



# IMPACT OF SERICULTURE PRACTICES ON WASTE GENERATION AND ITS MANAGEMENT IN INDIA

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## ABSTRACT

Indian sericulture, a cornerstone of the nation's agricultural and cultural heritage, plays a crucial role in the global silk industry. As the second-largest producer and the largest consumer of silk worldwide, India's sericulture primarily revolves around four stages: silkworm rearing, cocoon production, silk reeling, and dyeing. The research focuses on the waste management practices in the silk reeling and other processes, exploring their environmental impacts and sustainability challenges. This study investigates the extensive waste generated, including defective cocoons, pupal shells, and water effluents from silk reeling and dyeing, and assesses strategies for repurposing and minimizing these wastes. Key findings highlight the potential for using by-products such as silkworm castings and cocoon waste in agriculture and other industries, thus promoting a circular economy. Moreover, sustainable practices such as eco-friendly dyeing techniques and efficient wastewater treatment methods are essential for reducing the environmental footprint of sericulture. By embracing these innovations, the Indian sericulture industry can maintain its cultural heritage while ensuring economic viability and environmental sustainability.

**KEYWORDS:** Indian Sericulture, sustainable and eco-friendly practices, circular economy, and waste management.

## INTRODUCTION

Indian sericulture, a pivotal sector in the nation's agricultural landscape, stands as a testament to the symbiotic relationship between tradition and economic viability. Sericulture, the cultivation of silkworms to produce silk, has been deeply ingrained in the cultural tapestry of India for centuries. This age-old practice, intertwined with rich historical narratives, has not only preserved traditional craftsmanship but has also evolved into a significant economic contributor. India is the second largest producer of silk and also the largest consumer of silk in the world. It has a strong tradition and culture bound domestic market of silk. In India, mulberry silk is produced mainly in the states of Karnataka, Andhra Pradesh, Tamil Nadu, Jammu & Kashmir and West Bengal, while the non-mulberry silks are produced in Jharkhand, Chattisgarh, Orissa and north-eastern states (CSB).

The silk-producing states of India are pivotal in driving India's dominance in the global silk market. The Indian sericulture industry primarily revolves around four major components: silkworm rearing, cocoon production, silk reeling, and dyeing. This research paper delves into the intricate dynamics of the sericulture sector, focusing specifically on the waste management aspects related to the reeling and dyeing processes. By examining these critical phases, we aim to uncover the environmental impact and sustainability challenges faced by the industry. Silkworm rearing serves as the

foundational pillar of the sericulture process. Mulberry leaves, the primary food source for silkworms, are cultivated with meticulous care, emphasizing the need for sustainable agricultural practices. The intricate dance between sericulture and agriculture becomes apparent in this phase, where the health of the silkworms is directly linked to the quality of the silk produced.

As the waste management aspect comes in picture, it is essential to evaluate the agricultural waste generated during mulberry cultivation, and how it can be efficiently repurposed or managed to minimize environmental impact. Moving forward in the sericulture journey, the focus shifts to cocoon production. The delicate art of cocoon harvesting demands a delicate balance between maximizing yield and preserving the integrity of the silk threads. This phase introduces waste in the form of defective or damaged cocoons, emphasizing the need for a streamlined waste management system to mitigate losses and promote sustainability. Investigating methods to repurpose or recycle defective cocoons becomes imperative in the quest for a more environmentally conscious sericulture industry. The crux of waste management challenges within the Indian sericulture sector lies in the silk reeling and dyeing processes.

