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Innovative and Multidirectional Applications of Natural Fibre, Silk - A Review

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Abstract: Realization of current trends and innovative uses of insect fibre, silk is required to exploit its compatibility, eco friendly and value addition potential. The nutritive value as human diet for cardiac and diabetic patients, component for cosmetic preparations indicate silk application rate. The bio-compatibility made it a base material for tissue wall, membrane, muscle ligament, blood vessel, nerve gadget, cartilage and bone reconstruction. The anti-inflammatory and anti-tumefacient abilities suits for pharmaceuticals, while its bio-resorbability performs the drug delivery function. The superior moisture absorbance of silk fibre constructs bio-active textiles, while insulator and tensile properties substitute automotive and building construction applications. The silk sericin and fibroin proteins are prospective wound healing agents and are anti-oxidant and bio-adhesive mediators of human body. The silk wastes are used as feed for fish and poultry, besides adding revenue in the form of valuable art crafts. Of late, silkworm is being used as bio-factory to produce functional protein, promoting as a valuable biomaterial resource for modern applications. The comprehensive research on innovative trends and advanced applications of insect (natural) fibre 'silk' during the international year of natural fibres-2009 and beyond to make aware its stake holders is the imperative need of today's sericulture industry.

Key words: Silk · Natural fibre · Fibroin · Sericin · Bio materials · Bio compatibility · Eco friendly

INTRODUCTION

Silk is one of the oldest known textile fibres and according to Chinese it was used as long ago as the 27th century BC. The silkworm moth was originally a native of China and for about 30 centuries the gathering and weaving of silk was a secret process known only to Chinese. China successfully guarded the secret until AD300, when Japan and later India penetrated the secrecy. Silk is rightly called the queen of textiles for its luster, sensuousness and glamour. Silk's natural beauty and properties of comfort in warm weather and warmth during colder months have made it use in high-fashion clothing. Silk fibres have outstanding natural properties which rival the most advanced synthetic polymers, yet the production of silk does not require harsh processing conditions and hence, widespread investigations are on, even for artificial synthesis of silk fibre [1]. Apropos application scope, the immediate want is realization of methods to optimize silk utility and value, based on nutritive worth as human diet and animal feed [2, 3] precursors of cosmetic preparations [2, 4] synthesis of artificial films and membranes [4] application in pharmaceuticals, biomedical and biomaterials [2, 5, 6], vitamins, cardiac and diabetic food supplements [7], automotive [8, 9, 10] and building construction [11-13]. The silk proteins, sericin and fibroin were proven potential for healing wounds and post-surgical trauma [4, 5] possessing anti-oxidative, bio-adhesive and bio-active prospective [2, 14] while, the silk waste is suitable for making valuable art crafts [7, 15]. Recently, silkworm is being used as bio-factory for production of useful protein through its silk gland [16] and silk became a valuable biomaterial for diverse pragmatic applications.

Current Status: Though, the silk is produced in more than 20 countries, the major producers are in Asia and sericulture industries were also established in Brazil, Bulgaria, Egypt and Madagascar for its labour-intensive advantage. About one million workers are employed in silk sector in China and it provides income for 7, 00,000 households in India and 20,000 weaving families in Thailand. Though, China produces about 70% of the world's silk, rest followed by India, Brazil, Thailand and

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Viet Nam, with minor production in Turkmenistan and Uzbekistan. India, Italy and Japan are the main importers of raw silk and its unit price is much bigger to other natural fibres.

The rearing of silkworm is almost a prerogative in rural India as majority of host plants of all four types of silkworms i.e. mulberry, Tasar, Muga and Eri are available as cultivated or nature grown. The production of 16245, 1530, 428 and 117 MTs of mulberry, Eri, Tasar and Muga raw silk respectively by India during 2007-08 indicates the quantum potential of silk fibre and its related waste material. The majorities of silkworm growers are unaware of silk fibre value potential, they sell cocoons for immediate livelihood to reelers, who offer price assessing only silk and hence fibre's value addition was never thought of. Incidentally, the trends on cost benefit ratio and comparison with other alternatives made sericultural stake-holders to have a second thought on utilizing silk fibre on all possible applications and for adding returns.

Dietary Application: The rich proportion of essential amino acids in silk fibre and cocoon pelade indicates nutritive value and they are the cheap sources of shinki fibroin, a dietary additive. The finest silk powder, silk amino acids and hydrolyzed silk proteins are used in candy food products. Silk proteins are used as specialty diets for cardiac and diabetic patients due to their easy digestibility, low cholesterol and sugar contents and providing of additional energy [5, 7]. The silk proteins have applications as diet for the crew of Control Ecological Life Support System (CELIS), one of the most advanced and complicated ecological system in the world [2]. The Japan Aerospace Exploration Agency (JAXA) has released a recipe during scientific assembly of the Committee on Space Research (COSPAR) as astronaut food. Further, the silk waste and dried cocoon pelade powder are being used as feed for poultry and fish and reported better growth rate and egg quality in hens and improved survival, feed conversion rate and edible muscle growth in fish [3].

