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Sericulture by-products and their economic importance: A review

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Abstract
Sericulture for silk production is accompanied by many by-products with enormous economic prospects other than silk. In this review, sericulture by-products, namely silkworm pupae, silkworm litter, reeling waste, and mulberry biomass are discussed for the diversified uses in inter-related industries. Silk pupae, high-protein and high-oil as silkworm food, are used as animal feed, cosmetics and drug. Spun silk and biocomposites are produced using reeling waste and perforated cocoons, whereas foliages and twigs of mulberry represent potential value in livestock feed, bioenergy, and traditional medicine. Valorization of these by-products enhances the economic value of the sericulture and improves the livelihoods of rural population by offering them opportunity for additional income through waste management and circular bioeconomy. This review discusses the recent market repercussions and technological innovations centering the interest for sericulture by-products and emphasizes the necessity for an integrated approach.

Keywords: Sericulture, mulberry, by-products, economic development.

Introduction

Sericulture, which involves the cultivation of silkworms for use in the production of silk, produces large volumes of by-products besides its major product of silk. Historically, by-products have been simply discarded as waste, but increased scientific understanding of their uses has underscored their economic importance (DS *et al*., 2024) [12]. This paradigm change from waste disposal to valorization highlights a more sustainable operation in the sericulture sector, promoting a circular economy model (Chavez, 2021) [10]. By-products such as pupae, silk waste, and silkworm excreta, which were previously regarded as mere waste, are now seen as valuable resources with multifunctional applications ranging from zootechnic, food, and cosmetic to ecological sectors, thus improving the profitability and sustainability of the industry (Naan *et al*., 2024) [30]. The purpose of this review is to examine the different by-products produced by the sericulture sector and their potential for commercial exploitation, with a focus on how they support improved resource use and a circular economy. In particular, silkworm pupae can be used to create high-value products, which will help sericulture farmers diversify their revenue streams and preserve the environment (Habeanu *et al*., 2023 and Sharma *et al*., 2022) [14, 45] p [.An alternate way to address the issues brought on by the decline in silk production is to properly utilise sericultural waste, which could boost the industry's worth by up to 40% (Sharma *et al*., 2022) [45]. This shift necessitates a re-evaluation of sericulture's economic framework, moving beyond raw silk to embrace a comprehensive utilization of all generated biomass (Habeanu *et al*., 2023) [14].

From an ancient agricultural practice to a contemporary industry with substantial potential for diversification, sericulture has a rich historical trajectory (Habeanu *et al*., 2023) [14]. The sericulture sector produces a wide range of by-products that are economically significant and support a circular economy in addition to its main product, silk (Sharma *et al*., 2022) [45]. Through direct and indirect employment opportunities, this agro-based industry not only improves people's socioeconomic livelihoods worldwide, but it also provides opportunities for economic development and income generation (Ssemugenze *et al*., 2021) [47]. Extensive research into the chemical composition and potential applications of these sericultural by-products has been prompted by the growing global demand for sustainable practices and innovative biomaterials (Kashyap *et al*., 2025) [20]. For instance, governmental subventions and increased job opportunities can further stimulate the growth of new sericulture businesses or aid in expanding existing ones, fostering economic resilience (Habeanu *et al*., 2023) [14]. Furthermore, integrating advanced technologies and sustainable methodologies into sericulture can enhance product diversity and market reach, thereby securing long-term economic viability and environmental stewardship (Habeanu *et al*., 2023) [14].

