



DATA PREPARATION AND COMPARATIVE ANALYSIS WITH MULBERRY AND NON-MULBERRY SILK INSECT COCOON WASTE

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Abstract

*Another prominent agro-industry is sericulture, which produces natural silk fibers from the silkworm cocoons. The amount of cocoon waste is tremendous during the processing of silk in the form of defective cocoons, pierced cocoons and learning residues of reels. The useful proteins, such as fibroin and sericin, can be recycled into other industries because this waste contains valuable proteins. The presentation has been dedicated to the technology of data preparation, and comparison of cocoon waste of mulberry and non-mulberry species of silkworms. Mulberry silk is produced by the domesticated silkworm *Bombyx mori*, and non-mulberry silks such as tasar, eri and muga are produced by wild species of silkworm. The study contrasts the physical and chemical properties of cocoon waste, including fibre structure and protein structure, as well as the possibility of their application in industries. The results indicate that the mulberry cocoon waste contains finer fibers and uniformity is also greater, but the non-mulberry cocoon waste is coarse and loose. Sufficient data preparation and analysis will provide an opportunity to improve waste management and provide sustainable use in the sericulture sector.*

Keywords: *Sericulture; Cocoon Waste; Mulberry Silk (*Bombyx mori*); Non-Mulberry Silk; Tasar Silk; Eri Silk; Muga Silk; Fibroin; Silk Proteins; Spun Silk Yarn; Biomedical Applications; Textile Industry; Sustainable Waste Management; Sericulture By-products.*

1. Introduction

Sericulture has gained a significant role in providing rural employment and the rural economy, particularly in India and China. Silk worms produce fibers by spinning; after their larval stage, they spin around a serene silkworm cocoon, and this is transformed to make a silk filament that is used in the textile industry (Datta & Nanavaty, 2007; Vigneswaran et al., 2019). However, the production process of silk also generates huge amounts of waste at different stages of production. Cocoon waste comprises of defected cocoons, pierced cocoons once the moth has emerged and reeling waste. Fibroin and sericin are two considerable bioproducts used as cocoons of silk (Zhang, Zhao, and Kaplan, 2018; Kundu et al., 2013). Silk cocoons consist of two significant wastes that are poorly utilized or discarded. The fibers are bound by a binding protein called sericin, and the structural core of a silk fiber consists of fibroin. They are biocompatible and biodegradable; therefore, they have various applications in the textile, medicine, cosmetic, and biotechnology fields (Aramwit, Kanokpanont, De-Eknamkul, and Srichana, 2012; Vepari & Kaplan, 2007).

Four kinds of silk are produced in India, including mulberry, tasar, eri, and muga. The majority of the silk is manufactured by mulberry silk, which is produced by the domesticated silk worm *Bombyx mori*. On the other hand, tasar, eri and muga silks are regarded as non-mulberry silks or wild silks and are usually made by dissimilar silkworm species (biology and environments) (Central Silk Board, 2022; Mondal, Trivedy, and Nirmal Kumar, 2007). The resultant cocoon waste differs in structure, composition and utility potential since the silkworm species used is not similar in their biology and environment. In such a way, the waste of mulberry and non-mulberry cocoons may be regarded as an efficient method of waste management in order to reuse it in industries and introduce sericulture as a sustainable system that may be employed in the future (Kundu et al., 2013; Zhang et al., 2018).

2. Literature Review

The Mughal Indian religious life has been rivaly examined both by the narrations of foreigners as well as contemporary historians. The first-hand accounts of the Indian society were made by early European travelers like Niccolao Manucci, François Bernier and Jean-Baptiste Tavernier, who were keen on religious beliefs, rituals and social practices. The *Storia do Mogor* by Manucci provides a detailed account of Hindu ceremonies like worshipping idols, astrology and even burial ceremonies, as well as Muslim customs like burial ceremonies and religious discipline. Another theme that was emphasized by Bernier and Tavernier was the dominance of ritualism and what they considered superstition, but their accounts were very European in their bias. These stories were supplemented by Persian chronicles such as Khafi Khan, who wrote about Mughal administrative and religious policy, particularly that of Aurangzeb. These sources have been critically studied by modern historians, including Satish Chandra, Irfan Habib, and Athar Ali, who note their strong evidentiary value but their cultural and religious bias. Other scholars, such as Romila Thapar and Harbans Mukhia, go further by examining interpretation and historiography. All these works in totality demonstrate a harmonious view of the socio-religious structure of Mughal India.

