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Veenita MK
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Nikita Kankanawadi
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Tejaswini AS
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Kaveri Aramani
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Chethan MN
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Gagana Sindhu S
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Corresponding Author:
Veenita MK
Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka, India

Artificial Intelligence on Sericulture

Veenita MK, Nikita Kankanawadi, Tejaswini AS, Kaveri Aramani, Chethan MN and Gagana Sindhu S

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Abstract
Artificial Intelligence (AI) is revolutionizing sericulture, the cultivation of silkworms for silk production, by addressing key challenges and enhancing efficiency, productivity, and sustainability. This document explores the diverse applications of AI in sericulture, including automated disease detection in silkworms, precision feeding, and environmental control in rearing houses. Al-powered image processing and machine learning models enable early identification of diseases like flacherie and muscardine, reducing crop losses. IoT-integrated systems monitor and optimize environmental conditions such as temperature and humidity, ensuring optimal silkworm growth. Predictive analytics forecast silkworm development and yield, aiding in better resource allocation. AI also enhances mulberry plantation management through drone-based surveillance and nutrient analysis, improving leaf quality for silkworm nutrition. Additionally, robotics and automation streamline silk processing, from reeling to weaving, ensuring high-quality output. Al-driven pest management systems detect and control infestations, reducing chemical use and promoting eco-friendly practices. These advancements not only reduce labor dependency but also improve silk quality and yield, making sericulture more sustainable and economically viable. As AI technology evolves, its integration into sericulture promises to further modernize the industry, ensuring resilience against environmental and market challenges.

Keywords: Diseases, precision feeding, silkworms, silk production, silk processing etc

Introduction
The English word "Sericulture" came from the Greek word "Sericos", meaning silk and English word “culture” *i.e.* rearing, which entails the complete process of cultivating silkworms, growing their food plants, and producing silk (Chaturvedi, 2018) [1]. This agro-industry is economically beneficial and integrates various activities that have a profound impact on the economic prosperity of rural areas. Sericulture merges agricultural activities like silkworm rearing and food plant cultivation with industrial methods for silk production, which includes breeding silkworms to obtain eggs and cocoons.

In India, sericulture *i.e.* the rearing of silkworms and subsequent production of silk fiber, has become a promising rural industry. This is attributed to its short gestation period, low initial costs, significant employment opportunities, and high potential for returns on investment. Over the course of time, this industry is evolving to meet the demands of the market, new advances in technology, and concerns for the environment. (Sut *et al*., 2024) [24].

Sericulture has been a cornerstone of the textile enterprise for hundreds of years. However, traditional sericulture techniques are hard work in depth. It is useless and quite dependent on environmental and biological conditions. Temperature changes Irregular feeding schedules and disorder outbreaks may have a huge impact at the fitness of silkworms. Reduce productivity and fine? In a modern technological era, integrating modern innovations like Artificial Intelligence (AI) and the Internet of Things (IoT) into sericulture offers transformative potential. These technologies provide precision, real-time monitoring, and adaptive decision-making, which can significantly improve the efficiency and reliability of silkworm rearing. By using AI and IoT, this project aims to address the key challenges faced by traditional sericulture practices and redefine the industry's operational standards. This project is an AI-powered sericulture automation system for optimal sericulture. Addressing the challenges faced by traditional sericulture by developing intelligent automation solutions.

Need for modernization and digital transformation in sericulture

The key to progress is modernization. Unquestionably, the modern world is digital, and technological advancements are accelerating past any other revolutions in our history. The use of agricultural technologies continues to developing in India and aimed at improving the lives of farmers. Technology's influence will serve as a gateway to a new era in sericulture.

Indian sericulture is highly traditional, has been overlooked for a long time, and has been carried out for many generations with little in the way of technological advancement. India comes in second rank after China in the manufacturing of silk. Sericulture offers numerous job prospects and encompasses a wide range of tasks, both on and off the farm. The sequence of events necessitates regular observation and expert labour.

Abiotic and biotic variables, such as temperature, humidity, seasons, leaf quality, silkworm race, and hygiene, all affect the success of a cocoon harvest. The fate of the cocoon crop is determined by all of these factors taken together, but particularly by temperature and humidity. The seasonal changes in environmental elements such as The genotypic composition is influenced by temperature and humidity, and this is reflected in commercial characteristics such as shell weight, cocoon weight, and shell ratio percentage (Rahmathulla, 2012) [15].