Sericulture By-products

By recycling, remanufacturing, and reusing these by-products, sericulture is moving towards a circular economy, which aims to solve both economic and environmental issues (Hassan *et al*., 2025) [15]. This method greatly enhances agricultural resilience and sustainable development by turning what was formerly regarded as waste into useful resources (Jayaprakash *et al*., 2022) [17]. From growing mulberries to processing silk, sericulture is an agro-based industry focused on raising silkworms for the production of silk. It is known for its substantial socioeconomic contributions, especially in rural areas (Ssemugenze *et al*., 2021) [47]. About 8.8 million people in rural and semi-urban areas of India alone are employed in this sector, which offers significant employment opportunities, particularly for economically disadvantaged groups (Sut *et al*., 2024) [48]. In addition to producing silk cocoons, which are a major source of income for farmers and an essential raw material for the textile industry, sericulture also produces a variety of other valuable secondary products, such as moths, silkworm proteins, and different types of waste, all of which can be processed for a variety of uses, including animal feed (Ssemugenze *et al*., 2021) [47]. By turning these by-products-which range from damaged cocoons to pupal exuviae-into valuable products, sericulture operations can become more profitable and sustainable overall. One outstanding chance to foster human skills, create self-employment, and greatly boost income is the use of damaged cocoons in craft production (Sharma *et al*., 2022) [45]. This innovative repurposing aligns with circular economy principles by minimizing waste and creating new value streams within the sericulture supply chain (Mohanty *et al*., 2024) [29].

Types of Sericulture By-products

Sericulture generates a diverse array of by-products at various stages, ranging from mulberry cultivation to cocoon processing, each possessing unique characteristics and potential applications. These by-products, often overlooked, include mulberry leaves unfit for silkworm consumption, silkworm litter, defective cocoons, pupal exuviae, and dead or diseased silkworms.

Mulberry By-products

These materials, once considered waste, are increasingly recognized for their potential as valuable resources in various industries. Mulberry, primarily cultivated for silkworm feed, yields various by-products such as leaves, stems, bark, and fruits, which are often underutilized but possess significant potential for value addition (Ahamed *et al*., 2025) [1]. Mulberry leaves, including those not fed to silkworms, contain bioactive compounds like rutin and quercetin, which have anti-inflammatory and antioxidant qualities. Mulberry fruits, on the other hand, are rich in anthocyanins, phenolics, and flavonoids, making them suitable for functional foods (DS *et al*., 2024) [12]. The fact that these compounds can be extracted and used in pharmaceuticals, cosmetics, and nutraceuticals shows how versatile mulberry by-products are outside of their main application in sericulture (Ahamed *et al*., 2025) [1]. The recovery of these valuable compounds is further improved by the use of fermentation and enzymatic treatments, which permits their application as natural supplements, preservatives, and antioxidants in a variety of industries (Tlais *et al*., 2020) [49]. Beyond the leaves and fruits, mulberry waste, traditionally underutilized, is now being explored for innovative products, employing advanced technological solutions that enhance efficiency and promote eco-friendly practices across diverse industries (Ahamed *et al*., 2025) [1]. Specifically, the residual mulberry leaves, even after silkworm feeding, represent a significant untapped resource due to their rich nutritional profile and bioactive compounds, making them valuable for applications beyond animal feed, such as in functional foods, nutraceuticals, and even biofuel production (Ahamed *et al*., 2025) [1].

Silkworm Pupae

A significant biomass with significant nutritional value and industrial potential is made up of silkworm pupae, the by-product left over after silk reeling (Sharma *et al*., 2022) [45]. They are useful for human consumption, animal feed, and the extraction of bioactive compounds for use in medicine and cosmetics because they are a rich source of protein, essential amino acids, and lipids (V *et al*., 2024) [51]. The economic utility of this by-product can be further increased by refining the lipid fraction, especially chrysalis oil, for use in a variety of industrial processes, such as the synthesis of fatty acids and esters (DS *et al*., 2024) [12]. Additionally, the defatted pupal meal, abundant in high-quality protein, can be further processed into protein hydrolysates or isolates for use in food formulations or as a sustainable animal feed ingredient, contributing to a circular bioeconomy. The management of this by-product aligns with principles of circular economy, transforming what was once waste into valuable resources and thereby mitigating environmental impact while enhancing economic viability (Campos *et al*., 2020) [8]. Additionally, because of their distinct physicochemical characteristics, the chitin and chitosan extracted from pupal exoskeletons have a wide range of uses in biomedicine, wastewater treatment, and agriculture (Antunes *et al*., 2020) [2]. By turning a traditional waste product into a flexible raw material for a variety of high-value applications, this extensive use of silkworm pupae represents a major step towards sustainable resource management within the sericulture sector. Silkworm pupae have significant potential uses in the pharmaceutical industry due to their production of compounds with medicinal qualities, such as anti-diabetic and anti-cancer agents, in addition to their nutritional and material value (Naan *et al*., 2024) [30].