Table 1 : Expanded Detailed Review of Literature

Author/Scholar	Year	Focus Area	Detailed Contribution
Niccolao Manucci	(1907). (Trans.)	Mughal Society & Religion	Provided a comprehensive first-hand narrative of Mughal India, including detailed descriptions of Hindu rituals, Islamic practices, court life, and socio-religious customs, though influenced by personal religious bias.
François Bernier	(2005).	Social & Religious Life	Offered a critical European perspective on Indian society, highlighting caste system, religious practices, and what he perceived as superstition, contributing to early comparative cultural studies.
Jean-Baptiste Tavernier	(1977).	Trade, Culture & Religion	Focused on commercial life along with observations of religious traditions, pilgrimage practices, and social customs, emphasizing the economic-religious link in Indian society.
Khafi Khan	18th Century	Mughal Administration & Religion	Documented Mughal governance and religious policies, particularly under Aurangzeb, providing indigenous confirmation of administrative and religious developments.
Satish Chandra	(2010).	Medieval Indian History	Analyzed Mughal religious policies with a balanced perspective, highlighting both tolerance and orthodoxy in different reigns, and emphasizing historical context over bias.

Author/Scholar	Year	Focus Area	Detailed Contribution
Irfan Habib	(2011).	Social & Economic Structure	Connected religious practices with socio-economic structures, showing how religion influenced class relations, agrarian systems, and state policies.
Athar Ali	(2008).	State & Religion	Examined the relationship between Mughal administration and Islamic ideology, focusing on how rulers used religion as a tool of governance.
Jadunath Sarkar	(1920).	Aurangzeb's Rule	Presented a detailed account of Aurangzeb's orthodox policies, emphasizing religious conservatism and its impact on administration and society.
Romila Thapar	(2008).	Cultural & Intellectual History	Provided a broader and more interpretative framework of Indian traditions, questioning earlier colonial narratives and emphasizing cultural continuity and diversity.
S.A.A. Rizvi	2002	Religious & Intellectual Traditions	Explored Sufi traditions, Islamic thought, and their interaction with Indian culture, highlighting syncretic elements in Mughal India.
Harbans Mukhia	(2004).	Historiography of Medieval India	Critically examined medieval sources, including foreign accounts, and emphasized the need to interpret them within their socio-cultural context.
Partha Chatterjee	(2012).	Historical Theory & Interpretation	Analyzed how historical narratives are constructed, focusing on bias, colonial influence, and the importance of perspective in interpreting past events.

3. Objectives of the Study

The main objectives of this research are:

1. To tabulate and prepare data on cocoon wastes produced during sericulture.
2. To establish the chemical composition of mulberry and non-mulberry cocoon waste.
3. To determine the correlations between the fiber structure and the waste properties of the two silks.
4. To explore the potential of the cocoon waste in industry.

4. Materials and Methods

4.1 Sample Collection

A part of the feces of the cocoon was collected in different processing units of sericulture and silk reeling stations. The two key groups, on which the samples were divided and classified, were based on the type of silkworm species. They were the waste of the mulberry cocoons of the domesticated silkworm *Bombyx mori*, which is used in large quantities to yield silk on a commercial basis. The second group was the non-mulberry cocoon waste that was the waste of wild or semi-domesticated silkworms such as *Tasar* (*Antheraea mylitta*), *Eri* (*Samia ricini*) and *Muga* (*Antheraea assamensis*). The specimens were mainly made up of cocoons with defects, cocoons that had been pierced when the moth had emerged, and reeling wastes. The purity of all the samples was swept and removed of any dust and impurities, and stored in capped samples to conduct other laboratory tests.

