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Mechanization in Post-Cocoon Sector and Non-Mulberry Sericulture: Benefits, Challenges, and Future Perspectives

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Abstract

Mechanization has become an essential component of modern sericulture, particularly in the post-cocoon sector and non-mulberry silk production systems, where labour-intensive operations often limit productivity and profitability. The adoption of improved machinery for cocoon sorting, deflossing, cooking, reeling, re-reeling, spinning, twisting, winding, and weaving has significantly enhanced processing efficiency, reduced labour requirements, and improved the quality of silk products. In non-mulberry sericulture, including eri, tasar, and muga silk production, technological innovations such as improved spinning wheels, solar-operated spinning machines, cocoon sorting equipment, and motorized reeling-cum-twisting machines have increased yarn recovery, production capacity, and product quality while reducing drudgery. Mechanization has also promoted value addition, efficient resource utilization, and greater income-generating opportunities for rural communities engaged in silk production. Despite these advantages, challenges such as high capital investment, limited technical expertise, inadequate maintenance facilities, and poor access to modern technologies continue to restrict the widespread adoption of mechanized systems, particularly among small-scale producers. This article highlights the major mechanized technologies currently used in the post-cocoon and non-mulberry sectors, evaluates their impact on productivity and sustainability, and discusses the challenges and future prospects of mechanization. Wider adoption of appropriate, affordable, and environmentally sustainable technologies will be crucial for strengthening the competitiveness and long-term growth of the non-mulberry and post-cocoon sericulture industries.

Keywords: Post cocoon, non-mulberry, efficiency, mechanization, sericulture.

1. Introduction

Sericulture, the practice of cultivating silkworms for silk production, is one of the oldest agro-based industries in the world. Historical records indicate that silk production originated in ancient China around 2700 BCE before gradually spreading to countries such as India, Japan, Korea, and later to Europe and the Americas (Bharathi et al., 2023; Parthiban et al., 2021). Traditionally, the industry depended on manual operations, including mulberry cultivation, silkworm rearing, cocoon harvesting, and silk reeling. Although these conventional methods have sustained silk production for centuries, they are often labour-intensive, time-consuming, and susceptible to problems related to disease management, inconsistent product quality, and rising production costs (Bharathi et al., 2024). The introduction of mechanization during the twentieth and twenty-first centuries has transformed sericulture by improving operational efficiency, reducing dependence on manual labour, and enhancing productivity (Savithri et al., 2013).

In India, agriculture continues to be dominated by small and marginal farmers, making technological advancement an essential requirement for sustainable growth. Modernization of sericulture through the adoption of appropriate machinery and improved production technologies has become increasingly important for enhancing the productivity and profitability of these farming systems (Bindroo and Kishur, 2011). Integrating mechanization with traditional sericultural practices can strengthen the connection between smallholders and modern production systems, thereby increasing farm efficiency and ensuring sustainable rural development (Luo, 2020).

The promotion of mechanized sericulture also aligns with India's broader rural development objectives by improving farmers' incomes, reducing labour constraints, and encouraging technological adoption. Higher operational efficiency not only increases the profitability of sericulture but also motivates farmers to continue silk production while improving the quality and competitiveness of the industry (Liu et al., 2021). Several studies have demonstrated that greater mechanization positively influences production efficiency, economic returns, and farmers' income in both mulberry and post-cocoon sectors (Mohandas et al., 2010; Nikhade and Gunaki, 2020). Similar benefits have been reported across agricultural enterprises, where mechanization contributes to higher productivity, reduced production costs, and improved resource-use efficiency (Lakshmi, 2015).

Sericulture is a highly time-sensitive farming enterprise in which mulberry gardens are repeatedly pruned and managed to produce five or six leaf harvests annually (Srinivas et al., 2019). Each crop cycle, extending approximately 60–65 days, involves a series of critical operations such as pruning, intercultural practices, leaf harvesting, application of disinfectants, mounting mature larvae, and cocoon harvesting. Delays in any of these activities can adversely affect silkworm growth, cocoon quality, and overall silk yield (Bharathi et al., 2022; Dandin and Verma, 2002). The availability of sufficient labour during peak operational periods has become a major challenge, particularly on large sericulture farms (Jiang and Zhang, 2017). Therefore, improving labour productivity through the adoption of suitable farm tools, machinery, and mechanized technologies has become essential for ensuring timely operations, minimizing labour shortages, and enhancing the overall efficiency and sustainability of the sericulture industry (Gunasheela et al., 2018; Mohandas et al., 2010).