Silk reeling involves the unwinding of silk threads from the cocoon, a process that generates silk waste known as "pupal shells." Traditionally considered a by-product, this waste can be repurposed for various applications, ranging from agricultural use to manufacturing. In this process, water is the most important element, used for softening the sericin (silk protein) and facilitating the unwinding of silk fibres. While water is indispensable in silk reeling, its usage can lead to water wastage. Additionally, the dyeing process introduces chemicals that contribute to wastewater, necessitating careful consideration of disposal methods to prevent environmental degradation. As the complex web of waste management in sericulture is navigated, it becomes evident that sustainable practices are not only environmentally responsible but also economically advantageous. Developing innovative solutions to repurpose silk waste, implementing eco-friendly dyeing techniques, and adopting efficient wastewater treatment methods are pivotal steps in ensuring the long-term viability of the sericulture industry. In conclusion, the Indian sericulture industry, deeply rooted in tradition, is at a crossroads where modernization and sustainability intersect. As the world increasingly values environmentally conscious approaches, unraveling the threads of sericulture and waste management becomes crucial for shaping a resilient and responsible industry. By embracing eco-friendly practices and leveraging technological advancements, the industry can continue to thrive while preserving its cultural heritage for generations.

India is the second-largest producer of silk in the world. The type of silk depends primarily on two factors – the species of the silkworm and the leaves that they feed on before they start weaving the cocoon. Broadly, there are two major categories-

## **MULBERRY AND NON-MULBERRY SILK**

### **1. Mulberry Silk**

Mulberry silk is the most common form of silk comprising as much as 90% of global silk production. India is the second-largest producer of Mulberry silk. It comes from *Bombyx mori* worms that feed on mulberry leaves. This silk comes with a natural sheen, softness, and smoothness that we so associate with silk drapes.

Mulberry plants are cultivated to produce large quantities of leaves in a process technically called *Moriculture*. Roughly 500 grams of Mulberry leaves can feed one caterpillar for life. Mulberry silk is light, smooth, and strong, and comes with a natural sheen.

### **2. Vanya Silk – Wilder Types of Silk**

Non-Mulberry silk in India comes in three prime varieties – Tussar, Muga, and Eri. Collectively they are also called Vanya Silk as they are a slightly wilder variety of silk. Vanya comes from the word 'Vana' meaning forest or the wild. The silkworms here feed on wild plants and the same is evident in the yarn they spin – it varies in colour and texture, giving the final fabric an exotic look. Different Types of Vanya or Wild Silkworms.

#### **a). Tussar silk**

It comes from the Tussar belt of central India in the states of Jharkhand, Chhattisgarh, West Bengal, and Bihar. It occupies the biggest space in the Vanya silk category and is extremely popular among silk wearers. Moth Genus *Antheraea* feeds on wild plants of forests to produce this silk.

### b). Eri Silk

It comes from *Samia Ricini* and *Philosamia ricin* variety of worms. Word Eri comes from Era which means Castor in local Assamese, where the silk primarily comes from. These worms feed on castor plant leaves and weave an open-ended cocoon. Eri cocoons are harvested only after they have hatched as the weaving of the cocoon is uneven and irregular, making it a natural Ahimsa silk. Eri, also known as Endi or Errandi silk is also known for its thermal properties that make it a great fabric to keep oneself warm.

### c). Muga Silk

It is woven by the semi-domesticated multivoltine silkworm, *Antheraea assamensis* feeding on aromatic Som and Sualu leaves, primarily in Assam. This silk with a yellowish-green hue is the first choice for weaving Chadors and Mekhalas. It finds mention in many ancient scriptures of India like Ramayana and was patronized by the Ahom kings of the region.

## MAJOR SERICULTURE HUBS IN INDIA

India's sericulture industry thrives in several key regions, each contributing uniquely to the country's silk production. Karnataka, with districts like Ramanagara, Channarayapatna, and Mysuru, is a leading producer of Mulberry silk and a hub for sericulture research. Andhra Pradesh, known for Dharmavaram, Anantapur, and Hindupur, excels in both Mulberry and non-Mulberry silk varieties. Tamil Nadu's Dharmapuri, Salem, and Erode are notable for their diverse sericulture practices, including Mulberry, Tassar, and Muga silk cultivation. In West Bengal, regions like Malda, Murshidabad, and Bankura are prominent for Mulberry and Tassar silk. Jammu and Kashmir, particularly Srinagar, specialize in producing luxurious Pashmina silk. Assam is renowned for its traditional methods of cultivating Muga silk, a unique golden-hued variety. These hubs collectively enhance India's sericulture landscape, fostering socio-economic development and showcasing diverse silk types and cultivation practices.

