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# Weaving waste into wealth: The hidden potential of Seri-waste

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**Abstract**
India Sericulture is a critical industry in the nation's agriculture scenery. A testimony to the mutually beneficial the connection between economic viability and tradition. It involves rearing and management of silkworms for the production of raw silk which gives enormous benefits. The four primary phases of sericulture in India are silkworm rearing, cocoon production, softening and sorting, silk reeling, spinning, weaving and finishing. The silkworm rearing and production of silk ends up with a lots of wastes, this waste from silk industry aregenerally known as silk and seri-waste. This study investigates a review about how the sericulture waste can be treasured and later be treated to transform those into usables. Thus paving the ways for economic benefit and sustainable development for small scale sericulture industry. By adopting these innovations, of waste management and generation the Indian sericulture industry can guarantee economic growth and environmental sustainability while preserving its cultural heritage.

**Keywords:** Indian sericulture, relationship, spinning, weaving, reeling, rearing, Seri-waste

## 1. Introduction
### 1.1. Sericulture industry scenario in India
Indian sericulture, which is a core component of the nation’s farming and culture legacy, is essential to the global silk industry. India’s sericulture is predominantly focused on four stages:-silkworm rearing, cocoon manufacture, spinning and reeling and the second largest producer and consumer of silk globally. For generations, sericulture the raising of silkworms for the production of silk has been a fundamental part of Indian culture. The fact that 18% of raw silk is produced in India is evidence of the benefits of silk to the Indian economy. Sericulture is the second-largest sector of the Indian textile industry after the handloom sector, and it employs and offers opportunity to over 50 lakh people (Bharathi, 2018) [1]. India's top producers of mulberry silk are Karnataka, Andhra Pradesh, Tamil Nadu, Jammu & Kashmir, and West Bengal; the top producers of non-mulberry silk are Jharkhand, Chhattisgarh, Orissa, and the northeastern states (Assam) (Mariyappanavar, 2024) [21]. Most people with typical income works in sericulture, which is an agro-based, employment intensive profession both for rural and urban areas. Mulberry a well as non-mulberry are the essential crops for silk production. Although mulberries are mostly used worldwide for silk production, they are valued for other purposes such as medicinal, delicious fruits, landscaping, animal feed and many other feed (Singhal *et al*. 2005a, 2005b) [34, 35]. The relationship between sericulture and agriculture are very much interlinked at very phase as the quality of silk produced is directly link to the rearing of the silkworm. In every phase of silkworms rearing, there is waste produced from silkworm casting, damaged cocoon, pupa shells and other byproducts of silkworms can be valuable and used for various economic purposes. (Mariyappanavar, 2024) [21]. Silk which is a natural polymer, primarily valued for its shine, strength, luster and softness. This review paper deals with how the sericulture waste can be used for various applications that can have both economic and social value. The potential of silk and seri-waste as viewed as waste, to be transformed into valuable resources. Silkworms are the source of silk. The natural protein from silk is mostly composed of fibroin and sericin proteins. One of the essential silk protein is the fibroin which is also the core protein (Cui *et al*., 2018) [4]. It contributes to tensile strength, increased rigidity, and the central structure (Koh *et al*., 2015) [14] and the sericin, which makes up 25-30% of the protein in silk, forms a cocoon by enveloping the fibroin fiber

in a series of sticky layers. (Cao & Zhang, 2016) [2]. The interesting fact that might either complement or replace synthetic materials in By binding silk strands together, sericin maintains the cocoon's cohesiveness. In the reeling mill and other silk processing steps, the majority of the sericin must be eliminated during the manufacture of raw silk. Currently, sericin is primarily disposed of in wastewater from silk production, which can pollute the environment different uses is the conversion of silk waste into bio-composites and the one is of the promising potentiality how the waste can be valued through various waste management and applications (Qayoom & Manzoor, 2024) [29].