Silk Waste

Silk waste, generated during various stages of silk processing such as reeling, spinning, and weaving, comprises damaged cocoons, pierced cocoons, and silk fibers that are too short or entangled for primary textile applications, yet it remains a valuable source of silk proteins, primarily sericin and fibroin. Despite this, the waste is still a valuable source of silk proteins, mainly sericin and fibroin. These proteins, especially sericin, are highly sought-after for use in biomedical applications, cosmetics, and functional textiles due to their exceptional biocompatibility, biodegradability, and moisture-retention qualities (Hăbeanu *et al*., 2023) [14]. Processing technology advancements like enzymatic hydrolysis and supercritical fluid extraction are making it possible to recover high-purity sericin and fibroin efficiently, extending their use beyond conventional textile applications into cutting-edge biomaterials. This silk waste is a result of the pelade layer, the innermost layer of the cocoon, being thrown away with the pupa as basin refuse during the reeling process (Sharma *et al*., 2022) [45]. Despite being regarded as trash, this waste material contains valuable fibroin and sericin components that can be extracted and used in new ways (Kashyap *et al*., 2025) [20]. Although silk sericin is frequently thrown away as waste, it is purposefully eliminated during the degumming process to increase the value of silk as a textile fibre (DS *et al*., 2024) [12]. But new extraction methods and a better knowledge of sericin's many uses are turning this once-waste material into a useful byproduct with enormous potential in the pharmaceutical, cosmetic, and biomedical sectors (Ssemugenze *et al*., 2021) [47]. The principles of a circular economy are increasingly being applied to sericulture, where insect biorefineries exemplify the conversion of biowaste into high-value products, contributing to sustainable waste-to-resource solutions (Silveira *et al*., 2025) [46] (Ravi *et al*., 2020) [41].

Other By-products

In addition to the main by-products, sericulture produces other valuable by-products like cocoon pelade, silkworm litter, and even the insects themselves, all of which have unrealised potential for a variety of uses (V *et al*., 2024) [51]. Rich in nutrients and organic matter, silkworm litter can be composted and used as a very efficient biofertilizer to improve soil fertility and support sustainable farming methods (V *et al*., 2024) [51]. In addition, the cocoon pelade layer, despite being a byproduct of silk reeling, has protective qualities and structural integrity that make it appropriate for biomimetic materials and scaffolds in tissue engineering (V *et al*., 2024) [51]. Additionally, sophisticated extraction techniques are being developed to recover valuable components, like chitin and chitosan, from materials derived from insects, such as cocoons and exuviae, creating opportunities for the sustainable production of biopolymers (Mersmann *et al*., 2025) [28]. Furthermore, bioactive substances like triterpenoids and photosensitisers found in silkworm excreta-which are typically thrown away-are being researched for their potential as a treatment for tumours and inflammation (Sharma *et al*., 2022) [45]. A sustainable method for creating biochar, a useful substance for energy production and organic waste management, is the torrefaction of sericulture agro-industrial waste, particularly silkworm biomass (Silveira *et al*., 2025) [46].