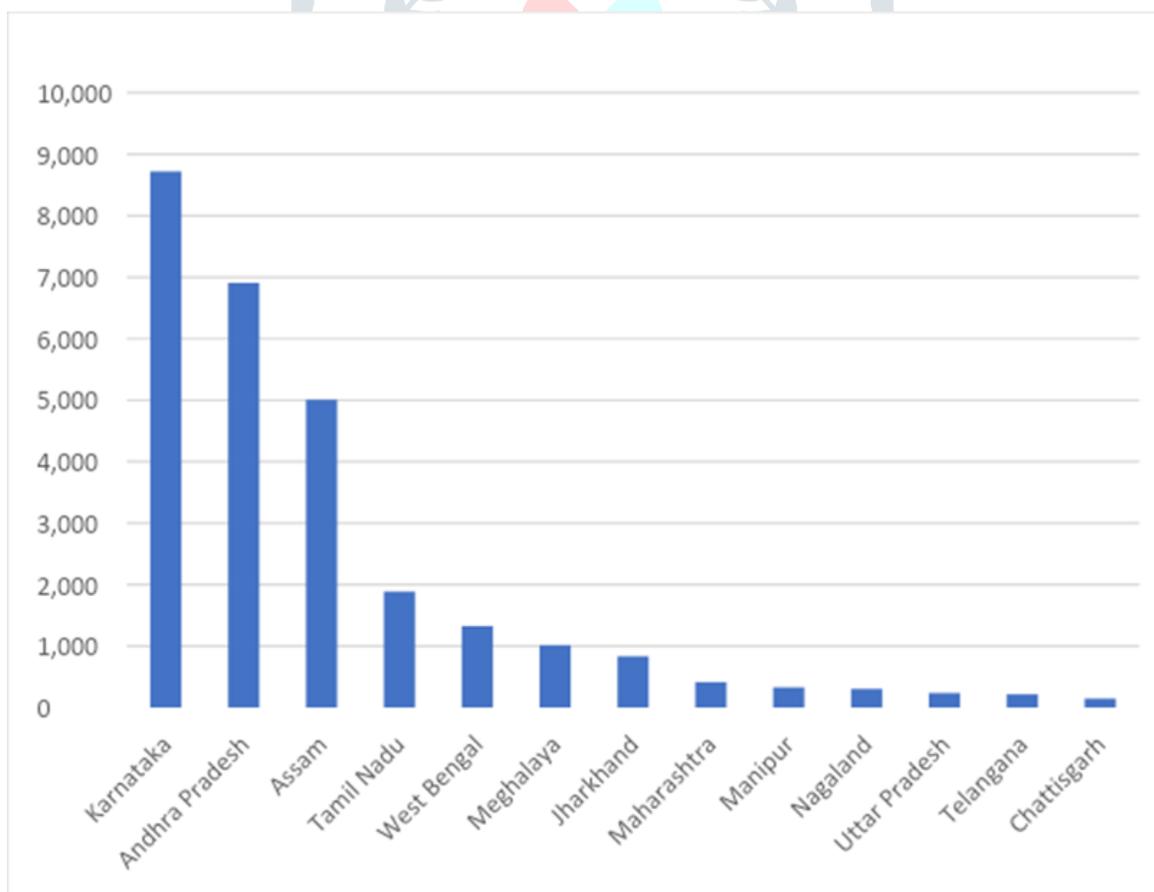


Fig. 1: The production of raw silk in India in FY 2023, (Statista 2024)

## PROCESSING OF SILK

The production of silk fabric involves a series of meticulous steps, primarily focusing on the cultivation of silkworms and the subsequent processing of their silk. They are -

### 1. Silkworm Rearing:

The process begins with the rearing of silkworms, primarily the *Bombyx mori* species, which feed on mulberry leaves. The lifecycle starts with the incubation of silkworm eggs in controlled environments to ensure proper hatching. Once hatched, the larvae are placed on trays and fed fresh mulberry leaves. Over the course of about 25-30 days, the larvae undergo several molting stages, during which they shed their skin and grow larger.