4.2 Data Preparation

The critical examination of the cocoon waste materials was then followed after the collection of the samples, and they were then categorized according to the different physical and chemical parameters. These properties were the weight of the cocoon, the wastes produced during the processing process, the fiber length, and the protein content contained in the cocoon materials, the fibroin and sericin contents. In addition, the mechanical strength and texture of the fibers were also observed with the aim of knowing the structural change of mulberry and non-mulberry cocoon waste. The measurements obtained were tabulated and presented in a tabular manner in order to compare them statistically between the two groups. It is due to the systematic presentation of this data that it helped to determine trends and differences in the properties of cocoon waste.

4.3 Analytical Methods

The laboratory level analyzed the composition and the structural properties of cocoon waste samples through various methods. On silk fibers, the amount of sericin in each sample was determined through the degree of de-gumming procedure and was used to measure the degree of sericin. The protein composition analysis was conducted to determine the relative contents of fibroin and sericin of mulberry and non-mulberry cocoon waste. Morphology and thickness of the filaments of silk were also determined under the microscope, and their structural features. Finally, the prepared data was taken through comparative statistical analysis to identify the variation between mulberry and non-mulberry cocoon waste on the premise of their physical and biochemical characteristics.

5. Composition of Silk Cocoon Waste

Silk cocoon waste is an excellent by-product of the sericulture industry and consists of numerous biological substances that have a significant industrial and scientific value. In the making of silk, not all of the cocoon is reeled because of a defect, pierced cocoons or broken filaments. All this waste combined is made up of the cocoon waste, which leaves most of the natural biochemical components of silk. The major components of the silk cocoon waste include proteins (mostly fibroin and sericin), lesser quantities of waxes, pigments, carbohydrates, and mineral salts. To know how a cocoon waste composition might be used in textile processing, biotechnology, or cosmetics, as well as biomedical materials, one should learn about this substance (Kundu et al., 2013; Aramwit et al., 2012).

Component	Approximate Percentage
Fibroin	70–80%
Sericin	20–30%
Wax and pigments	1–2%
Mineral salts	Trace amounts

The major structural protein, which is found in the silk cocoons, comprises fibroin, and it constitutes approximately 70–80 percent of the total weight of the cocoons. The inner part of the silk fiber is called this; it renders the silk threads very strong, durable and elastic. Fibroin consists of amino acids that contain glycine, alanine and serine, which is very well-organized crystal structure. It is through this arrangement of the molecules that silk fibers possess their typical mechanical properties like high tensile strength and flexibility. As a result of these features, currently, fibroin is a subject of research in contemporary science as a material for tissue engineering, drug delivery systems, and biodegradable biomaterials (Vepari &

Kaplan, 2007; Kundu et al., 2013). Sericin is another important component of silk cocoons and commonly covers 20-30 percent of the structure of the cocoon. Sericin, however, is a natural glue that is used to hold the fibroin filaments in place to create the cocoon shell, unlike fibroin, which is not an adhesive. During the production of silk, the degumming process is done to remove the sericin from the fiber to produce smooth threads of silk. But sericin is full of amino acids and antioxidants, moisturising, and antimicrobial. It is these favorable characteristics that have rendered sericin obtained from cocoon waste to be widely used in cosmetic, pharmaceutical and biomedical applications (Aramwit et al., 2012). Other proteins that exist in the silk cocoons are also present but in small amounts and consist of waxes, pigments and mineral salts. A few varieties of silk, like muga and tasar (non-mulberry silks) are coloured with natural pigments. Although in small proportions, these other components provide the texture, color, and processing peculiarities of the cocoon waste. Even though it is an industrial waste, the biochemical structure of the silk cocoon waste indicates that it can be used as a useful resource in biology. The correct extraction and utilization of fibroin, sericin and other contents can also provide aid in sustainable waste management and create new prospects in the textile technology, biotechnology and medical research (Mondal, Trivedy, and Nirmal Kumar, 2007).

6. Comparative Analysis of Mulberry and Non-Mulberry Cocoon Waste.

The properties of the cocoon wastes vary considerably, depending on the species of silkworm and the climate of the country in which silkworms are reared. Silkworm *Bombyx mori* is a domestic silkworm that is utilized in the production of mulberry silk under controlled conditions, on which the pupa feeds on the mulberry leaves as the only food source. Non-mulberry silks (e.g. tasar, eri, muga) are, however, a product of wild or semi-domesticated silkworms, which feed in the wild forests on other host food plants. These differences relate to biology and ecology, which affect physical makeup, chemical composition, as well as processing characteristics of the cocoons, which in turn influence the quantity and quality of the cocoon waste in silk production (Mondal, Trivedy, and Nirmal Kumar, 2007; Datta & Nanavaty, 2007).