2. Key Technological Advancements

2.1 Mechanization in Mulberry Cultivation

The adoption of mechanized technologies in mulberry cultivation has significantly improved the efficiency of field operations. Modern equipment such as power-operated planters, weeders, intercultural implements, and leaf harvesters reduces labour requirements while ensuring timely completion of agricultural activities. Automated leaf harvesting machines enable rapid cutting and collection of mulberry leaves with minimal human effort, ensuring a continuous and adequate supply of fresh foliage for silkworm feeding. These innovations also improve field productivity and reduce operational costs.

2.2 Mechanization of Silkworm Rearing

Silkworm rearing has benefited considerably from technological innovations designed to create an ideal rearing environment. Controlled environmental systems regulate temperature, relative humidity, and ventilation to maintain favourable conditions throughout the silkworm life cycle. Automated feeding devices further improve rearing efficiency by supplying mulberry leaves uniformly and at appropriate intervals. Such technologies enhance larval health, reduce mortality, and contribute to improved cocoon yield and quality.

2.3 Mechanized Cocoon Harvesting and Processing

Technological developments have modernized cocoon harvesting and post-cocoon processing operations. Automatic reeling machines efficiently extract silk filaments from cocoons with greater speed and accuracy than conventional manual methods. These machines minimize labour dependency, improve raw silk quality, increase reeling efficiency, and reduce processing time, ultimately enhancing the productivity of the silk industry (Kherkatary and Daimari, 2017).

2.4 Quality Monitoring and Process Control

Advanced monitoring systems equipped with sensors and digital technologies are increasingly used to supervise silkworm rearing conditions. These systems continuously monitor environmental parameters such as temperature, humidity, and air circulation, allowing immediate corrective measures whenever deviations occur. The integration of data analytics and real-time monitoring supports consistent cocoon quality, reduces production risks, and improves overall farm management efficiency (Hoque and Hasmi, 2017).

2.5 Mechanization of Silk Spinning and Weaving

Mechanization has also transformed silk spinning and weaving operations in the textile sector. Automated spinning machines produce silk yarn with greater uniformity, strength, and consistency, while modern power looms facilitate faster and more efficient fabric production. These technological advancements improve product quality, enhance manufacturing efficiency, and enable the silk industry to meet increasing domestic and international market demand.

3. Mechanization in the Post-Cocoon Sector

3.1 Cocoon Sorting Table

Cocoon sorting is an important post-cocoon operation carried out to separate healthy cocoons from defective ones before reeling. Conventional sorting is performed through visual inspection, whereas advanced Japanese cocoon sorting machines employ fluorescent lighting beneath a glass platform to detect both external and internal defects. The equipment also classifies cocoons according to their size, ensuring uniformity during reeling. A cocoon sorting table generally costs around □15,000 and has an operational capacity of approximately 20–30 kg of cocoons per hour.

3.2 Cocoon Deflossing Machine

Before reeling, the loose outer silk layer (floss), which cannot be reeled into filament, must be removed. To simplify this operation, the Central Sericultural Research and Training Institute (CSR&TI), Mysuru, developed hand-operated deflossing machines suitable for small-scale farmers, while motorized models are available for medium- and large-scale enterprises. These machines considerably reduce labour requirements and improve processing speed. The approximate price ranges from □15,000 to □25,000. Manual units process about 15–20 kg of cocoons per hour, whereas motorized machines can handle approximately 30–40 kg per hour (Dar et al., 2017).

3.3 Post-Cocoon Processing Equipment

3.3.1 Electrical Hot Air Dryer

The electrical hot air dryer is widely used for stifling and drying cocoons, pupae, and silk waste before storage or processing. It is available in different capacities, including 20, 30, 50, 75, and 100 kg, making it suitable for both small- and large-scale silk enterprises.

3.3.2 Epprovette

The Epprovette is a specialized device used to reel small silk hanks of a standard length for denier determination. It is also suitable for single-cocoon reeling and features a reel with an accurately calibrated circumference of 1.125 m to ensure precise filament measurement.

3.3.3 Weighing Balance

Precision weighing balances are used to determine the weight of cocoons, cocoon shells, and silk filaments. Accurate weight measurement is essential for quality evaluation and research purposes.