### 2. Cocoon Formation:

After the final molting stage, the mature silkworms are ready to spin their cocoons. They secrete a proteinaceous fluid from their salivary glands, which hardens upon exposure to air, forming silk filaments. The silkworms spin these filaments in a continuous figure-eight pattern, creating a protective cocoon around themselves. This process takes about 2-3 days, resulting in the formation of complete cocoons.

### 3. Cocoon Harvesting:

Once the cocoons are fully formed, they must be harvested before the moths emerge. This timing is crucial to prevent the moth from breaking the continuous silk filament while emerging. The harvested cocoons are then sorted based on quality, size, and texture. Only the best-quality cocoons are selected for further processing.

### 4. Softening and Sorting:

The harvested cocoons are boiled or steamed to soften the sericin, a protein that holds the silk fibers together. This process, known as degumming, makes the silk threads easier to unravel. After boiling, the cocoons are sorted based on their quality, size, and color. Higher-quality cocoons are set aside for premium silk production.

### 5. Reeling:

Reeling involves unwinding the softened silk threads from the cocoon. The process is done carefully to preserve the continuity of the filament. The threads are then gathered into a single strand, resulting in raw silk. This stage requires precision to avoid breaking the delicate threads and ensure the maximum length of silk fiber.

### 6. Twisting and Spinning:

The reeled silk filaments are then twisted together to form silk yarn, a process known as twisting and spinning. The number of filaments combined during twisting determines the thickness and strength of the silk yarn. The spun silk is wound onto spools, ready for weaving. This yarn can also be dyed at this stage, depending on the desired end product.

### 8. Weaving:

Weaving is the process of interlacing the silk yarns to create fabric. The basic components of weaving are the warp and the weft. The warp threads are set vertically on a loom, while the weft threads are woven horizontally over and under the warp threads. Various types of looms, including handlooms and power looms, can be used for weaving silk. The choice of weave pattern, such as satin, twill, or plain weave, affects the texture and appearance of the final fabric. Skilled weavers can produce intricate patterns and designs, adding to the uniqueness and beauty of the silk fabric.

### 9. Finishing:

The final stage of silk processing is finishing, which involves treatments to enhance the fabric's properties and prepare it for use. These processes include scouring for cleaning, bleaching for whiteness, softening for texture, sizing for strength, calendering for a glossy finish, and sanforizing to prevent shrinkage. Finally, the fabric undergoes inspection and quality control before packaging.

## WASTE MANAGEMENT

The textile industry is one of the sectors where production wastes are up to 25% of the raw material input. That consequently results in economic losses for companies and environmental problems. Silk production is not an exception. When silkworm cocoons and raw silk are harvested and processed, enormous amounts of waste are produced, including uncoiled cocoons, waste from silkworm cultivation, cocoon unwinding, silk spinning, and silk weaving. Only about 20% of the cocoons belong to the selected and first-quality grade and may be fully unwound having zero waste; the remaining cocoons are of the second and third grade and are not fully processed in silk factories. Together with the waste from silk spinning and silk weaving, the total amount of waste in all sectors of the silk industry is 55%.

The standard classification of silk waste is based on their origin from:

- Cocoon
- Cocoon unwinding
- Silk winding

- Silk spinning and weaving
- Silk dyeing and finishing

The waste from each stage of silk production varies in terms of physical, mechanical, and chemical fibre properties and geometric parameters (Sashina, E.S. and Yakovleva, O.I., 2023)

In the process of silk production, there are various by-products, waste, and water effluents generated, which require management to minimize environmental impact.