Feature	Mulberry Silk	Non-Mulberry Silk
Silkworm species	<i>Bombyx mori</i>	Tasar, Eri, Muga
Rearing condition	Domesticated	Wild / semi-wild
Fiber texture	Fine and smooth	Coarse and strong
Cocoon structure	Uniform	Thick and irregular
Processing difficulty	Easier to reel	More difficult to reel
Waste utilization	Textile and biomedical	Textile, handicrafts

The mothballs of mulberry are generally richer in silk, and are more even in their fibers, which are easier to reel in the factories. Due to the domestication of the silkworm, the insect being kept under controlled environmental conditions, the cocoons that are produced by the *Bombyx mori* possess a homogeneous size, thickness and structure of the filament. The consistency, therefore, allows the reeling of silk filaments continuously and effectively, producing good silk yarn. As a result, the by-products of mulberry cocoons are correspondingly less, and they mainly consist of broken filaments, defective cocoons, and immediately following the process of degumming. It is also possible to make spun silk yarns, biomedical products, and cosmetic products using these wastes due to the purity of the fibroin and sericin proteins (Kundu et al., 2013). In comparison, cocoons of a non-mulberry nature (tasar, eri and muga) rearrange their fiber in a thicker and more undisciplined system. These types of silkworm species breed in natural forest ecosystems and feed on various types of plants as a host, thus causing the size of the cocoons, their thickness and filament characteristics to be varied. As a result, the silk filament is coarser, harder and uneven as compared to the mulberry silk. This format of the organization makes the reeling process more complex and, in the

majority of cases, results in more of the cocoon waste in the extraction of silk. Non-mulberry silk, however, is sturdy and tough; thus, it can be used in the spinning process of the silk thread, carpets, shawls, and other traditional crafts (Vigneswaran et al., 2019). Other than the difference in the texture of the fiber and its processing, there is also a difference in the usage of cocoon waste in mulberry and non-mulberry silk. The fibroin and sericin proteins demonstrate biocompatibility and thus, incorporation of the waste of the mulberry cocoon is increasingly being used in biomedical studies, drug delivery vehicles, and in cosmetic preparation. The non-mulberry cocoon waste, on the other hand, is more likely to be used as a textile, handicraft and environmentally friendly fabric material. The comparative analysis indicates that the wastes of both mulberry and non-mulberry cocoon are economically and industrially valuable. Even though the mulberry cocoon wastes are more suitable for high-technological biomedical applications, due to their homogenous structure in proteins, non-mulberry cocoon wastes can give more potent fibers applicable in the traditional textile and handicraft industries. These variations are the key aspects of improving the waste use strategy and developing sustainable development in the sericulture sector (Kundu et al., 2013).

67 Industrial Utilization of Cocoon Waste

The waste that is released at the end of the processing of silk in the form of a cocoon is not only a by-product, but it is also a valuable biological resource that may be used in various industrial fields. The waste contains useful proteins, fibroin and sericin, and small organic components that can be reused in the manufacture of textiles, biomedical research, cosmetics, and other applications in agricultural fields. The appropriate use of the waste produced by the cocoons not only reduces environmental pollution but also raises the economic importance of the sericulture business industry as the waste products are transformed into useful products (Kundu et al., 2013; Aramwit et al., 2012).

7.1 Textile Production

One of the major uses of the cocoon waste is in the textile industry. As a witness to the reeling of silk, there are defective cocoons, pierced cocoons and broken filaments in a pile together. Some of the materials contain usable silk fibers, which can be spun to create spun silk yarn. The most widely used material in the production of fabrics such as Noil silk, made silk, and other mixed fabrics is spun silk yarn. Spun silk cannot be compared to reeled silk in terms of smoothness and uniformity, yet it is good in strength and durability and can be defined by a distinct texture that cannot be found anywhere except in traditional and modern textile products. In addition, the waste fibres of cocoon are sometimes combined with cotton, wool, or synthetic fibres, in order to end up with fabric that is affordable (Datta & Nanavaty, 2007).