Beyond silk waste like sericin, other sericulture waste from the sericulture industry can be the organic residues known as the seriwaste and the different byproducts waste during the silkworm rearing. Because of its rather low demand. Sericulture is a farm-based, commercially viable enterprise that benefits the unorganized rural poor (Kalaiyarasan *et al*., 2015) [13]. Larval excreta, leaf litter, dead larvae, dead moths, and wasted cocoons and pupae are among the organic leftovers found in the trash of the sericulture industry. At present, the tribal farmer now do not effectively use the organic matter rich Seri-waste for any profitable and valuable purposes. Currently, both native and foreign earthworms are the best in vermicomposting organic wastes derived from plants and animals (Nath *et al.,* 2009) [22]. This paper explains how, sericulture waste like the byproducts and the Seri-waste are effectively used through composting and by using various applications to treasure the trash. Recent, studies and research have suggested various perspectives how sericulture waste including sericin and other organic waste can be managed and treasured using various waste management and waste generations process. The waste from silk, the sericin, can be recognized as a valuable products to be used efficiently in pharmaceuticals, medicines, drug delivery. The diverse applications of sericin in environmental management, wound healing. The other organic residues have also effectively processed and can be recycled through composting, this will enhance soil fertility and through waste management will lead a sustainable life. The proper use of the Seri-waste will also benefit the poor farmers economically and will reduce environmental pollution. Thus the growing interest of upcycling silk and seri-waste will always reflects towards broader movement and will benefit human race both in economic and environmental aspects and will unlock new technology advancements in various fields.

## 2. Discussion

Silk rearing and production generates significant byproducts such as sericin and other sericulture wastes known as seriwaste that are before traditionally discarded, but with modern research this wastes are valuably used in many fields. Their potential value is now recognized and is discussed below-

### 2.1 Silk Sericin- From waste to valuable treasure

Silk is composed of fibroin and sericin, with sericin making 20-30% of the silk mass and it wraps around the fibroin fibre with gummy coating that helps in the emergence of the cocoon. Sericin holds the bundle together by gluing the silk filament together. During the silk production, most of the sericin must be removed and this process of removing sericin protein is known as degumming process (Cao & Zhang, 2016) [2]. Discarding of this sericin protein without utilizing it efficiently can lead to environmental pollution. Sericin is also a macromolecular protein like fibroin. Fibroin which is water in soluble, but sericin is a soluble protein. Sericin is a naturally occurring polymer that is extremely hydrophilic and has gelatin-like sticky properties. During its creation, sericin enables the joining of silk threads to preserve the cocoon's structural integrity (Sharma *et al*., 2022) [32-33]. The size of the resultant sericin molecules varies depending on temperature, pH, and processing time when sericin is hydrolyzed in acidic or alkaline solutions, dissolved in a polar solvent, or broken down by a protease(Cao & Zhang, 2016) [2].In recent years, sericin has shown promise in the silk industry, pharmaceutical, biomedical, and cosmetics industries. Sericin is utilized in the creation of cosmetic goods for the skin, nails, and hair because of its amazing qualities, which include biocompatibility, biodegradability, and wettability (Padamwar& Pawar, 2003) [25]. Silk sericin has also many anti -aging properties expect for used in oxidative stress. Natural colors that build up in sericin layers, usually flavonoids and carotenoids, can be obtained from *Bombyx mori* L (Kurioka and Yamazaki, 2002) [16]. These pigments are generally used as a biological properties and sericin is also used in food packaging material (Mariyappanavar, 2024) [21].

The tiny sericin peptides can be extracted early in the raw silk production process and are soluble in cold water. The larger sericin proteins can be obtained at the later stages of silk processing or from the degumming process and are soluble in hot water. The qualities of sericin make it especially helpful for enhancing synthetic polymers like polyesters, polyamides, polyolefins, and polyacrylonitriles. Additionally, sericin is applied as a coating or mix. material for textiles, polymer products, and natural and synthetic fibers (Cao & Zhang, 2016) [2]. Medications, skincare and haircare products, and cosmetics all use lower molecular weight sericin peptides (~20 kDa) (Cao & Zhang, 2016) [2]. The properties of silk proteins are beneficial for the skin, hair, and nails of the body. It has several cosmetic uses, including promoting hair growth, enhancing hair softness and luster, reviving body and skin cells, protecting against UVB rays, and preventing of skin lightening and nail brittleness and chapping (Qadir & Islam, 2024) [28].