3.3.4 Cocoon Cooking Unit

The cocoon cooking unit softens the sericin layer surrounding silk filaments before reeling. Proper cooking facilitates easy identification of filament ends and improves reeling efficiency while minimizing filament breakage.

3.4 Power-Operated Reeling Machines

3.4.1 Sitting-Type Cottage Basin Reeling Machine

The sitting-type cottage basin reeling machine is available in both manually operated and motorized versions. Although the motorized model increases productivity, the absence of a stop-motion mechanism may result in irregular winding speed, which can adversely affect the quality of raw silk.

3.4.2 Multi-End Reeling Machine

The multi-end reeling machine enhances silk quality by increasing the number of filaments reeled simultaneously from each basin. Commonly referred to as the standing-type reeling machine, it produces nearly 800 g of raw silk per basin per day. Small units generally contain 20–40 ends, whereas larger commercial models may accommodate up to 200 ends.

3.4.3 Automatic Reeling Machine

Automatic reeling machines perform several operations, including cocoon feeding, filament picking, grouping, and separation, with minimal manual intervention. They can produce approximately 800–1000 g of raw silk per basin daily and are equipped with around 400 ends. However, operators are still required to rectify filament breakages and other operational issues during reeling.

3.4.4 Reel Permeation Chamber

The reel permeation chamber is designed to soak and moisten raw silk wound on small reels before the re-reeling process. It accommodates up to 20 reels simultaneously and measures approximately 1.54 m × 1.09 m. The chamber operates efficiently using a single-phase motor of 0.5 HP.

3.4.5 Closed-Type Re-Reeling Machine

This machine transfers silk from small reels onto larger reels with a circumference of about 1.5 m. It is manufactured in configurations containing four, six, or eight winding windows and is powered by a three-phase, 1 HP electric motor. The machine improves winding quality and facilitates easier handling during subsequent textile processing.

3.5 Winding Machine

The winding machine is used to transfer raw silk from hanks onto bobbins for further processing. It ensures smooth winding, minimizes thread damage, and prepares silk yarn for twisting and weaving operations.

3.6 Doubling Machine

A doubling machine combines two or more silk yarns into a single strand by winding them together onto one bobbin. This process enhances yarn strength, uniformity, and suitability for fabric production.

3.7 Twisting Machine

Twisting machines impart controlled spiral twists to raw silk yarn, improving its tensile strength, elasticity, and surface appearance. Twisted silk yarn is widely used in the manufacture of high-quality silk fabrics.

3.8 Long Skein Book Making Machine

The long skein book making machine is designed for packaging silk skeins into neatly arranged bundles weighing up to 5 kg. With dimensions of approximately 0.9 m × 0.35 m, the machine facilitates efficient handling, storage, transportation, and marketing of finished silk products.

4. Mechanization in Non-Mulberry Sericulture

4.1 Mechanization in Eri Cocoon Spinning

4.1.1 Takli Spinning

Takli spinning is one of the traditional methods used for producing Eri silk yarn. The device consists of a spindle attached to a circular disc at its base. During spinning, the operator holds the processed cocoon in one hand while manually drawing the fibre and rotating the spindle to twist and wind the yarn. Although simple and inexpensive, this method has low productivity, yielding approximately 40–50 g of yarn per person per day (Dandin and Verma, 2002).

4.1.2 Improved Spinning Wheel

To overcome the limitations of the traditional Takli, the Central Silk Technological Research Institute (CSTRI) developed an improved spinning wheel. This equipment enhances spinning efficiency, producing nearly 120–150 g of yarn per person per day while achieving a cocoon shell recovery of about 70–80%. The improved design reduces manual effort and produces yarn of better quality.

4.1.3 Solar-Operated Eri Spinning Machine

The solar-operated Eri spinning machine, developed by CSTRI, utilizes renewable energy for yarn production. It has a production capacity of approximately 400–500 g of yarn per operator per day and is available at an estimated cost of Rs.60,000. The machine is particularly suitable for rural areas where access to conventional electricity may be limited.

4.2 Mechanization in Tasar and Muga Cocoon Processing

4.2.1 Tasar Cocoon Sorting Machine

The Tasar cocoon sorting machine has been designed to classify cocoons accurately into A, B, and C grades. It is capable of sorting around 40,000–50,000 cocoons per hour with an accuracy of nearly 99%, offering a significant improvement over manual grading in terms of speed, consistency, and labour efficiency.