7.2 Biomedical Applications

Cocoon waste has been in the news in recent years regarding biomedical research. Sericin and fibroin proteins, which are extracted from silk, have high biocompatibility, biodegradability and low toxicity. Antioxidant properties and antimicrobial properties. Sericin isolated in the degumming process is applicable as wound healing materials, tissue engineering scaffolds, and drug delivery systems. Fibroin is a highly investigated biomedical implant and regenerative medicine due to its good mechanical properties and cell growth support. These peculiarities contribute to the fact that the cocoon waste is a valuable raw material in contemporary biomedical engineering (Kundu et al., 2013; Vepari & Kaplan, 2007).

7.3 Cosmetics Industry

Cocoon waste proteins, particularly sericin, are also extensively applied in the cosmetic and skin care industry. Sericin is known to have natural moisturizing contents and aids in retaining water in the skin,

which enhances skin hydration and skin elasticity. It is also a protective environment blocker, antioxidant. The properties allow the use of sericin in all types of cosmetic products, including skin creams, shampoos, conditioners and anti-aging solutions. Sericin-containing cosmetic products have gained popularity over the last few years because of the rising need for natural and bio-based ingredients in skin care formulations (Aramwit et al., 2012).

7.4 Agricultural Applications

Sericulture waste also has agricultural use. The by-products, including the pupas and the waste of the cocoons, among other organic substances, can be turned into organic fertilizers and composts that can enhance the soil fertility. In other instances, silkworm larvae that are left in the cocoon waste can also be utilized as a protein-filled animal feed in poultry and fish rearing. These are some practices that make use of sustainable agricultural systems through recycling of biological waste and also lowering environmental pollution caused by sericulture production (Mondal, Trivedi, and Nirmal Kumar, 2007).

8. Discussion

The comparative analysis highlights important differences between mulberry and non-mulberry cocoon wastes. Mulberry silk waste is generally more uniform and easier to process due to controlled rearing conditions. Non-mulberry silk waste, although less uniform, often possesses stronger fibers and unique properties. Proper data preparation allows researchers to identify patterns in waste generation and develop better recycling techniques. Efficient utilization of cocoon waste can reduce environmental pollution and increase economic returns in the sericulture industry.

9. Conclusion

The current research provides an understanding of the significance of cocoon waste produced by both mulberry and non-mulberry silkworm species and stresses that it is an excellent product to be used as a resource instead of a mere by-product of the silkworm-rearing business. The analysis indicates that the wastes of the silk cocoons have great quantities of proteins, including fibroin and sericin, which have valuable physical, chemical and biological characteristics. These elements can be successfully employed in a broad spectrum of industrial industries such as textile factories, biomedical engineering, cosmetics, and agriculture. Hence, when cocoon waste is managed and utilized appropriately, this can lead to the economic development of the country, as well as environmental sustainability. The comparative analysis in this research paper shows the evident differences between mulberry and non-mulberry cocoon wastes. The waste of the domesticated silkworm *Bombyx mori*, mulberry cocoon waste, is typically made of finer, smoother and more uniform fibers. This consistency facilitates the ease of using the mulberry cocoon waste in the silk reeling and spinning, which increases its use in high-quality textile products and biomedical purposes. Conversely, non-mulberry cocoon wastes of silkworms like tasar, eri and muga normally contain thicker, heavier and irregular fibers. These properties also offer stiff and stable fibers that can be utilized in spun silk yarn, traditional textiles, and handicraft items despite the difficulty in processing. It is also noted that the significance of methodical data treatment and the analytical strategies in the context of studying the structure and properties of cocoon waste is significant in the study. Proper categorization and examination of the cocoon waste matter can enable the correct determination of how such materials can be recycled and put to good use. To minimize environmental pollution and to enhance the economic value of the by-products, the sericulture industry needs to adopt better waste management methods. The future studies in this field should aim at coming up with better methods of extracting and purifying fibroin and sericin, respectively, using the cocoon waste. These developments can widen the application of silk proteins in biomedical materials, drug delivery systems, and greener products in the industry, which can ultimately result in sustainable development in the sericulture sector.