Cosmetic Application: The silk bio-polymer used in tissue regeneration for treating burn victims and as matrix of wound healing. The silk fibroin peptides are used in cosmetics due to their glossy, flexible, elastic coating power, easy spreading and adhesion characters [16, 17]. The silk sericin with saturation, revitalization and UV ray absorption properties has got potential as skin moisturizer, anti-irritant, anti-wrinkle and sun protector in addition to shaping the hair [4, 18]. The extracts of silk fibre protein like hydrolyzed silk, silk amino acids, silk powder and raw silk fibre are used in soap making, personal care and cosmetic products [4]. Silk protein contains eighteen amino acids, among which glycine, alanine, serine and tyrosine are of vital importance in skin nourishment [2, 4, 6, 7]. Silk powder is touted and relieves from sunburns, due to crystalline structure it reflects UV radiation and as demulcent it acts as protective buffer between skin and environment. The lower micron silk powder is added with hair and massage oils and water dispersible finer grade silk powder is an ingredient of liquid cosmetic preparations.

Pharmaceutical Application: The silk is used to fight edema, cystitis, impotence, adenosine augmentation therapy, epididymitis and cancer [2]. Silk protein derivative, Serratio peptidase is used as anti-inflammatory, anti-tumefacient for treating acute sinusitis, tonsiloctomy, oral surgery, tooth filling, cleaning and extractions [5-7]. The derivatives of silk fibre were used as non-steroidal anti-inflammatory agents for treating rheumatoid arthritis. The silk is used in anti-hay fever masks, bandages to treat dermatological disorders, catheters and anti-coagulants during surgeries [4, 6]. The sericin is reported to suppress tumor promotion, provide protection against ulcers and exert other health supporting effects like cell proliferation to provide a basic matrix for wound healing. Sericin is also used in clinical diagnostic techniques, production of medically important enzymes and lowering blood glucose levels. The silk fibroin is a useful dressing material with the property of non-cytotoxic to the tissues and also in veterinary medication [4, 6, 16, 18].

Biomedical Application: Since long, silk fibre is being used as surgical sutures as it does not cause inflammatory reactions and is absorbed after wounds heal. Other promising medical applications are as biodegradable micro tubes for repair of blood vessels and as molded inserts for bone, cartilage and teeth reconstruction [4, 19-23]. The tenacity and gum-like quality of sericin makes silk fibre a good entrant for biomedical joining and sealing applications. Fibroin has been used extensively in the biomedical field with a novel bio-mimetic design of silk fibroin-nerve guidance conduit (SF-NGC) used for peripheral nerve regeneration. Silk fibroin films facilitate reepithelialization, remodeling of connective tissues and collagenization [24]. The fibroin powder is known for wound dressing by regulating exudates of wound providing moist environment [25, 26]. In biomedical and bioengineered field, the use of natural fibre mixed with biodegradable and bio-resorbable polymers can produce joints and bone fixtures to alleviate pain for patients. The readily available silk waste can be transformed in to materials of both variable length and diameter with increased bio-stabilities and performance. The superior mechanical properties and lower inflammatory potential of modified silk fibres made them a promising candidate for ligament tissue engineering [27]. The silk fibre can be purified to eliminate immunogenic components (particularly sericin) and implants as tissue-supporting prosthetic devices due to their immune-neutral properties. The other proven applications include hernia repair, tissue wall reconstruction and organ support as bladder slings, scaffolds for tissue engineering and as controlled release drug delivery vehicles [18, 21, 23].

The main requirement of biomaterials is biocompatibility and silk has phenomenal mechanical properties essential to convert it to biopolymers suitable for medical applications [7, 18]. The properties of high oxygen and vapor permeability makes silk fibre ideal for soft tissue applications and in spite of its higher adhering ability to tissue cells, still be biodegradable. The silk fibre show no toxicity to living bodies during degradation because it is composed of amino acids similar to those found in humans [2, 4, 26]. Future applications of silk biomaterials include new generation soft contact lenses that enable greater oxygen permeability, artificial corneas, skin grafts and epilepsy drug permeable devices [28]. The silk sericin is a natural protein macromolecule derived from silk fibre has resistance to oxidation and UV rays, capacity of higher moisture absorption/ moisture release. The sericin protein can easily be cross-linked, copolymerized and blended with other macromolecular materials, especially artificial polymers, to produce biocompatible medical and mechanical gadgets of improved properties [29, 30]. The silk protein is also used as coating material for other natural and artificial fibres, fabrics and articles. The sericin composites are useful as degradable biomaterials, biomedical equipment and polymers for forming bioengineering articles, functional membranes and ligaments. In recent years, silk has been widely applied in native and reconstituted forms as nano fibre, film, hydrogel, membrane, sponge and particles for targeted biotechnological applications [2, 4, 31-34]. The commercial production of sericin hydrolyzates as components of tissue culture media will expand its uses for tissue repair. The sericin can polymerize to 3-D structures that provide scaffolds for complex tissue reconstructions [18, 26]. The silk being a non-mammalian derivative, carries far less bio-burden compared bovine and porcine based biomaterials [2].