4.2.2 Open Pan Cooking Method

CSTRI has standardized an improved open pan cooking technique for Tasar cocoons using a combination of hydrogen peroxide and soda ash. This method softens the cocoons effectively, resulting in improved filament strength and elongation. It is particularly suitable for wet reeling operations and contributes to better silk quality.

4.2.3 CSTRI Two-in-One Reeling-cum-Twisting Machine

The CSTRI Two-in-One Reeling-cum-Twisting Machine performs both reeling and twisting simultaneously, thereby reducing processing time and labour requirements. The machine produces approximately 350 g of silk yarn during an 8-hour working day and provides 7–12 twists per inch. It is suitable for both dry and wet reeling and is capable of producing fine-denier silk yarn. The controls are ergonomically positioned, allowing convenient operation from a seated position.

4.2.4 CSTRI Motorized Reeling-cum-Twisting Machine

This motorized machine combines the operations of silk reeling and twisting into a single unit. It has a production capacity of around 250 g of silk yarn in an 8-hour shift and imparts 5–9 twists per inch. The equipment is compatible with both dry and wet reeling techniques for Tasar silk and can also be used, on a limited scale, for preparing warp yarn.

4.2.5 CSTRI Solar-Operated Spinning Machine

The CSTRI solar-powered spinning machine is an eco-friendly and energy-efficient technology designed to simplify silk spinning. Its lightweight construction and ball-bearing-mounted flyer reduce physical effort, making the machine particularly suitable for women, elderly workers, and differently abled individuals. The use of solar energy also lowers operating costs and promotes sustainable silk production.

4.2.6 CSTRI Permeation Chamber for Silk Sizing

The CSTRI permeation chamber is used for sizing Tasar and Muga warp yarns before weaving. The sizing process enhances fibre cohesion, increases yarn strength, and improves elongation properties, thereby producing yarn that is more durable and suitable for high-quality weaving applications.

5. Weaving Machines

A. Handloom

A handloom is a manually operated weaving device used to manufacture fabrics without the use of electricity or mechanical power. It has been employed for centuries to produce a wide variety of textiles, ranging from simple fabrics to highly intricate artistic designs. Although originally developed to satisfy basic clothing needs, handlooms are now widely recognized for producing premium-quality and handcrafted textiles with unique patterns. The continued growth of the textile and handicraft sectors has sustained the demand for skilled handloom artisans (Attri et al., 2024).

B. Power Loom

A power loom is a mechanized weaving machine driven by electric motors or steam power that enables the rapid production of woven fabrics. Compared with traditional handlooms, power looms operate at much higher speeds, substantially increasing production efficiency and reducing labour requirements. These machines are capable of producing large quantities of fabric within a short period, making them indispensable in the modern textile industry. However, despite their high productivity, power looms have relatively limited flexibility for producing complex artistic designs when compared with handloom weaving.

6. Benefits of Mechanization in Sericulture

a. Improved Operational Efficiency and Productivity

Mechanization enhances the efficiency of sericultural operations by accelerating activities such as mulberry cultivation, silkworm rearing, cocoon harvesting, and post-cocoon processing. Modern equipment ensures timely completion of farm operations, reduces delays, and improves the consistency of production. Mechanized leaf harvesters, for example, collect mulberry foliage more rapidly than manual methods, ensuring an uninterrupted supply of fresh leaves for silkworm feeding and contributing to higher cocoon productivity (Chauchan et al., 2015).

b. Reduced Labour Requirement and Production Cost

Sericulture traditionally depends on intensive manual labour, making production costly and time-consuming. The adoption of mechanized equipment decreases dependence on human labour, lowers production expenses, and addresses labour shortages, particularly in regions where skilled workers are difficult to obtain or labour wages are high. Consequently, mechanization improves the economic viability of sericulture enterprises (Attri et al., 2024).

c. Better Quality Control

Modern mechanized systems enable precise regulation of environmental factors such as temperature, humidity, and ventilation throughout the silkworm rearing period. Maintaining optimal environmental conditions minimizes stress on silkworms, promotes uniform larval growth, and improves cocoon and raw silk quality. Automated systems also reduce variations caused by manual management practices, resulting in more consistent silk production (Bhattachariya et al., 2020).