The frequency of disease in silkworms is significantly influenced by environmental conditions, which leads to loss of crops. Because they live indoors, mulberry and eri silkworms can withstand the fluctuations of nature, but tasar and muga are uncontrollable.

By using digital technology, production may be further enhanced and the gap can be overcome. Artificial Intelligence (AI), the Internet of Things (IoT), image processing systems, and other computer-based technologies will undoubtedly improve the quality of the produce when used in the right combination. Data is the fundamental component of databases, maps, and models created in sericulture using Geographic Information Systems (GIS), another subset of computer information systems (Chaturvedi, 2018) [1].

The raw silk production statistics for the year of 2023-2024 was 38913 MT while there was a decrease in the production statistics for the year of 2024-2025 *i.e.* 18,355 MT (Source: CSB, Bengaluru). Although modern techniques exist, many farmers lack access to high-yield mulberry varieties and superior bivoltine silkworm breeds

These days, the industrial process of making silk is evolving as a result of the incorporation of cutting-edge technologies including big data, cloud computing, artificial intelligence (AI), and the Internet of Things (IoT). Unquestionably, the main prerequisite for sericulture is the use of wholesome and nutrient-dense food plants in order to maximize output capacity. Improvements to food plants include effective nutrition management, defense against pests and illnesses, etc.

In this case, artificial intelligence (AI) offers one of the most appealing technologies, namely disease detection through machine learning algorithms like support vector machines and convolutional neural networks, which show remarkable proficiency in classifying images of plants and their leaves to detect visual signs of disease. The manual inspection process takes a lot of time, and one of the limiting variables is human mistake. Thus, the application of AI greatly increases accuracy while cutting down on time (Vijayareddy *et al*., 2023) [28]

The use of CNN and other Deep Learning techniques for disease and pest detection is additionally growing common in the agricultural industry. On the other hand, having access to healthy seed production is also very important. Small objects, such as silkworm eggs, are difficult to hand count when they overlap or occur in high quantities, which can result in mistakes and take a lot of time. Because manual approaches are inaccurate and inefficient, computer vision must be used instead. (Liu *et al*., 2023) [12].

Key applications of AI in sericulture include

- **Environmental Control and Automation**

AI-driven systems and IoT sensors can monitor and automatically adjust temperature, humidity, and other environmental factors crucial for optimal silkworm development in rearing chambers, ensuring consistent and high-quality growth.

- **Disease Detection and Prevention**

AI algorithms, especially those utilizing image processing and machine learning, can identify diseases in silkworms and mulberry plants early on, enabling timely interventions and reducing crop failure.

- **Silkworm and Egg Management**

AI models can be trained to predict the hatching status of silkworm eggs and count them accurately through image analysis, improving seed quality and management.

- **Quality Control and Optimization**

AI powered by computer inspection and machine learning algorithms can analyze silk quality for better texture and sustainability, even predicting the class of silkworm eggs for optimal hatching.

- **Precision Mulberry Cultivation**

In conjunction with drone technology, AI can optimize resource management, including pest control, irrigation, and fertilization, for mulberry fields, leading to increased leaf yield.

- **Potential for Advanced Applications**

Future applications of AI in sericulture include the potential to enhance the production of specialized silks and even genetically modified silkworms that produce hybrid silk fibres with unique properties, according to a research article.

Artificial intelligence is a highly advanced branch of computer science that creates computers with perception, action, data processing, storage, and judgment that are on par with or even more intelligent than humans. Artificial intelligence is a brain-like system that uses data from several sensor networks to determine what needs to be done in a certain region.

AI based monitoring of mulberry plantation

Artificial Intelligence (AI) is transforming the monitoring and management of mulberry plantations, essential for sustainable sericulture. Al-powered remote sensing and machine learning models help analyze soil health, detect nutrient deficiencies, and predict irrigation needs, ensuring optimal mulberry growth (Sharma and Patel, 2021) [19]. Drone-based AI surveillance enables real-time monitoring of plantation health, identifying pest infestations and diseases early for timely intervention (Kumar *et al*., 2022) [11]. Computer vision techniques assess leaf quality, allowing automated sorting and classification to enhance silkworm nutrition (Gupta and Rao, 2020) [7].