#### **A. BY-PRODUCTS:**

1. **Silkworm Castings:** Silkworm castings refer to the waste produced by silkworms during their feeding and spinning stages. This waste primarily consists of undigested mulberry leaves, silk moth excrement, and leftover silk cocoon debris. Silkworm castings can be rich in nutrients and are sometimes used as organic fertilizer in agriculture.
2. **Cocoon Waste:** After the silk filaments are extracted from the cocoons, there is typically some waste material left behind. This waste includes the outer layers of the cocoon that are not suitable for silk production. Cocoon waste can be repurposed for various purposes, such as animal feed or even as a substrate for mushroom cultivation.
3. **Pupa:** During the silk reeling process, some pupae may not survive or may be discarded as part of the process. These pupae can be used in various ways, such as in animal feed production or as a source of protein in some cultures.
4. **Sericulture By-products:** Sericulture, the practice of rearing silkworms for silk production, often involves cultivating mulberry trees as food for the silkworms. Mulberry leaves that are not consumed by the silkworms or are trimmed during cultivation can be considered byproducts. These leaves can be used as fodder for livestock or in the production of herbal teas and traditional medicines.
5. **Silkworm Exuviae:** Silkworm exuviae are the outer skins shed by silkworms as they grow. These exuviae are typically removed from the rearing trays during the silkworm rearing process. While not commonly used, they may have potential applications in certain industries or crafts.
6. **Silkworm Pupa Oil:** In some cases, silkworm pupae are processed to extract oil, which can be used in various applications such as cosmetics, pharmaceuticals, or even as a nutritional supplement.
7. **Silk Gum:** Silk gum refers to the natural adhesive substance that holds the silk fibers together within the cocoon. During the silk reeling process, this gum is typically removed through a degumming process to obtain smooth silk fibers. The extracted silk gum may have applications in industries such as textiles, cosmetics, or even as a natural adhesive.

#### **B. WATER EFFLUENTS:**

The degumming process in silk production removes the natural adhesive substance (silk gum) that holds silk fibers together, resulting in effluents containing gum residues and other contaminants. In the dyeing process, wastewater may contain dye residues, chemicals, and heavy metals, posing environmental risks if untreated. Cleaning and washing silk fibers or equipment can also produce water with organic matter, detergents, and other contaminants.

#### **MEASURES TO UTILISE WASTE**

The byproducts, waste, and water effluents from silk production can be effectively repurposed, contributing to sustainability and minimizing environmental impact. Cocoon waste, the outer layers not suitable for silk, can be used as a nutritious component in animal feed or processed into organic fertilizer rich in essential nutrients. Silkworm castings, a byproduct of the silkworms, serve as nutrient-rich organic fertilizer, enhancing soil fertility and plant growth. Discarded silkworm pupae, a valuable protein source, can be repurposed into animal feed for livestock or aquaculture and are even consumed as a delicacy or food ingredient in some cultures. Mulberry leaves, essential for silkworms, also have applications beyond sericulture; they can feed livestock like cattle, goats, or rabbits and be used in herbal teas and traditional medicines due to their medicinal properties. Additionally, silkworm exuviae contain chitin, a natural polymer with applications in pharmaceuticals, cosmetics, and agriculture. These strategies ensure that byproducts and waste from silk production are efficiently utilised, enhancing the overall sustainability of the industry.

#### **WATER EFFLUENTS MANAGEMENT**

Effluents from the silk degumming process can be treated to recover and reuse silk gum in textiles or adhesive products, reducing environmental pollution. Dyeing process wastewater can undergo filtration, sedimentation, and chemical treatment to remove dye residues, chemicals, and heavy metals, allowing for water recycling and reuse in subsequent dyeing processes, thus minimizing water consumption and environmental impact. Similarly, wastewater from cleaning and

washing can be treated for reuse in non-potable applications like irrigation or industrial processes, conserving freshwater resources.

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.

## FINDINGS

The findings likely involve an analysis of the impact of sericulture practices on waste generation and management in India. The discussion will delve into the relationship between silk production processes, waste generation, and the effectiveness of waste management strategies. It may explore sustainable practices within sericulture and propose recommendations for improving waste management in the industry, contributing to a more environmentally conscious approach. Thus, sericulture by-products regarded as wastes can be put into better use in the production of value-based commodities (Sharma *et al.*, 2022).

