Chapter 14

Silk Farms of the Future: The Impact of Sericulture 4.0

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Abstract

Resources for natural fiber are abundant in Asian nations, but they have not yet been fully utilized. In terms of pleasant national demand, there was a yearly difference of millions between 2014 and 2020. Enhancing economic potential and utilization requires a comprehensive analysis. The study aimed to demonstrate the economic advantages, technological processing, and availability of natural fibers. National R&D groups, government policymakers, and academic institutions working together are critical for producing national bio-products based on home innovation and advancing the circular economy. Sericulture, meaning the art of silk manufacturing, is a complicated enterprise with important economic, social, and environmental implications. It all begins with mulberry agriculture, which includes silkworm rearing and fabric weaving. Sericulture provides long-term employment opportunities, particularly in rural regions where over 60 percent of the workforce is female. Mulberry agriculture and silkworm rearing are profitable investments, making this a significant business. Silkworm Bombyx mori L. needs nourishment to grow, and premium mulberry leaves are needed for the best cocoon creation. Applying manures and bio-fertilizers after pruning can boost leaf production and enhance mulberry quality while preserving soil fertility. Bio-fertilizers, which contain live microorganisms, colonize the rhizosphere and stimulate growth by boosting the host plant's primary nutrition source. They are renewable plant nutrition sources that may be used in conjunction with chemical fertilizers. Mulberries require main nutrients from organic manures and bio-fertilizers, since organic manures promote soil microflora proliferation and supplement the crop with minor nutrients such as NPK. The interior micro-structure of cultivated and wild silkworm cocoons is investigated in this work via means of X-ray micro computed tomography (XCT). According to the statistics, fiber percentages first decrease as fiber widths increase from the inner to the outside layer. Because of the cocoon's modest diameter, the fibers in different layers are more aligned. which is advantageous for biomaterial development. The findings emphasize the relevance of knowing the interior microstructure of silkworm cocoons for biomaterial development.

Keywords

Sericulture, Natural Silk Fiber, Muga Silkworm, Silkworms, Bombyx Mori

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1. Introduction

Sericulture is a sustainable agricultural strategy that helps rural communities by minimizing forest strain and improving soil conservation. It burns mulberry twigs and branches as fuel, lessening the need on forests. Despite its potential, mulberry production accounts for just a small proportion of arable land. Sericulture activities are being expanded, notably in upland regions and among landless households, as part of efforts to promote inclusive growth and rural expansion [1]. Natural silk fiber is gaining popularity as a possible material for multifunctional intelligent biomaterials. Its success in the fashion sector, particularly in ecologically friendly production, is driving its research into smart biomaterials for a variety of applications, including medicines, health, electronics, and optical fibers. Natural color dyeing of silk yarn with fixators and mordants has been the focus of recent research on silk fiber as a multipurpose smart biomaterial and raw material for textiles and fashion [2]. A wide range of industries, including automotive, aerospace, construction, bio packaging, textiles, biomedical applications, and military vehicles, can benefit from the renewable and biodegradable nature of natural fibers. It takes the right technological and social strategies to increase their applicability. The most promising natural fibers for domestic items can be selected with the aid of an integrated management system by using digital data on potential and associated technical methods. [3]. The Muga silkworm, a semi-domesticated species, is distinguished by its golden-yellow color and has been produced for millennia by numerous ethnic and tribal groups. This mono race, which has minimal genetic diversity, is raised in open conditions and is vulnerable to a variety of illnesses, pests, and predators. Unpredictable weather, natural disasters, disease outbreaks, and natural enemies have all had a substantial impact on muga silk output. To increase productivity, it is critical to understand the elements influencing this silkworm [4]. Hand reeled silk yarns are categorized based on physical attributes like weight, color, and circumference. Nowadays, certified inspectors select pieces at random and assess uniformity, which can be time-consuming and unreliable owing to the inspectors' expertise. To remedy this, an optical sensor device known as “Silk Check” was built to identify hand reeled silk strands, calculating their length and linear mass density in real time and precisely categorizing them into the appropriate agricultural category [5]. Silkworms are sensitive to environmental conditions; thus their rearing is focused on developing high-quality cocoons with a high silk content. Larval growth and cocoon crop quality are significantly impacted by temperature, humidity, light, and air. The quality of the leaf supply and rearing practices including feeding, cleaning, and spacing are additional elements that affect raising activities. A bad environment has a negative impact on silkworm growth, and behavior varies depending on the stage of development [6]. New low-risk control strategies and chemical pesticides, including nano-pesticides, have to be developed in response to the expanding environmental and health concerns. Given the rapid advancement of nanomaterials, a deeper comprehension of their toxicity to non-target organisms is vital. Using chitosan, silver, and zinc oxide nanoparticles, a study on Eri silkworms discovered that higher concentrations increased corrected larval mortality while lowering length, girth, and cocoon weight [7].