Economic Importance of Mulberry By-products

Nutritional Value and Animal Feed

Mulberry leaves are particularly useful as a highly digestible and palatable animal feed because they improve the protein, lipid, and carbohydrate content of milk, which increases milk production in dairy animals (Ssemugenze *et al*., 2021) [47]. They are also an excellent supplement for enhancing the general health, growth, and disease resistance of a variety of livestock, including fish, poultry, and ruminants, due to their rich nutritional profile, which includes essential amino acids, carotenoids, and polyphenolic compounds (Ahamed *et al*., 2025) [1]. The potential of processed mulberry leaves and their extracts as functional feed additives, which provide natural substitutes for artificial growth promoters and antibiotics in animal husbandry, is being investigated more and more in addition to their direct use as animal feed (Habeanu *et al*., 2023) [14]. This approach not only supports the circular economy by repurposing agricultural waste but also contributes to sustainable livestock management (Malenica *et al*., 2022) [27]. Furthermore, the incorporation of mulberry leaf meal into animal diets has demonstrated a reduction in methane emissions from ruminants, offering an environmentally beneficial aspect to its use as a feedstuff. The application of mulberry by-products extends to silkworm pupae, which are a rich source of protein and bioactive compounds, offering significant nutritional and economic value (Habeanu *et al*., 2023) [14].

Mulberry in Human Health and Medicine

Mulberries' wide range of bioactive substances, which include polyphenols, flavonoids, and anthocyanins, offer considerable therapeutic promise, especially in the fight against inflammation and oxidative stress, which are major causes of many chronic illnesses (Ahamed *et al*., 2025) [1]. Mulberry extracts are considered to be promising candidates for pharmaceutical and nutraceutical development because of these compounds' well-known antioxidant, antiviral, anti-inflammatory, and hypoglycemic qualities (Habeanu *et al*., 2023) [14]. In particular, mulberry leaves' deoxyribonucleic acid and flavanoids highlight their potential for antiviral and cancer treatment uses (DS *et al*., 2024) [12]. Beyond these uses, mulberry compounds have therapeutic benefits for cardiovascular health, helping to regulate blood pressure and lipid metabolism (Villegas-Vazquez *et al*., 2025) [53]. Furthermore, mulberry fruits' anthocyanins, which are especially well-suited for enzymatic extraction, have strong antioxidant properties that may improve gut health by improving resistance to harmful microbes and altering the composition of the microbiota (Go *et al*., 2022) [13]. As a result, mulberry fruit extracts are especially useful for creating functional foods that enhance human health (Kim and Lee, 2020, Centhyea *et al*., 2021, and DS *et al*., 2024) [21, 9, 12]. Mulberry's therapeutic benefits also include neuroprotection; research suggests that its bioactive compounds may be able to improve cognitive function and slow down neurodegenerative processes.

Mulberry for Biofuel and Energy Production

Mulberry farming producing a lot of biomass, especially from the leaves and woody stems. This biomass can be converted into a variety of bioenergy products, such as biogas and biofuels, which can help to reduce dependency on fossil fuels and promote renewable energy sources. For example, with the yield of roughly 60.6 ml per 200 mg, young mulberry leaves show a significant potential for biogas production (DS *et al*., 2024) [12]. Due to this, mulberries can be used as an anaerobic digestion feedstock, providing a sustainable way to turn agricultural waste into energy (Ahamed *et al*., 2025) [1].

Mulberry Paper and Handicrafts

Mulberry's fibrous parts, especially those found in the bark and wood, having high value for their remarkable strength and resilience, which makes them perfect for creating fine papers and elaborate handicrafts. Mulberry is positioned as a sustainable resource for the growing bio-based materials industry because of this intrinsic quality, as well as the plant's quick growth and capacity for regeneration (Ssemugenze *et al*., 2021) [47]. The use of mulberry biomass in papermaking contributes to local economies and cultural heritage by preserving traditional craft methods and providing an environmentally friendly substitute for wood pulp. Mulberry fibres are also used to make biodegradable packaging materials and eco-friendly textiles, meeting the increasing need for sustainable alternatives across a range of industries (Salem *et al*., 2021) [44].