AI-integrated IoT sensors track environmental conditions such as temperature, humidity, and soil moisture, ensuring precise

farming practices (Verma and Singh, 2019) [21]. These innovations not only increase yield but also promote eco-friendly farming by reducing chemical inputs. As AI technology advances, its role in precision agriculture for mulberry plantations will further optimize productivity, reduce labor dependency, and improve sustainability in sericulture.

Precision Feeding and Nutrition Optimization in Sericulture

Precision feeding and nutrition optimization play a vital role in improving silkworm growth, cocoon quality and silk yield. Traditional feeding methods often result in inefficiencies and inconsistent outcomes, but Al-driven solutions are transforming the sericulture industry. Al-based predictive models analyze environmental conditions, such as temperature and humidity, to determine the optimal feeding schedule for silkworms, ensuring better nutrient absorption and growth (Sharma and Gupta, 2021) [8]. Machine learning techniques assess mulberry leaf quality by detecting variations in nutrient composition, helping farmers select the most nutritious leaves for silkworms. IoT-integrated automated feeding systems further enhance precision by tracking silkworm consumption patterns and adjusting leaf supply accordingly, reducing waste and ensuring optimal nutrition (Singh and Patel, 2019) [13]. Additionally, Al-powered nutritional assessment tools detect deficiencies in silkworm diets and suggest dietary modifications to enhance silk quality and yield.

These innovations improve efficiency, reduce costs and contribute to sustainable silk production by minimizing resource wastage. Furthermore, precision feeding techniques help mitigate the risks associated with overfeeding or underfeeding, technology advances, smart sericulture will play a key role in ensuring higher yields and better-quality silk in a sustainable and cost-effective manner.

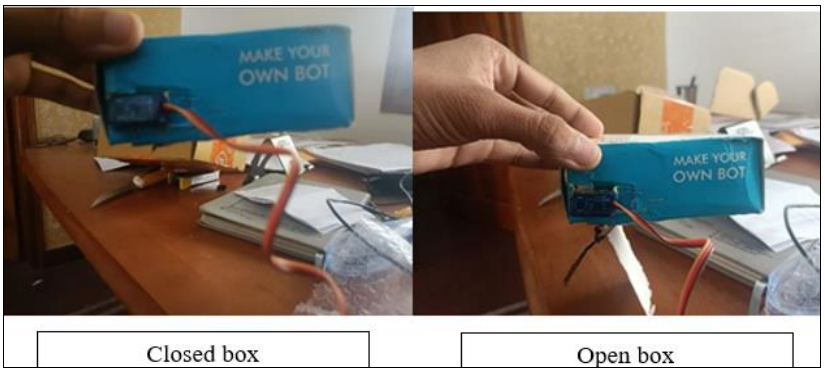

Fig 1: Silkworm Feeding

The Fig 1: Shows a servo motor-controlled box designed for automated operations, such as feeding mulberry leaves in sericulture. In the closed state, the box securely holds the contents, while in the open state, the lid is lifted to dispense materials. This mechanism can be integrated with a microcontroller like Raspberry Pi to automate feeding schedules. It helps reduce manual labour and ensures timely, hygienic and consistent feeding for silkworms.

Predictive analytics for silkworm growth and yield

Predictive analytics is transforming silkworm rearing by enabling accurate forecasting of growth patterns, cocoon yield and disease risks. Al-driven predictive models analyze multiple factors such as temperature, humidity, feed intake and silkworm behavior to optimize rearing conditions and improve productivity (Sharma and Verma, 2021) [20]. These models use historical data and real-time inputs from IoT sensors to provide precise growth predictions, helping sericulturists make data-driven decisions (Gupta *et al*., 2022) [8]. Machine learning algorithms detect early signs of abnormalities in silkworm development, allowing farmers to take preventive measures against diseases and environmental stressors (Kumar and Rao, 2020) [9]. Additionally, Al-powered analytics optimize feeding schedules based on predicted silkworm nutritional needs, ensuring improved silk quality and higher yield (Patel and Singh, 2019) [13]. Cloud-based predictive platforms further assist in monitoring large-scale sericulture farms, providing actionable insights to enhance productivity. By integrating predictive analytics into sericulture, farmers can minimize losses, enhance yield consistency, and improve resource efficiency. Future advancements in AI and big data analytics will refine these predictive models, making sericulture more sustainable and economically viable. The adoption of predictive analytics in silkworm farming represents a significant step toward precision sericulture, ensuring improved production outcomes and reduced dependency on manual expertise.