2. Silk Farms of the Future: The Impact of Sericulture 4.0

Silkworms have attracted people throughout the world for millennia owing of the by-products of transformation. Although industrialization and illness worries have caused a reduction, some factors still promote their existence. Proteins are the most abundant nutrition in silkworm rearing. Other nutrients are present, including as fatty acids, vitamins, minerals, and polyphenols. The amino acids metabolized by larvae and pupae in mulberry leaves, together with their amino acid composition, give silkworm by-products great nutritional potential, equivalent to or superior than fish meal and other aquaculture-specific feed products [8]. Silk is a fiber-like material composed of fibroin and sericin (SER) proteins derived from silkworm cocoons. Glycine, serine, aspartic acid, and threonine are among the amino acids that make up these proteins. SER, which can be made in a number of ways, is used in hydrogels, films, and sponges for a range of biological applications. It is perfect for cell proliferation, tissue engineering, and skin tissue regeneration because of its moisturizing, anti-inflammatory, antioxidant, and mitogenic properties [9]. The performance of local complex and simple silkworm hybrids was assessed using reproductive, biological, productive, and technical indices. The findings revealed that these hybrids outperformed control varieties, showing a great potential for silk production. Local silkworm hybrids produced more and higher-quality cocoons than international counterparts. The essay recommends expanding the volume of preparation for industrial cocoon manufacturing due to their superior performance compared to international counterparts [10]. A microfluidic method has been developed to create biological fibers from easily accessible proteins such collagen, milk, bovine serum albumin, chicken, quail, and goose eggs. High tensile strength and toughness comparable to regenerated silkworm or recombinant spider silks are produced by the crosslinking action and double-drawn treatment that follow spinning. These fibers are also utilized to suture rat and minipig models [11]. The researchers indicated that cocoon fiber widths rose from the inner to outer layers, although fiber percentages decreased at first. The fibers were better aligned with the cocoon's small diameter, with Antheraea mylitta fibers displaying the highest alignment. The fractal dimension of domestic cocoons was less than that of wild cocoons, which had higher breaking energy, initial modulus, and maximum strength. The breaking energy and peak strength of Antheraea pernyi are higher than those of Antheraea mylitta [12]. Silkworm productivity and health depend on the gut microbiota, and sericulture depends on both. SrRNA sequencing was used to examine the impact of three diets on silkworm gut microbiomes: a diet consisting only of mulberry leaves, a diet consisting solely of artificial feed, and a gradual transition from artificial feed to mulberry leaves. The findings demonstrated that the microbial diversity of the various groups varied significantly [13]. The pathogenicity of Antheraea proylei nucleo-polyhedrovirus (AnprNPV), a major impediment to oak tasar sericulture output. Transmission electron micrographs show single rod-shaped entities and occlusion-derived viruses enveloped in many envelopes. The virus exhibits tissue tropism and multiplies in all silkworm developmental stages, demonstrating its capacity to dispersed across an individual's lifespan. The potential host range for infections has been expanded by the cross-infectivity of the baculovirus identified from infected A. proylei in other wild silkworm species [14]. Since ancient times, the domestic silkworm Bombyx mori has been used to generate silk. Today, it is used to mass-produce recombinant bioactive proteins in the textile and pharmaceutical industries. Silkworms are also used for food and to cure human diseases. The purpose is to look into the biophysical and chemical features of edible silkworms in order to assess their therapeutic and nutritional potential [15]. Eri silkworm is a polyphagous worm that feeds on over host plants. However, not all food plants are appropriate for Eri silkworm rearing, with castor, kesseru, cassava, borkesseru, borpat, and payam being more suited for commercial Ericulture. Varieties and genotypes have a substantial influence on Ericulture production and profitability. The primary purpose of Eri host plant enhancement is to create perennial plants with non-bloomy red varieties, lower anti-nutrient content in cassava leaves, boost rooting power in borpat, make dwarf plants for pruning, and improve leaf production and tolerance to a variety of climatic situations [16]. Mulberry plants can benefit from the use of manures and bio-fertilizers following pruning, which increases leaf output and quality while without reducing soil fertility. Biofertilizers, which include live microorganisms, colonize the rhizosphere and boost the plant's primary nutrition sources. They are a renewable supply of plant nutrients that may be used with chemical fertilizers. Bulky organic manures stimulate soil microflora growth while also supplementing the crop with minor nutrients like NPK [17].