## APPLICATION OF SERICULTURE BY-PRODUCTS

By-products from silkworm rearing can be used in vermicomposting whereas silkworm litter alone can be used in biogas production and pharmaceutical industry (Sharma *et al.*, 2022). From one hectare of the mulberry farm, about 15 MT of sericultural waste is generated yearly in the form of silkworm rearing waste and other farm waste which is equivalent to 280-300 kg of nitrogen, 90-100 kg of phosphorus and 150-200 kg of potash (Das *et al.*, 1997).

Studies showed that both breeding waste and caterpillar excreta generate a biogas yield comparable to other substrates of agricultural origin, such as cattle, pig, and chicken manures. Fermented silkworm excreta under mesophilic conditions produces 167.32 m<sup>3</sup>/Mg TS of methane and 331.97 m<sup>3</sup>/Mg TS of biogas, while fermentation of silkworm breeding waste yields 256.59 m<sup>3</sup>/Mg TS of methane and 489.24 m<sup>3</sup>/Mg TS of biogas (Lochynska and Frankowski, 2018).

Silkworm excreta or faeces are a major waste product of sericulture. Physically, silkworm excreta has a cylindrical shape of 2-3 mm in length with a deep green colour (Vimolmangkang *et al.*, 2013) and have equally pharmaceutical and food industrial uses. In traditional medicine, silkworm faeces have been used as a therapeutic agent in China, Korea, and some Eastern Asian countries to treat infectious diseases, headaches, and abdominal pain (Tulp and Bohlin, 2004). The chemical constituents of silkworm excreta that have principally been reported are chlorophyll and chlorophyll derivatives, xanthophylls, carotenoids, and flavonoids (Park *et al.*, 2011). Chlorophyll derivatives (CpD-A, -B, -C, and -D) were extracted from silkworm (*Bombyx mori*) excreta, among them CpD-A was extensively studied to clarify its role as a "photosensitizer" for photodynamic therapy (PDT) of tumors *in vitro* (Lee *et al.*, 1990). Three bioactive compounds have been isolated from excreta *viz.*, 1-tri triacontanol, lupeol, and  $\beta$  sitosterol. Of these lupeol and  $\beta$ -sitosterol are derivatives of mulberry leaves on which silkworms are fed and are excreted in an unchanged form and are used in treating inflammation, while 1-tri triacontanol is likely synthesized in the silkworm intestine (Vimolmangkang *et al.*, 2013). Moreover, silkworm excreta are also a good source of natural colorant for the food industry. Vila *et al.* 2018 studied that silk and polyamide fabrics can be easily dyed with the natural dye extracted from the excrement of the silkworm, obtaining yellowish-brown colour.

In the silk industry, the term silk waste refers specifically to silk fibres that are not continuous and long enough for reeling as silk reeling. The innermost layer of the cocoon is known as pelade layer which is discarded in the reeling process along with the pupa as basin refuse. Silk sericin was also discarded in the silk industry during the degumming process to improve the value of silk as a textile fiber and simply regarded as waste (Sharma *et al.*, 2022).

Silkworm pupa is an immediate by-product of the reeling industry, obtained after reeling. Annually India produces about 40,000 MT of silkworm pupae on a dry weight basis (Priyadharshini *et al.*, 2017). 75 per cent daily protein necessity of human individuals can be obtain from 100g of dried silkworm pupae (Singh and Suryanarayana, 2003).

Dried silkworm pupae contain 8 per cent nitrogen. Since the pupa contains a high amount of nitrogen and protein along with micronutrients like zinc, copper, magnesium, and manganese, there is a prospective potential for the bioconversion of pupal waste to enriched compost and utilization as a nutrient source (Mahesh *et al.*, 2020). The application of Silkworm

pupae residual biocompost (SPRB) along with chemical fertilizers significantly increased both the growth and yield parameters of mulberry (Mahesh *et al.*, 2020). Karthikeyan and Sivakumar (2007) cultivated in mass the biopesticide bacterium, *Bacillus thuringiensis* by utilizing silkworm pupal waste where viable spore count (VSC) was taken as a criterion for evaluating the efficiency of pupal waste medium.