AI- powered pest and disease management

Artificial Intelligence (AI) is transforming pest and disease management in sericulture by enabling early detection, real-time monitoring and precise intervention strategies. Silkworm diseases such as grasserie, flacherie, muscardine and pebrine significantly impact silk production, while pests like uzi flies and dermestid beetles cause substantial economic losses. Al-powered image processing and deep learning models analyze silkworm health through microscopic images, allowing early disease identification and reducing outbreaks (Sharma and Verma, 2021) [20]. Machine learning (ML) algorithms process environmental and biological data to predict disease outbreaks, helping sericulturists implement preventive measures.

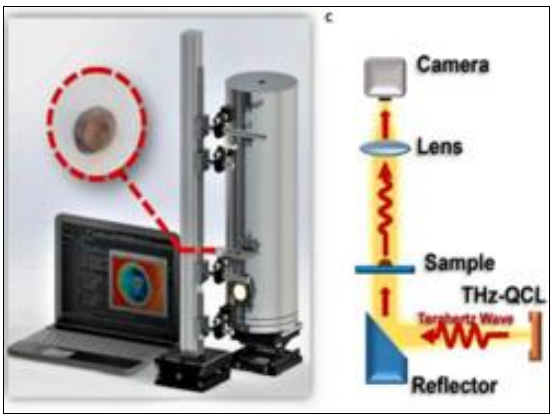

Fig 2: THz QCL video imaging system

Fig 2: Illusatrates for an example of an AI model based on image processing is a model designed with You Only Look Once (YOLO) algorithm that can effectively classify leaf disease and detect the disease for further treatment

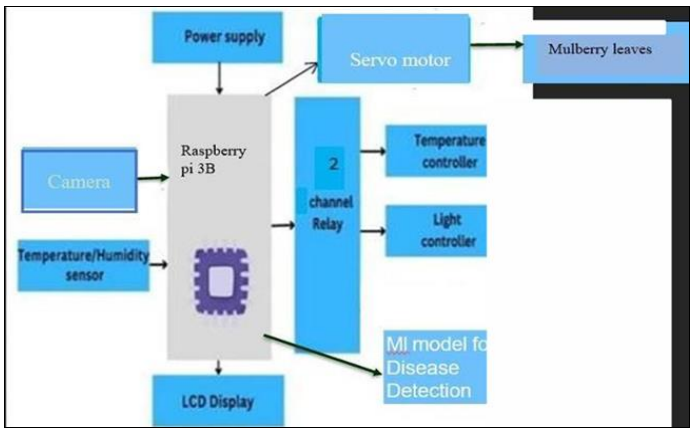

Fig 3: System architecture Diagram

The Fig 3: illustrates a smart sericulture system that integrates Artificial Intelligence (AI) and Internet of Things (IoT) technologies using a Raspberry Pi 3B microcontroller as the central processing unit. This system is designed to automate and monitor key aspects of silkworm rearing and mulberry leaf management. Environmental parameters such as temperature and humidity are continuously monitored using appropriate sensors, and real-time data is processed by the Raspberry Pi. A camera captures images of the mulberry leaves and silkworm environment, which are analyzed by an inbuilt machine learning (ML) model to detect diseases, ensuring early intervention and better health management. A 2-channel relay controls both the temperature and light conditions through respective controllers to maintain an optimal environment. Additionally, a servo motor mechanism is connected to automate the feeding of mulberry leaves based on system commands. The LCD display provides real-time visualization of sensor data and system status. Overall, this integrated setup significantly enhances productivity, reduces labour, minimizes disease outbreaks, and modernizes traditional sericulture through precise, data-driven automation.