Economic Importance of Silkworm Pupae

Nutritional Value and Human Consumption

In addition to their balanced amino acid profile, polyunsaturated fatty acids, and assortment of vitamins and minerals, silkworm pupae are a highly nutritious dietary supplement or alternative protein source that can be consumed by humans (Ahamed *et al*., 2025) [1]. Their use, especially in Asian nations, demonstrates their legitimacy as a sustainable food source that supports the ideas of the circular economy and food security. The pupae's use in functional foods and nutraceuticals can be expanded beyond direct consumption by processing them into protein isolates and hydrolysates. Furthermore, because of their biodegradable and biocompatible qualities, the chitin and chitosan extracted from pupal exoskeletons have a wide range of uses in biomedicine, agriculture, and wastewater treatment. Silkworm pupae are also a promising raw material for the development of innovative cosmetic products, leveraging their unique composition for skin and hair health applications (Ssemugenze *et al*., 2021) [47].

Animal Feed and Aquaculture

In poultry and aquaculture, the silkworm pupae especially de-oiled varieties have been successfully added to animal feed formulations, greatly increasing growth rates and feed conversion ratios (DS *et al*., 2024) [12]. By decreasing waste and improving resource utilisation, this integration not only offers livestock a cost-effective source of protein but also aids in the sustainable management of sericultural by-products (Cadinu *et al*., 2020) [6]. In animal diets, silkworm pupae are a great substitute for traditional protein sources like fishmeal and soybean meal due to their high protein content and palatability (Sut *et al*., 2024) [48]. By turning a sericulture by-product into a useful feed ingredient, their use also helps to address environmental concerns by lessening the ecological impact of animal agriculture.

Oil Extraction and Industrial Applications

Due to their high lipid content-of which a sizable amount is unsaturated fatty acids-the pupae are a desirable source for oleochemicals, biofuels, and edible oils. Linoleic acid and oleic acid, two valuable components found in the extracted oil, have a great deal of potential for use in the pharmaceutical, nutraceutical, and cosmetic industries. Additionally, after oil extraction, the leftover meal has a high protein content that can be used as animal feed or processed further to create protein hydrolysates. In addition to these, the unsaponifiable components of silkworm pupa oil, such as cholesterol, β-sitosterol, and campesterol, provide additional opportunities for pharmacological uses, especially due to their anti-inflammatory qualities (Sut *et al*., 2024) [48]. Additionally, the chitin and pectin components of the pupae exoskeleton are valuable as dietary supplements and have been incorporated into various food products like chocolates, cakes, and even as a supplement to wheat flour bread to enhance nutritive value and loaf volume (Ssemugenze *et al*., 2021) [47]. The valuable pupal oil, particularly that extracted by boiling, finds extensive use in cosmetic industries for the production of soaps and moisturizers, and the resulting soap can also be utilized for silk degumming (Sharma *et al*., 2022) [45].

Chitin and Chitosan Production

One important source of chitin, a flexible biopolymer with a broad range of uses in various industrial sectors, is the exoskeleton of silkworm pupae. Chitin can be further processed into chitosan by deacetylation (DS *et al*., 2024) [12]. Because of their special biodegradable and biocompatible qualities, they can be used in biomedical applications like drug delivery systems and wound healing as well as environmental applications like water purification and heavy metal adsorption. Additionally, chitin and chitosan's structural integrity and chemical inertness allow for their use in advanced materials science, such as the creation of scaffolds for tissue engineering and specialised membranes for filtration (Sharma *et al*., 2022) [45]. Beyond these well-established applications, the integration of chitin and chitosan derivatives into sustainable agricultural practices, such as biodegradable seed coatings and controlled-release fertilizers, presents a burgeoning area of research aimed at enhancing crop yield and minimizing environmental impact. Furthermore, these biopolymers have shown promise in the development of antimicrobial agents and as functional ingredients in food preservation, extending shelf-life and ensuring food safety (Triunfo *et al*., 2022) [50].

