of developed products using granules, gels, solutions and films of this protein (Table 1). These developments can be found in countries such as Italy, USA, China, Austria, Japan and Romania. (Kundu et al., 2008).

Table 1. *Sericin applications.*

Industry	Application	Reference
Food	Useful for constipation treatment.	(Sasaki et al., 2000)
	Improvement of some minerals (Zn, Mg, Fe and Ca) bioavailability.	(Sasaki et al., 2000)
	Antioxidant and suppressant of colon tumours.	(Zhaorigetu et al., 2001)
Cosmetic	***Skin care:*** skin elasticity, anti-wrinkle and anti-aging effect. Moisturizing and cleansing properties. UV protection effect.	(Ogawa & Yamada, 1999; Baby & Raj, 2013; Voegeli et al., 1993; Sasaki et al., 2000)
	Nail care: prevents cracks, brittleness, and increases the inherent brightness.	(Yamada et al., 2001)
	Hair care: conditioner, cleansing properties and hair damage prevention.	(Pawar & Padamwar, 2004)
	Gel: moisturizing properties.	(Kirikawa et al., 2000; Yasuda et al., 1998)
	Powder: moisture absorption capacity and anti-dermatitis.	(Hoppe et al., 1984; Engel & Hoppe, 1988; Hata, 1987)
Biomedical, pharmaceutic	Cancer prevention, wound healing and drug delivery.	(Zhaorigetu et al., 2001; Aramwit et al., 2013; Kaewkorn et al., 2012)

Source: Adapted from (Kundu et al., 2008).

5.1 Cosmetic applications

Sericin's properties such as biocompatibility, biodegradability and wettability allow the development of cosmetic products for skin, nails and hair (Pawar & Padamwar, 2004; Voegeli et al., 1993; Yamada et al., 2001). Moisturizers have had a special development; they are mainly used to prevent and delay the dehydration of the top layer of the skin. This condition occurs when the water of the stratum corneum (outermost layer of the epidermis) is lost faster of what it receives from the inner layer, and also can be possible due to a reduction of lipids of the stratum corneum (GmbH Ziolkowsky, 1998). The dehydration can be evidenced when skin is brittle and rough, although water is being constantly supply from inside the body (Barel et al., 2001).

Normal and healthy skin has a wet, clean, soft, flexible, malleable, and practically wrinkle-free look (Idson, 1987). The smoothness of the skin is determined by its content of water, which should be at least 10% to keep this condition. When water content lowers this level, keratin, epidermis major component, becomes less flexible (Blank, 1952). Besides keratin, the corneum stratum has a special humectant mixture known as Natural Moisturizing Factor (NMF). This factor is defined as a group of hydrosoluble and/or hydrodispersible molecules, which are present in the intercellular spaces of the stratum. They also can be found at the skin free surface, as a result of the physiological processes that occur at skin level (Fábregas & Del Pozo, 2007).

Wide varieties of moisturizers are available in the market. They contain wetting agents such as vegetable glycerine, water, jojoba oil, vitamin E oil, sorbitol, among other products. In recent years, wetting properties of sericin have been evaluated in different cosmetic formulations, such as creams and lotions (Table 2). It has been found that a powder mixture of silk fibroin (70-95%) and sericin (5-30%) has antistatic characteristics and capacity to absorb moisture (Kirikawa et al., 2000); and both detection and UV filtration are enhanced (Yoshioka et al., 2001). Other cosmetic applications include sericin powder (Yamada &Yuri, 1998), and other products that absorb sweat and grease secreted from the sebaceous glands of the skin (Miyashita, 1999).