Al-integrated IoT sensors monitor temperature, humidity, and air quality in rearing houses, maintaining optimal conditions to minimize pest infestations (Gupta and Rao, 2020) [7]. Drone-based AI surveillance further enhances pest detection by scanning mulberry plantations and identifying affected areas, enabling targeted pesticide application and reducing chemical overuse (Patel and Singh, 2019) [14]. AI-driven advisory systems assist farmers in selecting eco-friendly pest control measures, improving sustainability in sericulture. Automated tracking of silkworm growth patterns ensures healthier larvae, leading to better cocoon yield and silk quality. By integrating AI and big data analytics, sericulture can become more resilient to climate changes and emerging disease threats. As AI technology advances, its role in pest and disease management will continue to evolve, providing sericulturists with cost-effective, data-driven solutions for improving productivity. The adoption of AI in sericulture ensures a sustainable and efficient silk production system while reducing losses caused by pests and diseases.

AI-Powered Genetic Analysis-Enhancing Silkworm Breeding for Quality and Productivity

Through genetic analysis and machine learning algorithms, AI can assist in identifying specific genes associated with desirable traits in silkworms, such as silk quality, cocoon size and disease resistance. This information is crucial for targeted breeding programs. AI can predict the outcomes of different breeding combinations, helping Sericulturists select parent pairs to produce offspring with the desired characteristics. This accelerates the development of superior silkworm strains, leading to better silk quality and overall productivity (Sonal *et al*., 2024) [22].

Artificial Intelligence in Silkworm Seed Production

Silkworm seeds can be hibernating or non-hibernating, sensitive to light and vibration. Some of the crucial information about eggs like date of oviposition, probable date of hatching, hibernating or non-hibernating, free from any disease or not are mandatory to provide along with the eggs being transported for proper planning for rearing. Sometimes, the eggs are induced with hibernation artificially or break the hibernation artificially for the rearing to coincide with availability of feeding. For these to achieve, artificial intelligence helps obtain the developmental stage of the embryo in a Non-destructive manner. Experimentations regarding recognition of the developmental stages of an embryo inside egg shell was done using terahertz imaging technology, where the terahertz images from 8 days prior to hatching are fused with optical images of same duration to get accurate results of the developmental stage of the embryo. This model not only resulted in THz images but also less time consuming with high recognition accuracy (Xiong *et al*.,2021) [29].

This helps in predicting date and time of hatching, hibernation period, initiation and termination period of hibernation etc. A method was suggested to detect, count, and classify silkworm eggs using modern computer vision techniques like Image processing, Machine learning, and Deep learning. Image processing algorithms such as SSD, RCNN, and Yolo v3 were utilized, along with Machine learning methods like ANN, KNN, and SVM, and Deep learning models such as VGG16, ResNet50 and InceptionV3. The method is structured into four main steps: input images, pre-processing, segmentation and counting (Pavitra *et al*., 2022) [30].

Artificial Intelligence in Silkworm Gender Classification

Silkworm gender can be visually classified during larval, pupal and adult stages. Certain sex-specific traits, like colour variations in eggs, larvae and pupae, exist but have not been commercially utilized in India for various reasons. Gender classification is crucial in sericulture for breeding and silk production. Male silkworms are typically preferred for commercial silk production due to their higher silk content per cocoon and lower leaf consumption compared to females. This distinction is essential for optimizing silk production and managing resources effectively.

There are two ways of classification of gender *viz*. destructive and non-destructive way. Gender classification of pupae traditionally requires skilled visual observation without damaging the cocoon, which is crucial since silk is the final product. Destroying cocoons for gender identification isn't economically feasible. The classical method relies on the size difference as females are generally larger, but it has limitations. Hence, AI-based approach uses image processing and load sensors to non-destructively classify pupae by visually comparing cocoons and considering their weight, effectively separating male and female cocoons (Raj *et al*., 2019) [16].

X-ray imaging offers a non-destructive method for cocoon gender separation. Using an AI-based system, it compares the

shape features of the pupa inside the cocoon with computed shape features of both male and female pupae and cocoons. This process classifies the gender without the need to cut open the cocoon [23]. Such systems can easily identify the sex with higher accuracy using less time and labour which is the main aim for using artificial intelligence i.e., less time and labour consuming. Sorting of cocoons is another important step in sericulture industry as good quality cocoons ensure higher productivity as well as better fecundity. Traditionally, this process is done by experienced persons based on visual examination that is having many drawbacks, of which time consumption & inaccuracy is at top. Sorting of cocoons with the help of Machine Learning methods comes handy in such cases. Use of imaging algorithms, sensors and AI models to detect shape, size and defectiveness of cocoon is the smartest way to overcome the drawbacks as well as getting efficient results [24-27].