Sericin is also a promising protein to prevent food from browning without increasing the production of antioxidant chemicals in artificial cells. Food items made with sericin aid diabetics in adhering to their diet. The use of sericin-based edible coatings or films enhances the food product's nutritional qualities while also imparting anti-browning, antibacterial, and antioxidant qualities. There have been very few attempts to use sericin in food applications, despite the fact that it is produced at a high rate in India. Therefore, using sericin in food applications has several benefits and expands its use in the food sector (G *et al*., 2023) [8].

**Table 1:** Potential applications of silk waste bio-composite Source (Qayoom *et al*., 2024) [29]

| Applications | Atrributes of silk based bio-composites | Benefits derived |
|---|---|---|
| Textiles | Lightweight; enhanced tensile strength; biocompatibility | Durable clothing; eco-friendly accessories |
| Automotive | Sound absorption; lightweight; high strength-to-weight ratio | Fuel efficiency; reduced noise; sustainable interiors |
| Construction | Thermal insulation; moisture resistance; lightweight | Energy-efficient buildings; sustainable infrastructure |
| Electronics | Biodegradability; flexibility; non-toxicity | Eco-friendly gadgets; reduced e-waste |

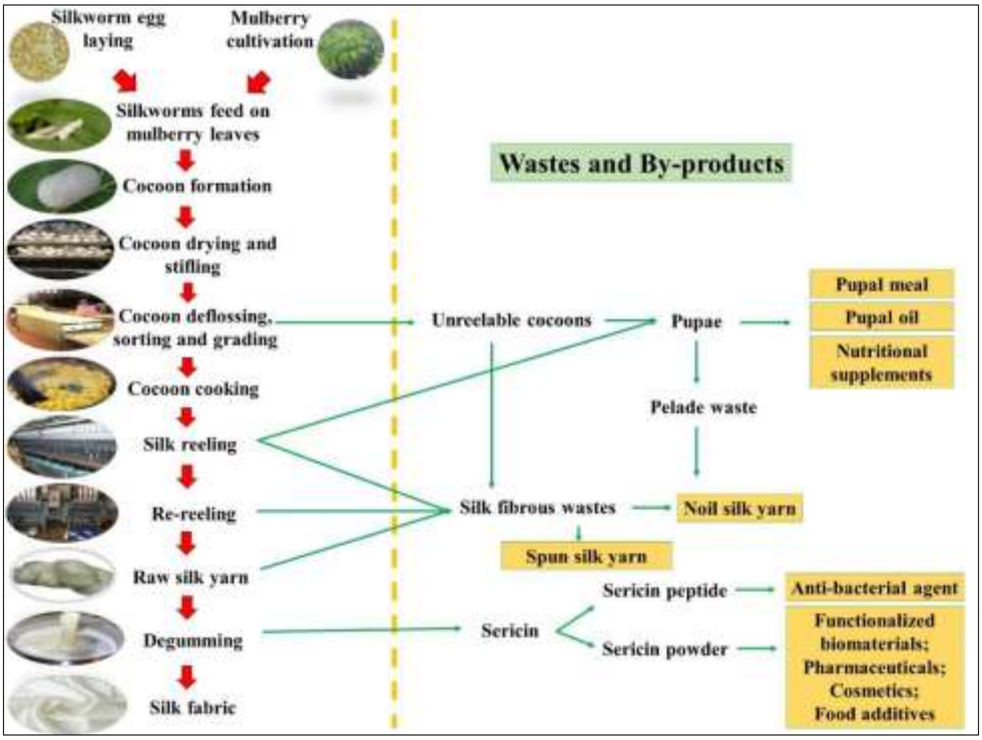


**Fig 1:** Potential use of sericulture waste (Qayoom *et al*., 2024) [29]

**Other by products of Sericulture:**

1. **Silkworm Castings:** The trash that silkworms make while they are feeding and spinning is referred to as silkworm castings. The main components of this waste are residual silk cocoon debris, undigested mulberry leaves, and silk moth excrement. The nutrient-rich silkworm castings are occasionally utilized in agriculture as an organic fertilizer. (Mariyappanavar, 2024) [21].
2. **Cocoon Waste:** Cocoon Waste: Usually, some waste is left over after the silk filaments are removed from the cocoons. The outer cocoon layers that are unsuitable for the manufacture of silk are included in this trash. Waste from cocoons can be recycled into animal feed or even used as a growing medium for mushrooms. (Sharma and others, 2022) [32-33].
3. **Pupa:** pupae may not survive or may be thrown away as part of the silk reeling process. Some civilizations employ these pupae as a source of protein, while others use them to make animal feed. (Mariyappanavar, 2024) [21].
4. **Sericulture By-products:** Growing mulberry trees for the silkworms' feeding is a common part of sericulture, the process of raising silkworms for the manufacture of silk. By products may include mulberry leaves that are clipped during cultivation or that the silkworms do not eat. These leaves can be used to make herbal drinks and traditional treatments, or they can be fed to animals.