Table 2. *Cosmetic products formulations including silk sericin.*

Product	Effects	Reference
Gels using 1.5% (p/p) and 2.0% (p/p) of sericin, 2.5-10% (p/p) of pluronic acid, and 0.05-0.20% (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.	(Padamwar et al., 2005)
1% (p/p) sericin and 4% (p/p) D-glucose lotion.	Moisturizer.	(Yamada et al., 2001)
Creams containing 0.001-30% (p/p) of sericin.	Improves cleaning properties with less skin irritation.	(Sakamoto & Yamakishi, 2000)
	Controls skin problems as dermatitis.	(Yasuda et al., 1998)
Nail cosmetics with 0.02-20% (p/p) of sericin.	Helps to prevent brittleness and provides shine to the nails.	(Yamada et al., 2001)
Hair cosmetics containing sericin between 0.02 to 2% (w/w), and bath preparations with 0.01-1 % (w/w) of fatty acids from olive oil.	Reduces surface hair damage.	(Hoppe et al., 1984)
Hydrolysed sericin with low molecular weight.	Hair and skin conditioner.	(Hata, 1987)
Shampoo with sericin and pelargonic acid.	Helps with hair cleaning.	(Engel & Hoppe, 1988)

5.2 Medical applications

Sericin has both antioxidant and anticoagulant properties (Kundu et al., 2008). These characteristics have led to the development of multiple investigations in order to apply these in the medical field. Some examples include applications in anticarcinogenic and healing products, and in tissue engineering.

Anticarcinogenic. The antioxidant effect of sericin can represent a significant health benefit. Studies have shown that this protein allows a reduction in the oxidative stress in the human organs such as the colon; as well as a reduction in the number of cancer cells. Studies have shown that, the sericin that is taken orally (by mouth) by rats and mice, helps to effectively suppress the 1,2-dimethylhydrazine agent. As this agent is a cancer growth promoter, a reduction of the incidence of colorectal cancer was observed when this agent was eliminated (Zhaorigetu et al., 2001; Kaewkorn et al., 2012). Additionally, it has been reported that sericin inhibits the growth of cloned tumor cells and activates the apoptosis factor, leading to an apoptosis of cancer cells in rats. Furthermore, sericin that is not digested by the colon, it has a strong antioxidant effect, which reduces the oxidative stress and colon tumorigenesis (Haorigetu et al., 2007).

Healing. Sericin has good hydrophilic properties, it is also biocompatible and biodegradable, it actives the collagen production in wounds, and induces epithelialization (Aramwit et al., 2010; Sangcakul Aramwit, 2007). It is also reported that sericin promotes both attachment and proliferation of fibroblasts and keratinocytes in the human skin (Aramwit et al., 2013). These features allow its potential use as a wound healing agent. Aramwit & Sangcakul (2007) have made various tests using topical applications of sericin. They reported that cream with sericin powder (8% w/w) improvesscarring and reduces wound size in rats, without causing any allergic reactions (Aramwit & Sangcakul, 2007).

Aramwit et al. (2009) have worked on developing a cream of sericin (8% w/w) in combination with silver sulfadiazine (SSD); the authors took advantage of these ingredients by promoting the collagen and antimicrobial properties, respectively. However, they observed that sericin could partially inhibit the sulfadiazine action, due to the presence of small areas of microbial inhibition, thus, the size of the wound did not significantly chance (Aramwit et al., 2009). Between 2010 and 2011, a new investigation conducted in Bangkok showed for the very first time that silk sericin could be successfully used in clinical application for wound healing. In this work, sericin (8% w/w) was added to a standard antimicrobial cream of sulfadiazine that contained zinc (1%). This new formulation was able to help healing an open wound of second-degree and preventing an infection without serious adverse reactions (Aramwit et al., 2013).

Bandage. Development of new wound dressing materials have been possible due to healing properties of sericin. Clinical evaluation of a sericin/PVA scaffold, which was used in patients with skin grafts, was evaluated. Results showed an accelerated healing and patient pain reduction, compared to wounds that were treated with the commercial bandage Bactigras® (Siritientong et al., 2014).

Tissue engineering. Materials that can be used in drug delivery, grafts and immobilizing matrices such as matrices in 2D (films) and 3D (scaffold) are one of the mail goals of biomedical research (Vepari & Kaplan, 2007). Films and scaffold have been successfully made using a mixture of gelatine and sericin extracted from silkworm *Antheraea mylitta*. Fabricated supports have evenly distributed pores, good compressive strength and high swellability. In addition, they show high porosity, low immunogenicity, and improvement in both cell attachment and viability. These properties are critical for tissue engineering and biomedical applications, which reveals the potential use of sericin in future development of bio-polymeric grafts (Mandal et al., 2009).