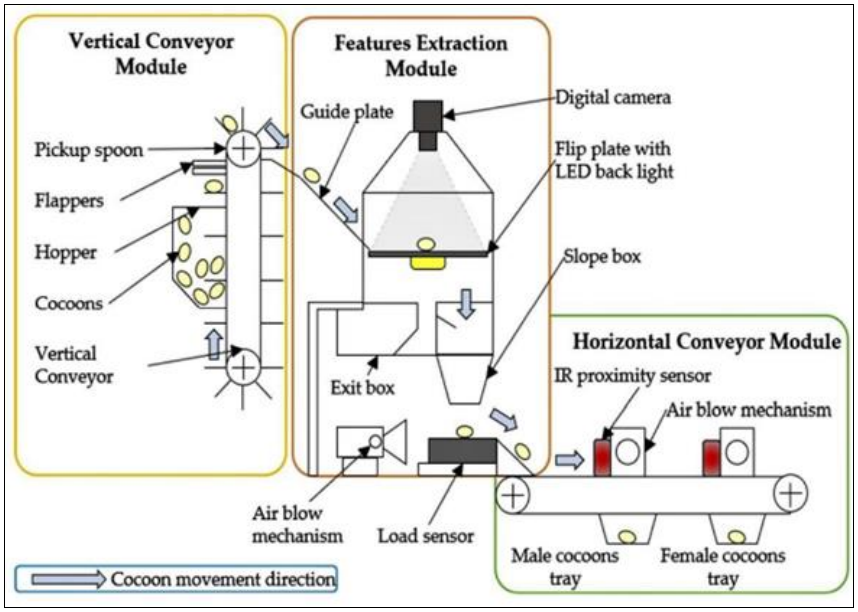

Fig 4: Schematic diagram of cocoon separating machine

Robotics and automation in silk processing

The integration of robotics and automation in silk processing has revolutionized efficiency, quality and sustainability in the sericulture industry. Automated silk reeling machines enhance cocoon processing speed while maintaining fiber quality (Kumar and Sharma, 2022) [11]. Robotic arms equipped with AI-driven sensors optimize silk thread extraction, reducing manual errors and increasing productivity (Gupta *et al*., 2021) [8]. Automated weaving technologies, such as computerized Jacquard looms, enable precision in silk fabric design (Singh and Patel, 2019). Additionally, machine vision systems detect defects in silk fibers, ensuring high-quality products (Rao and Verma, 2022) [17].

Robotics also plays a role in packaging and quality control, minimizing labor costs and improving efficiency. As advancements continue, automation is expected to further transform silk processing, promoting sustainable and high-yield production.

Artificial Intelligence (AI) is set to revolutionize sericulture by enhancing productivity, disease management and silk quality. AI-powered predictive analytics can help forecast climate impacts on silkworm rearing, ensuring optimal environmental conditions (Sharma and Verma, 2021) [20]. Machine learning models facilitate early disease detection, reducing losses through automated diagnostics (Gupta *et al*., 2022) [8]. AI-integrated robotics stream line silk reeling and weaving processes, improving efficiency and product consistency (Kumar and Rao, 2020) [9]. Furthermore, smart IoT systems enable real-time monitoring of silkworm growth, optimizing feeding schedules for maximum yield (Patel and Singh, 2019) [13]. As Al continues to evolve, its applications in sericulture will drive sustainable production, reduce manual labor, and enhance economic viability. Future advancements in AI-driven automation promise a new era of precision sericulture, making the industry more resilient and productive

AI in Market Trends and Demand Forecasting

AI can play a vital role in analyzing market trends and demand forecasting. AI can analyze marketing patterns, consumer preferences, and historical sales data to forecast demand for different types of silk products. By understanding market dynamics, Seri culturists can adjust their production plans to align with consumer demand. This prevents overproduction or underproduction, enabling efficient resource allocation and better profit margins. (Sonal *et al*., 2024) [22].