Waste silkworm pupae generate a lot of resources containing nutrients beneficial for livestock and poultry. The de-oiled pupae can improve the egg-laying capacity in hens and fat-free pupae used as a feed of carps and fish for better yields. In silver barb fingerlings (*Barbonymus gonionotus*), highest growth rates were observed in fish fed in diet with about 38 per cent of total dietary protein replaced by silkworm pupal meal (Mahata *et al.*, 1994).

Silkworm (*Bombyx mori* L.) pupae have 4.8 per cent and 9.0 per cent oil content in males and females (Suresh *et al.*, 2012).. The oil extracted from silkworm pupae contains more than 70 per cent unsaturated fatty acids, particularly the  $\alpha$ -linolenic acid and oleic acid accounting for a high percentage (Rao, 1994). Oil extracted from silkworm pupae by boiling is used in the cosmetics industries for making soaps and moisturizers (Winitchai *et al.*, 2011) and this soap was used for degumming of silk. The pupae oil can be used in jute industry for lubricating (presently rice bran oil is being used) and in leather processing (presently, fish oil is being used) (Sharma *et al.*, 2022).

Sericin is a natural polymer, highly hydrophilic, with adhesive characteristics such as gelatin. Sericin allows the union of silk filaments to maintain the structural integrity of the cocoon during its formation. Structurally, sericin is a globular protein consisting of random coil and  $\beta$ -sheets (Sharma *et al.*, 2022). Sericin has been use potentially in cosmetics, biomedical, pharmaceutical and food industries during recent years. Sericin has some marvelous properties like biocompatibility, biodegradability and wettability, which are used in the preparation of cosmetic products for skin, nails and hair (Padamwar & Pawar, 2003). Silk sericin has also anti-aging properties comparable to vitamin C, except for oxidative stress, where silk sericin was superior as sericin can stimulate synthesis of collagen type 1 which suppress the regulation of nitrate, which may induce oxidative stress, and up regulate the expression of b-cell lymphoma 2 (bcl-2) to inhibit cell apoptosis, without altering fibroblast growth kinetics or cellular ultra-structure (Kitisin *et al.*, 2013). 8 per cent sericin can induce wound healing in the patients of second-degree burns (Aram wit *et al.*, 2013). Cocoons of *Bombyx mori* L. can provide natural pigments typically flavonoids and carotenoids that accumulate in sericin layers (Kurioka and Yamazaki, 2002). These pigments are known for their biological properties as antioxidants and anti-tyrosinase. Sericin can also be used as food packaging material.

Cocoon craft is one of the very remarkable utility of by-products which can provide scope to develop human skills in adding up generating self-employment and revenue. The value addition in post cocoon sectors is predictable to generate income ranging from 10 to 25 per cent in total returns. Various products like garlands, flower vase, wreath, pen stand, dolls, jewellery, wall hangings, wall plates, clocks, bouquets and greeting cards are being prepared by using the waste silk cocoons (Vathsala, 1997). Some laboratories of Japan have produced silk paper in different colors for making craft products like flowers and lamp stands. A paint containing silk powder known as silk leather is used to decorate plastics, steel and fabrics (Sharma *et al.*, 2022).

## CONCLUSION

In conclusion, this research highlights the intricate dynamics between Indian sericulture and waste management. The sericulture industry, while a significant contributor to economic development, poses environmental challenges due to substantial waste generation. It is evident that effective waste management strategies are imperative to mitigate the ecological impact. Achieving a sustainable balance between economic gains from sericulture and environmental conservation is crucial for the industry's future resilience. The study advocates for integrated approaches, emphasizing circular economy principles to transform sericulture waste into valuable resources. Policy interventions are essential to incentivize sustainable practices and ensure the industry's responsible growth. Collaboration among stakeholders, including government bodies, industry players, and environmental advocates, is vital to address the identified challenges. Looking ahead, this research calls for continued exploration of innovative waste-to-resource technologies and alternative sericulture practices. By fostering a comprehensive understanding of the intricate relationship between sericulture and waste management, the way can be paved for a more sustainable and resilient future for the Indian sericulture industry.

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