3. Recommendations

Based on our thorough literature, we propose the following recommendations for the future.

- It is possible to make better use of natural fibers in a range of applications by considering their basic characteristics and the relevant technologies. An integrated management system may aid in the selection of potential natural fibers for national goods, while cooperation among national R&D agencies, government policymakers, and university institutions are critical to the circular economy.
- Silkworms, a fascinating species across the world, have been employed for millennia owing to its byproducts. Despite reduction owing to industrialization and disease concerns, reasons to keep it alive include the abundance of protein found in silkworm rearing, like mulberry leaves and silk.
- A study of silkworm gut microbiota composition and functional capability demonstrated exceptional adaptation and resistance to dietary changes. Key microbial taxa, including Methylobacteriaceae, Weissella, and Lactobacillus, were shown to be differently enriched among food groups, paving the door for targeted therapies to improve silkworm health and production.
- Cooperative silkworm rearing necessitates technical expertise, which many rural farmers lack. Poor upbringing might result in crop failures and illnesses in later instars. Furthermore, many rearers cannot afford the essential equipment for ideal circumstances. To solve these challenges, cooperative raising has been created to give technical help and optimal settings, and rearing is carried out until the second or third molt.
- Researchers discovered substantial declines in fiber and average pore area in core rings for three cocoon species, with B.mori displaying greater reductions than wild cocoons. Additionally, the fiber intersection density is greatly decreased, in contrast to wild cocoons, which first diminish and then increase along the direction of the cocoon's thickness. The fibers of A. mylitta exhibit the highest fiber orientation, while the fibers of other layers of cocoons align more toward the small diameter of the cocoons.
- Both domestic and wild cocoons show notable fractal characteristics, according to the researchers. Although wild cocoons had relatively stable fractal dimension values, suggesting that B. mori's structure was more optimized from outer to inner layers, B. mori's fractal dimension was significantly reduced along the thickness direction.
- New technology should be developed to help muga silkworms live and avoid extinction. This unique asset represents our rich history and social identity, and a silk revolution is required to preserve it.

Conclusion

The study indicated that mulberry leaves treated with vermin-compost Azospirillum had a good effect on silkworm larval duration. This is due to the fact that earthworms promote microbial breakdown of organic debris, which releases nutrients to the mulberry tree. This has a direct impact on the quality of the leaves, improving their palatability and acceptability, boosting silkworm feeding efficiency, and resulting in higher cocoon yields. To assess the physical quality of hand-reeled silk yarn in real time, an optical sensor system has been put into place. The apparatus evaluates the uniformity of color variance, diameter, and denier, transforming an analog manual process into a digital one for Sericulture 4.0. The system combines mechanics and basic optical metrology to provide quick operation and ease of application. Farmers and associated peoples encounter several problems when cultivating silkworms, notably for Muga silk, which is a heritage product. Scientific research is required to understand the causes of muga silkworms and their silk output. Proper indoor rearing strategies for domesticating larvae are critical because they are extremely susceptible to climatic and environmental changes. Seridiversity and its utilization have the ability to enhance rural socioeconomic situations while also becoming a favoured industry in the Indian subcontinent. India's huge biological resources provide opportunities for development, but conservation systems must be strengthened urgently. Popularizing new technology among farmers is critical for widespread acceptance, which will change transforming the old-fashioned cottage industry into a modern, high-tech industrial endeavor. In order to change India's reputation as a traditional cottage industry to one of a modern, high-tech industrial activity, research and development should be primarily focused on poverty reduction and sustainable socioeconomic development.

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