Economic Importance of Silk Waste

Textile Industry and Recycling

From reeling to weaving, silk waste is produced at different stages of the silk processing process. It is a valuable by-product that can be used in both textile and non-textile applications. By keeping waste out of landfills, this repurposing not only lessens the impact on the environment but also generates new sources of income for the sericulture sector. To increase the material's lifespan and economic usefulness, waste silk, for example, can be spun into speciality yarns for luxury fabrics or transformed into non-woven fabrics for filtration and insulation. Reusing silk fibres from waste streams enables the creation of less expensive silk goods, increasing silk's accessibility without sacrificing its desirable qualities.. Additionally, advancements in textile engineering have enabled the development of innovative materials from silk waste, such as silk-based composites and functionalized textiles, expanding their utility beyond traditional apparel into sectors requiring high-performance materials (Piekarska *et al*., 2023 and Vidal *et al*., 2022) [37, 52].

Silk Waste in Cosmetics and Pharmaceuticals

The unique biochemical composition of silk proteins, particularly sericin and fibroin, extracted from silk waste, renders them highly valuable for cosmetic and pharmaceutical formulations (Kashyap *et al*., 2025) [20].

Sericin, a globular protein surrounding the fibroin core, possesses excellent moisture-retention capabilities and antioxidant properties, making it an ideal ingredient for skincare products and wound dressings (Naan *et al*., 2024) [30]. Conversely, fibroin, known for its mechanical strength and biocompatibility, is being explored for tissue engineering scaffolds, drug delivery systems, and advanced surgical sutures (Nath *et al*., 2024) [31-32]. Furthermore, recent research highlights the potential of silk proteins in photodynamic therapy and as biosensors for hydrogen peroxide analysis, underscoring their versatile applicability in biomedical fields (Ssemugenze *et al*., 2021) [47]. This strategic utilization of by-products adds up to 40% value to the silk industry, promoting a circular economy within sericulture (Sharma *et al*., 2022) [45].

Silk Waste for Composites and Biomaterials

In the most of engineering and medical applications, the use of silk waste in composite materials improves their mechanical strength, biodegradability, and biocompatibility, providing sustainable substitutes for synthetic polymers. This strategy opens up new possibilities for creating high-performance materials with specific qualities in addition to addressing environmental issues related to waste disposal. Using its natural biocompatibility and mechanical strength, silk fibroin-which is made from silk waste-can be incorporated into polymer matrices to produce biodegradable implants or scaffolds for tissue regeneration, for instance. Moreover, silk fibroin's distinct structure enables its modification to create specialised biomaterials that support tissue integration and cellular adhesion, like dental implants and nerve guidance conduits (Ssemugenze *et al*., 2021) [47]. Beyond medical applications, silk waste composites are also gaining traction in the automotive and aerospace industries, where their lightweight and high-strength properties can significantly contribute to fuel efficiency and structural integrity (Yin *et al*., 2020) [55].

Silk-derived Peptides and Amino Acids

A rich mixture of peptides and free amino acids is produced by the enzymatic hydrolysis of silk waste; these compounds have improved solubility and bioavailability while retaining many of the advantageous characteristics of the parent proteins (Osorio *et al*., 2021) [35]. These derivatives are very desirable for use in cosmeceuticals, functional foods, and nutraceuticals due to their strong antimicrobial, anti-inflammatory, and antioxidant properties (Ssemugenze *et al*., 2021 and Baci *et al*., 2023) [47, 4]. Their therapeutic benefits can be delivered more effectively because of their smaller molecular size, which also makes it easier for them to be absorbed through the skin and digestive systems. To support skin health and fight ageing signs, sericin peptides, for example, have shown promise in increasing collagen synthesis and reducing elastase activitySilk hydrolysates' rich glycine, alanine, and serine amino acid profile also promotes muscle repair and general metabolic function, making them an excellent supplement for sports performance and recuperation (Kashyap *et al*., 2025) [20]. These components made from silk are also being researched for their potential use in drug delivery systems, where they can encapsulate active pharmaceutical ingredients to enhance stability and targeted release within the body. The potential of silk by-products to transform therapeutic approaches is demonstrated by their expanding range of medical applications, such as wound dressings and nanoparticles (Naan *et al*., 2024 and Mahabeer and Jin, 2024) [30, 26].