Future Prospects of AI in Sericulture Development

Artificial Intelligence (AI) is set to revolutionize sericulture by enhancing productivity, disease management, and silk quality. AI-powered predictive analytics can help forecast climate impacts on silkworm rearing, ensuring optimal environmental conditions (Sharma and Verma, 2021) [20]. Machine learning models facilitate early disease detection, reducing losses through automated diagnostics (Gupta *et al.*, 2022) [8]. AI-integrated robotics stream line silk reeling and weaving processes, improving efficiency and product consistency (Kumar and Rao, 2020) [9]. Furthermore, smart IoT systems enable real-time monitoring of silkworm growth, optimizing feeding schedules for maximum yield (Patel and Singh, 2019) [14]. As Al continues to evolve, its applications in sericulture will drive sustainable production, reduce manual labor, and enhance economic viability. Future advancements in AI-driven automation promise a new era of precision sericulture, making the industry more resilient and productive

Pilot studies or startups using AI in sericulture

ReshaMandi is India's first and largest digital ecosystem for the natural fibre supply chain, connecting farms to fashion. ReshaMandi is determined to standardise the industry, starting from the grassroots, such as farmers, reelers, weavers, retailers and finally, consumers. They are digitising the supply chain of natural fibres and eradicating hurdles faced by stakeholders across the chain. (Dhanapriya, 2025) [4].

Farmer advisory services: SeriApp was created to provide field-focused solutions for Seri-farmers' advantage (Gowda *et al*., 2020) [6]

Central Silk Board (CSB) pilot project case studies in Karnataka and Assam depict the beneficial benefits of insightful interventions on yield growth, disease management, and efficient post-harvesting. The policy recommendations heavily focus ont he necessity of public-private collaborations, capacity-building programs, harmonization of AgriStack and Digital India, and economic support in terms of insurance policies and subsidies. By leveraging digital innovation, the smart sericulture model presents an innovative solution to transform India's silk industry, reduce climate stress exposure vulnerabilities, and support inclusive rural growth. The research concludes that India could emerge as a global leader in sustainable and intelligent silk production if the right balance of technology, governmental support, and mass participation is established. (Dhanapriya, 2025) [4].

Limitations of AI

- **High initial investment:** Implementing AI technologies like robotics, sensors, and data analytics platforms can be expensive, making it inaccessible for small and medium-sized farms. This can exacerbate existing inequalities in the agricultural sector.
- **Job displacement:** Automation through AI could lead to job losses in agricultural labor, impacting rural communities and livelihoods.
- **Data ownership and access**: Large corporations often own and control agricultural data, potentially creating monopolies and disadvantaging smaller players.

Discussion

- Promoting equitable access to AI technologies: Governments and organizations can play a role in providing financial and technical support to small and medium-sized farms to adopt AI technologies.
- Developing training programs to improve digital literacy among farmers: Bridging the digital divide is crucial to ensure that all farmers can benefit from AI advancements.
- Mitigating bias in AI algorithms: AI systems should be rigorously tested and audited to ensure fairness and prevent discrimination against specific groups.
- Ensuring data privacy and security
- Minimizing the environmental impact of AI-driven agriculture
- Developing ethical guidelines for AI applications in animal farming

Conclusion

The integration of Artificial Intelligence (AI) in sericulture is transforming traditional practices by enhancing efficiency, productivity, and sustainability. Al-driven technologies, such as automated disease detection, predictive analytics, and IoT-based monitoring, are revolutionizing silkworm rearing and mulberry cultivation. Machine learning models enable early disease identification, ensuring timely interventions that minimize losses Precision feeding systems optimize nutrition, while smart environmental controls regulate temperature and humidity for optimal silkworm growth. Additionally, robotics and automation in silk processing improve efficiency, quality, and cost-effectiveness. AI-powered pest management and drone-based monitoring further contribute to sustainable silk production

By reducing manual labor, optimizing resources, and improving overall productivity, AI ensures a competitive and eco-friendly sericulture industry. As AI continues to evolve, future advancements will further refine automation, predictive modeling, and quality control, making sericulture more resilient to environmental changes and market demands. The adoption of AI not only modernizes silk production but also paves the way for a more sustainable, profitable, and technologically advanced industry.

Disclaimer (Artificial Intelligence)

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

Competing Interests

Author has declared that no competing interests exist.

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