5. **Silkworm Exuviae:** The outer skins that silkworms shed as they mature are known as silkworm exuviae. When rearing silkworms, these exuviae are usually taken out of the rearing trays. Despite being uncommon, they could find value in specific crafts or businesses.
6. **Silkworm Pupae Oil and gum:** Silkworm pupae are occasionally processed to extract oil, which has a variety of uses in the medicinal, cosmetic, and even dietary supplement industries. The natural adhesive material that keeps the silk threads together inside the cocoon is called "silk gum." In order to get smooth silk fibers during the silk reeling process, this gum is usually eliminated by a degumming procedure. The extracted silk gum could be used as a natural adhesive or in the textile and cosmetics sectors.

### 2.3. Applications of seri-cultural by-products

#### 2.3.1. Waste as Vermicomposting

Vermicomposting is a process of converting waste into vermicompost with the help of earthworms (Lim *et al*., 2016; Lee *et al*., 2018) [18, 17]. By-products from silkworm rearing can be used in vermicomposting, while silkworm litter by itself might be utilized in the pharmaceutical and biogas production industries (Sharma *et al*., 2022) [32-33]. Around 15 MT of sericultural waste, which is equal to 280-300 kg of nitrogen, 90-100 kg of phosphorus, and 150-200 kg of potash, are produced annually from one hectare of mulberry farms as silkworm rearing waste and other farm trash. (Das *et al*., 1997) [5].


**Fig 2:** Seriwaste as vermicomposting (Verma *et al*., 2022)

Research has demonstrated that both breeding waste and caterpillar excreta provide biogas yields that are on par with those of other agriculturally derived substrates, including manures from cattle, pigs, and chickens. One of the main waste products of sericulture is silkworm excrement, or feces. According to Vimolmangkang *et al*. (2013) [43], silkworm excreta is cylindrical, 2-3 mm long, and deep green in color. It is used in both the culinary and medicinal industries. China, Korea, and certain Eastern Asian nations have utilized silkworm feces as a medicinal agent in traditional medicine to cure headaches, stomachaches, and infectious disorders (Tulp and Bohlin, 2004) [39]. Chlorophyll and its derivatives, xanthophylls, carotenoids, and flavonoids are the chemical components of silkworm excrement that have been mostly documented (Park *et al*., 2011) [26]. After reeling, silkworm pupa is a direct by-product of the reeling business. On a dry weight basis, India produces over 40,000 MT of silkworm pupae annually (Priyadharshini *et al*., 2017) [27]. 100g of dried silkworm pupae can provide 75% of the daily protein required by humans