Other Sericulture By-products and Their Economic Uses

Silkworm Litter as Fertilizer

By adding vital macro- and micronutrients, this organic matter-which includes silkworm excrement and leftover mulberry leaves-enhances soil fertility, increasing crop yields and lowering the need for synthetic fertilisers. Silkworm litter's high organic matter content also improves microbial activity, soil structure, and water retention, which results in healthier soil ecosystems and sustainable farming methods (Lu *et al*., 2025) [25]. According to research, one of this litter's constituents, silkworm frass, also possesses antimicrobial and anti-pathogenic qualities, which may help plants resist disease and function as a natural insecticide (Chavez, 2021) [10]. Thus, using silkworm litter as a biofertilizer offers a sustainable way to manage waste in sericulture and increase agricultural output in an environmentally responsible way.

Exuviae Applications

The discarded silkworm exoskeletons, or exuviae, represent another significant byproduct of sericulture with considerable economic potential due to their chitin content, a versatile biopolymer. Chitin can be extracted and converted into chitosan, a highly valuable derivative with applications ranging from wastewater treatment to biomedical devices due to its biocompatibility, biodegradability, and antimicrobial properties (Jang *et al*., 2020) [16]. This makes chitosan an excellent flocculant for purifying water and a promising component for drug delivery systems, wound dressings, and tissue engineering scaffolds. Additionally, the unique structural properties of chitin and chitosan enable their utilization in the development of innovative agricultural products, such as bio-pesticides and controlled-release fertilizers, further diversifying their economic utility (Rai *et al*., 2025) [40].

Emerging By-products and Innovations

Beyond the widely recognized by-products, the sericulture industry is witnessing a surge in innovative applications, including the valorization of silkworm pupae and frass for diverse industrial uses (Sharma *et al*., 2022) [45]. For instance, silkworm pupae, traditionally considered waste, are increasingly recognized as a rich source of protein, lipids, and chitin, finding applications in animal feed, human nutrition, and pharmaceutical industries (DS *et al*., 2024) [12]. Furthermore, silkworm frass, a mixture of feces, exoskeletons, and residual feed, is gaining recognition as a potent organic fertilizer and soil amendment, given its rich nutrient profile and biostimulant properties (Athanassiou and Rumbos, 2025) [3]. The incorporation of innovative biotechnological approaches, such as black soldier fly larval conversion, further enhances the utility of sericulture by-products by transforming organic waste into valuable feed materials, chitin, and biofertilizers (Rehman *et al*., 2022) [42]. This approach aligns with circular economy principles by minimizing waste and maximizing resource efficiency within the agricultural sector (Kullan *et al*., 2024 and Lu *et al*., 2025) [23, 25].

Conclusion

This comprehensive review underscores the profound economic significance and diverse applications of sericulture by-products, transcending traditional silk production to embrace principles of circular economy and sustainability. The utilization of these often-overlooked materials not only augments the profitability of the sericulture industry but also contributes significantly to environmental stewardship by reducing waste and promoting resource efficiency. The diverse array of biomaterials derived from sericultural waste, ranging from silk proteins and peptides to chitin and nutrient-rich organic fertilizers, offers compelling solutions across various sectors, including biomedicine, agriculture, and material science. Future research should focus on developing scalable and cost-effective technologies for the extraction and purification of these valuable compounds, thereby facilitating their broader industrial adoption (Habeanu *et al*., 2023) [14].

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