Automobile Application: The silk fibres can be arranged in parallel and optionally, intertwined (twisted) to form a construct; sericin may be extracted at any point during formation of fabric, leaving a construct of silk fibroin fibres having excellent tensile strength and other mechanical properties. The silk fibre is extremely hygroscopic which can absorb moisture up to 30% of its weight and still appear dry to the touch. Similarly, it exhibits elongation up to 35% and even in tensile strengths it is comparable to steel per unit weight [10]. Unlike most visco-elastic fibres that arrive at a limit of break point, silk increases in strength, stiffness and elongation as the loading rate increases made them applicable in automobile industry [8, 9]. The use of natural fibre, silk as automotive parts improves environmental sustainability to some extent with reduced pollution.

House Building Application: Within the building industry, the interest in silk fibres is due to economical and technical advantages of having insulation properties higher than current materials. The mechanical properties of silk fibre and polypropylene (S-PP) composites were found superior to standard glass fibre reinforced plastics (GFRP) for house building [8, 11, 13] and their tensile and elastic properties were found improving with increase in silk fibre content. In particular, the Izod impact value of S-PP composite was the same as that of GFRP, besides better adhesion compatibility among hydroxyl set of polypropylenes and silk amino groups. Hence, the use of renewable insect based silk fibre-reinforce polymeric composites is becoming an important design criterion for industrial and house building products [13]. Usually cellulosic fibres are used to reinforce the composites, but silk fibre was proven to serve the same purpose and the application of reinforced biodegradable plastic composite from silk fibre (silk composite), made interiors more glossy and silky. The decorative laminates with wood as core material has expanded the applications of silk composite, since plywood and medium-density fiberboard (MDF) are widely used in flexible interior laminates [11]. These laminates have high flexural strength and found suitable in various modern decorative applications. The innovative multi coloured silk paper of high embellishment value used for making pleasant silk flowers and radiant shades of lamp found fast marketing in Japan [7]. The silk leather, paint with silk powder is used to decorate plastics, steel and fabrics, to beautify interiors during propitious and religious celebrations in China, Hong Kang and Japan [7].

The application of these eco friendly and biodegradable silk based polymeric composites substituting reinforced cement concrete, can contribute towards green and safe environment.

Antibacterial Application: The sericin available in degummed reeling waste water can be recovered through precipitation using acid because of its antibacterial, UV resistant and easy moisture management properties and application potential as biomaterial [4, 6, 7, 16]. The concentrated solution of sericin so obtained can be dialyzed and coated to cotton fabric to enhance its antibacterial property and bending rigidity. The extraction and recycling of sericin from waste water of reeling can save water and reduce the pollution. The high absorption and anti bacterial capacities of silk fibres are highly suitable for making bioactive textiles and under garments [4, 6].

Art Craft Application: The eye catching art of crafting silk waste is one of the interesting utility of silk, which develop human skills besides generating self employment and additional revenue. The crafts like garlands, flower vase, wreath, pen stand, dolls, jewelers, wall hangings, clocks, bouquets and greeting cards can be carved using silk wastes [7, 15]. The silk based paper is used to craft flowers, buffet lamps and decorate plastics, steel and fabrics. The hybrid silk, net raw silk, silk tow and silk waves were converted as high valued fancy jackets, carpets and furnishings [15].

Epilogue: Sericulture industry should look at the utilization of silk fibre in total for innovative marketable products of modern society's application and appreciation, which facilitate its all-round development. Though, the traditional practices make silk to construct only textiles, the new approach extend its application towards nutritional, cosmetic, pharmaceutical, biomaterial, biomedical and bioengineering, automobile, house building and art craft applications. The inclination rightly suits to silk due to faster production rate and increasing global demand for its variable eco-friendly composites and viable contributing impact on value, employment and environmental safety. This move, however, requires more of awareness among stakeholders; trainings and idea exchange between entrepreneurs, besides service accessibility to consumers. The celebration of International Year of Natural Fibres, 2009 will creates awareness on insect based natural fibre, silk for its continued use and innovative research during the year and beyond.

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