Pupae of dried silkworms have 8% nitrogen (Singh and Suryanarayana, 2003) [36]. There is a chance that pupal waste might be bioconverted into enriched compost and used as a source of nutrients because the pupa has a lot of nitrogen and protein in addition to micronutrients like zinc, copper, magnesium, and manganese (Mahesh *et al*., 2020) [20]. When combined with chemical fertilizers, the application of Silkworm pupae residual biocompost (SPRB) greatly improved the mulberry's growth and yield metrics. Pupae of waste silkworms produce a lot of resources with nutrients that are good for poultry and cattle. De-oiled pupae can increase hens' ability to lay eggs, while fat-free pupae can be fed to fish and carp to increase yields. The fish fed a diet that replaced approximately 38% of the total food protein with silkworm pupal meal showed the highest growth rates among silver barb fingerlings (Barbonymus gonionotus) (Mahata *et al*., 1994) [19]. More than 70% of the oil recovered from silkworm pupae is unsaturated fatty acid-based, with oleic acid and α-linolenic acid making up the majority (Rao, 1994).

In the cosmetics industry, oil derived from silkworm pupae through boiling is used to make moisturizers and soaps, and this soap was used to degum silk (Winitchai *et al*., 2011) [45]. According to Sharma *et al*. (2022) [32-33], the pupae oil can be utilized for lubrication in the jute industry (currently, rice bran oil is used) and for leather processing (currently, fish oil is used). One of the most amazing uses of byproducts is cocoon craft, which can offer opportunities for human skill development in addition to creating income and self-employment. Value addition in post-cocoon sectors is expected to yield profits between 10 and 25 percent of overall returns. The leftover silk cocoons are being used to make a variety of items, including garlands, flower vases, wreaths, pen stands, dolls, jewelry, wall hangings, wall plates, clocks, bouquets, and greeting cards. Silk paper in a variety of colors has been created in some Japanese laboratories for use in crafts like lamp stands and flowers. Silk leather is a paint that contains silk powder and is used to adorn fabrics, steel, and plastics (Sharma *et al*., 2022) [32-33].

### 2.3.2. Sustainable agriculture applications

Sericulture waste compost can be used also in Agriculture that can enhance soil fertility and reduces agricultural inputs. This sustainable approach to recycling sericulture residues supports can improve soil health and offers market potential for organic fertilizers, contributing fir more sustainable practices

## 3. Conclusion-Measures to utilize sericulture waste

It is possible to efficiently repurpose the waste, water effluents, and byproducts from the manufacture of silk, reducing its negative effects on the environment and promoting sustainability. Waste from cocoons the outer layers that are unsuitable for silk can be turned into organic fertilizer that is high in vital nutrients or utilized as a wholesome ingredient in animal feed. A byproduct of the silkworms, silkworm castings are an organic fertilizer that is rich in nutrients and improves soil fertile and plant are growing's. In certain cultures, the muga silkworm pupa a important source of protein are even eaten as a delicacy or food element. They can also be recycled into animal feed for aquaculture or animals. Mulberry leaves, which silkworms need, also have uses outside of sericulture; because of their therapeutic qualities, they can be used to make herbal teas and traditional remedies, as well as to feed animals like cattle, goats, or rabbits. Chitin, a naturally occurring polymer having uses in agriculture, cosmetics, and medicine, is also present in silkworm exuviae. These tactics guarantee the effective use of waste and byproducts from the manufacture of silk, improving the sector's overall sustainability (Mariyappanavar, 2024) [21]. By recovering and reusing silk gum in textiles or adhesive goods, wastewater from the silk degumming process can help to lessen pollution in the environment. Wastewater from dyeing processes can be treated chemically, filtered, and sedimented to get rid of chemicals, heavy metals, and color residues. This makes it possible to recycle and reuse the water in other dyeing processes, which reduces water use and its negative effects on the environment. Overall, the utilisation of byproducts, waste, and water effluents generated during silk production can contribute to resource efficiency, waste reduction, and environmental sustainability in the silk industry. Adopting innovative technologies and sustainable practices can further enhance the beneficial use of these materials while minimizing their environmental impact.

## 4. Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative. AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text -to-image generators have been used during writing or editing of this manuscript.

## 5. Competing interests

Authors have decalared that no competing interests exist.

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