d. Effective Disease Monitoring and Management

Advanced mechanization supports early detection and effective management of silkworm diseases through the use of automated monitoring devices and environmental sensors. These technologies continuously assess rearing conditions and provide early warnings whenever unfavorable changes occur. Timely corrective measures help reduce disease incidence, minimize production losses, and improve the overall health of silkworm crops (Barcelos et al., 2021).

e. Efficient Utilization of Resources

Mechanized technologies contribute to the sustainable use of essential production resources, including irrigation water, fertilizers, energy, and other agricultural inputs. Automated irrigation and precision farming systems supply water according to crop requirements, reducing wastage and improving water-use efficiency. Similarly, energy-efficient machines minimize power consumption while maintaining high production standards, thereby supporting environmentally sustainable sericulture (Savithri et al., 2013).

7. Challenges of Mechanization in Sericulture

1. High Capital Investment

One of the major constraints in adopting mechanization is the substantial initial investment required for purchasing modern equipment and related technologies. Small and marginal sericulture farmers often face financial limitations, making it difficult to afford advanced machinery. In addition to the purchase cost, expenses associated with installation, operation, and maintenance further restrict the widespread adoption of mechanized technologies (Chauhan and Taval, 2017).

2. Requirement for Technical Skills and Training

The effective use of mechanized equipment depends on the availability of skilled operators and adequate technical knowledge. Farmers and workers must receive proper training on machine operation, routine maintenance, and troubleshooting to achieve optimum performance. In many rural areas, limited access to training facilities and extension services remains a significant obstacle to successful mechanization (Dar et al., 2017).

3. Maintenance and Service Constraints

Mechanized systems require regular servicing, timely repairs, and the availability of spare parts to ensure uninterrupted operation. In remote sericulture regions, inadequate repair facilities and limited access to technical support can result in prolonged machine downtime and increased maintenance costs. These challenges may reduce the efficiency and economic benefits of mechanization (Dewagan, 2018).

4. Suitability under Diverse Local Conditions

Most agricultural machines are developed for specific production environments and may not perform equally well under varying agro-climatic conditions. Differences in climate, soil characteristics, farm size, topography, and pest incidence across sericulture-growing regions often require modifications or customization of machinery. Therefore, locally adaptable technologies are essential for maximizing the effectiveness of mechanization (Gowda et al., 2011).

5. Environmental and Sustainability Concerns

Although mechanization enhances productivity and operational efficiency, excessive or inappropriate use of machinery may increase energy consumption and contribute to environmental degradation. Sustainable mechanization practices, including the adoption of energy-efficient equipment, renewable energy sources, and eco-friendly production methods, are necessary to minimize environmental impacts while maintaining long-term productivity and resource conservation (Nikade and Gunaki, 2020).

8. Conclusion

Mechanization has emerged as a transformative approach for improving the efficiency, productivity, and sustainability of the sericulture industry. The integration of modern technologies across mulberry cultivation, silkworm rearing, post-cocoon processing, and weaving has reduced labour dependence, enhanced operational precision, improved silk quality, and increased overall profitability. These technological interventions enable timely farm operations, efficient utilization of inputs, and better management of production resources, thereby strengthening the competitiveness of the silk sector.

Despite these advantages, several challenges continue to hinder the widespread adoption of mechanization, particularly among small and marginal sericulture farmers. High capital investment, inadequate technical training, limited access to repair and maintenance services, and the predominance of small, fragmented, and rain-fed holdings remain major constraints. Addressing these issues through financial assistance, capacity-building programmes, technology transfer, and improved extension services is essential for accelerating the adoption of mechanized practices.

Future growth of the sericulture sector will depend on the effective integration of modern farm machinery with renewable energy technologies, efficient irrigation systems, and precision farming techniques. Expanding the use of tractors, power tillers, electric motors, and other mechanized equipment can further improve cropping intensity, optimize resource utilization, and enhance farm productivity. Increased availability of irrigation and agricultural electricity will also support more intensive and profitable mulberry cultivation.

Overall, mechanization represents a key driver for the modernization of sericulture. With appropriate policy support, technological innovation, and farmer-friendly interventions, it can contribute significantly to sustainable silk production, higher rural incomes, employment generation, and the long-term development of the sericulture industry.

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