5.3 Food applications

Today, FDA has included sericin and its derivatives in the “Generally Recognized as Safe - GRAS” list (Food and Drug Administration, 2001). The main characteristic of this protein is its antioxidant function; therefore, it has been proposed a functional food. However, commercial foods that contain this protein or any related products are still not available.

Oxygen is responsible for the production of free-radicals in the organism. This as a consequence of physiologic processes that are involved in the correct functioning of the human body, including breathing and reactions at cell level (Dasgupta & Klein, 2014). For this reason, the biological production of antioxidant compounds is needed, in order to balance the concentration of the free radicals. Naturally, the body produces its own antioxidants, called endogenous (Samaranayaka & Li-Chan, 2011).

Free radicals are produced inside the body due not only by physiological processes, but also by external factors such as environmental contamination and smoking. This last situation leads to the overproduction of these radicals, which cannot be stabilised by the endogenous antioxidant. As a solution, it is suggested the intake of exogenous antioxidants in a daily basis, which help to avoid the oxidative reactions increase. These reactions are related to human illness such as cancer, rheumatoid arthritis, and diabetes (Gigardi et al., 2010), and also to neurodegenerative diseases such as Alzheimer and arteriosclerosis (Rizzo et al., 2010).

Additionally, there are evidences that show some beneficial effects of sericin in stabilizing free- radicals such as hydroxyls, super oxides, DPPH and ABTS (Chlapanidas et al., 2013; Dash et al., 2007). Furthermore, sericin has antioxidant effect during of the linoleic acid per-oxidation (Fan et al., 2007) and in vitro lipid peroxidation (Norihisa et al., 1998). Beneficial effects of sericin have been linked to its proteinic characteristic and other substances (flavonoids, katekins, kercitinas, epicatequins and carotenoids) present in this protein after the extraction process (Butkhup et al., 2012; Chlapanidas et al., 2013). Additionally, sericin can suppress peroxidation of lipids and inhibit tyrosinase enzyme activity. This enzyme catalyzes the tyrosinase oxidation, which is the amino acid responsible for the skin melanin biosynthesis, and the enzymatic browning in foods (Norihisa et al., 1998).

According to Padamwar & Pawar (2004), sericin has a synergic effect during the intestinal absorption of minerals such as iron, zinc, magnesium and calcium. Other laboratory studies have demonstrated an increase in absorption of iron (41%), zinc (41%), magnesium (21%) and calcium (17%) in rodents, after they ingested this protein (Sasaki et al., 2000). In addition, there are evidences of favorable effects in the intestinal health of rodents, as sericin helps to modular both fermentation and barrier processes (Okazaki et al., 2011). Due to these properties, sericin could be used in developing fortified foods and nutritional supplements.

Furthermore, there are reports related to the effect of sericin in food products. For instance, results released by Takechi et al. (2011) showed the emulsifying effect of sericin when it was added to salad dressing. These results proved that high molecular weight protein increases the emulsion stability up to two days. Also, there is another report published by the same authors in 2014, where both palatability and structure of a bread produced with sericin were evaluated. The study evidenced a reduction of the specific volume of the bread, and a darker color on its crust, without significant alteration of its physical properties (Takechi & Takamura, 2014).

Sericin has a high content of bioactive peptides (PB) that are specific fragments of proteins. Their amino acid sequence is directly related to the beneficial effects on corporal functions, specifically on systems such as cardiovascular, nervous, gastrointestinal and immune (Samaranayaka & Li-Chan, 2011). However, peptides of sericin have been also studied with the aim to improve both, the antioxidant and inhibitor tyrosinase activity, related to an increased intestinal absorption as consequence of the size protein reduction (Wu et al., 2008).

6. Conclusions

Silk sericin is considered a waste of the silkworm current Colombian industry. Properties such as its capacity: hydrophilic, antioxidant, antimicrobial, anticancer and anticoagulant, as well as its UV protection, biodegradability and cell biocompatibility, have enabled it to have cosmetic applications successfully. Sericin presents a potential in the development of biomedical, pharmaceutical and food products. In Colombia, there are few studies addressed to reuse waste generated in the silkworm industry, leaving a significant gap in the science. For this reason, it is important to investigate about new ways to obtain high added value products, in order to generate a potential environmental, social and economic benefit to farming families.

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