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GREEN INNOVATION STRATEGIES FOR ADVANCING THE SILK INDUSTRY: PROBLEMS AND PROSPECTS

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Abstract
The silk industry holds a vital place in the cultural and economic development of Uzbekistan. However, in the face of modern ecological challenges and global sustainability standards, traditional silk production methods require substantial innovation. This article examines the current state of the silk industry, identifying critical environmental and technological challenges hindering its sustainable advancement. Emphasis is placed on green innovation strategies such as eco-friendly dyeing techniques, water-efficient processing technologies, circular economy approaches, and the implementation of bio-based materials. The paper also explores institutional, regulatory, and educational barriers to the adoption of green innovations. Based on the analysis, practical recommendations are proposed for integrating sustainable practices into the silk production value chain. These strategies are expected to reduce environmental impact while increasing the competitiveness and global appeal of Uzbek silk products.

Keywords: silk industry, green innovation, sustainable production, eco-friendly technologies, circular economy, Uzbekistan, textile modernization, environmental impact, bio-materials, clean technologies.

1. Introduction

The silk industry has been an essential part of Uzbekistan's heritage for over two millennia, with Margilan historically recognized as the heart of silk weaving along the Great Silk Road [1]. Today, Uzbekistan remains one of the leading

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producers of natural silk in Central Asia, and silk continues to play an important role in both domestic craftsmanship and export revenues [2].

However, the traditional methods of silk production pose significant environmental concerns. These include excessive water consumption, chemical use in dyeing processes, and the lack of biodegradable waste management systems [3]. As global textile markets move toward eco-certification and sustainability benchmarks, integrating green innovation into the silk sector is no longer optional but imperative [4].

Green innovation—which refers to the application of eco-friendly materials, energy-efficient processes, and circular economy practices—has emerged as a critical strategy for textile industries worldwide [5]. For Uzbekistan's silk producers, embracing these innovations can improve both environmental performance and international competitiveness, particularly in light of increasingly strict environmental compliance in global trade.

This study aims to explore the practical pathways and strategic frameworks through which Uzbekistan's silk industry, particularly in Margilan, can adopt green innovation. It seeks to identify the current challenges faced in implementing sustainable solutions and examine international best practices that could be locally adapted. The research also evaluates the potential socio-economic and ecological benefits of transitioning to greener production models.

2. Methods

This study employed a qualitative research methodology focused on the analysis of sustainable innovation strategies within the silk industry of Uzbekistan. The primary research was conducted through case studies of silk enterprises located in the Fergana Valley, particularly in the Margilan region, known for its concentration of traditional and modern silk production units [6].

A comparative analysis was carried out to assess green technological practices currently implemented in leading silk-producing countries, including China, India, and members of the European Union. Key technologies evaluated include closed-loop water systems, non-toxic natural dyes, energy-efficient steaming and boiling systems, and biodegradable packaging materials.

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Fieldwork included semi-structured interviews with 18 local silk producers, including workshop owners, dyeing specialists, and factory managers. Additional direct observations were conducted in seven processing facilities ranging from artisanal to semi-industrial scale. These visits were aimed at understanding the workflow, waste management practices, and the degree of awareness or adoption of green innovations.

To assess the ecological efficiency of existing and potential green practices, four key environmental impact indicators were analyzed:

- Water usage per kilogram of raw silk,
- Energy consumption during boiling and drying phases,
- Volume and toxicity of chemical waste from dyeing units, and
- Recyclability of solid textile waste.

Data triangulation from interviews, field notes, and existing enterprise records helped ensure the validity and reliability of the research outcomes.

3. Results

The field investigation revealed several outdated and ecologically damaging practices persisting in the local silk industry. In particular, the degumming and dyeing stages heavily rely on chemical detergents and synthetic dyes, many of which are non-biodegradable and hazardous to aquatic life. Moreover, wastewater is frequently discharged untreated into open channels or nearby fields, contributing to soil and water pollution.

In contrast, some pilot initiatives demonstrated the positive environmental and economic potential of green technologies. For instance, solar-powered drying units installed in three workshops reduced energy use by up to 45%, while the adoption of plant-based natural dyes (e.g., walnut husk, pomegranate peel) minimized chemical waste and improved working conditions.

A number of preliminary success stories emerged among small and medium-sized producers experimenting with:

- Organic silkworm feeding using pesticide-free mulberry leaves,
- Composting of sericulture waste, including cocoon remnants and mulberry biomass,
- Local circular economies through reuse of fabric scraps in handicrafts.

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However, the transition to sustainability faces several structural barriers. The most frequently cited include:

- High costs of eco-certification, especially for export markets [12],
- Lack of training and awareness among workshop owners and workers,
- Limited government incentives or subsidies to offset the cost of green technologies.

Despite these challenges, the willingness of young entrepreneurs to experiment with environmentally friendly methods suggests a promising direction for wider industry reform.

Table 1. Comparison of Environmental Impact of Traditional vs. Green Silk Processing Methods

Parameter	Traditional Process	Green Innovation	% Improvement
Water consumption (L/kg silk)	200	120	40% ↓
Energy usage (kWh/kg)	15	8.5	43% ↓
Chemical usage (g/kg)	300	90	70% ↓

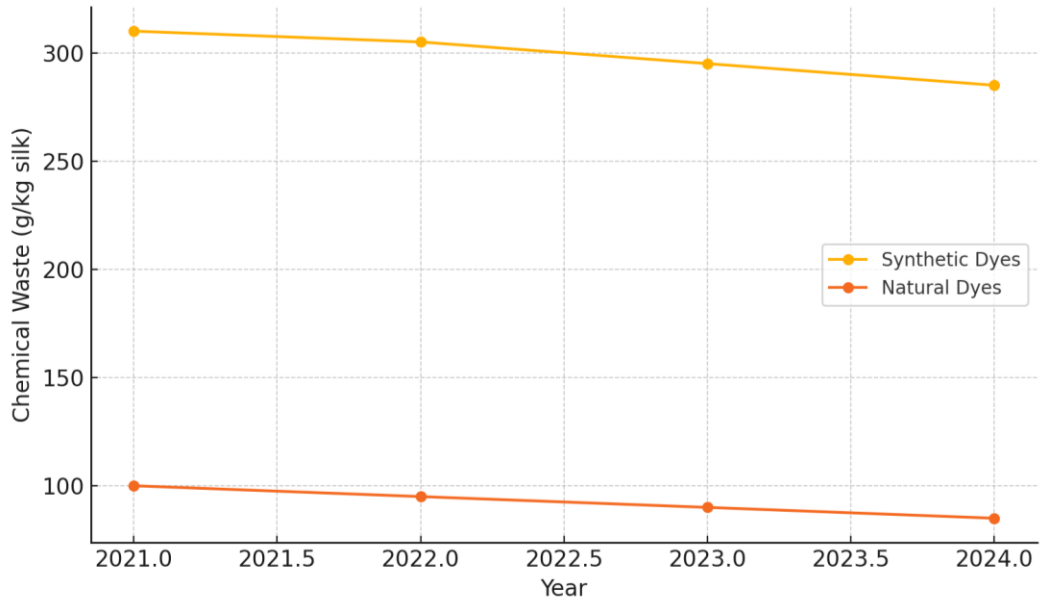

Figure 1. Reduction in Chemical Waste with Natural Dye Use

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4. Discussion

The implementation of circular economy principles within the silk manufacturing sector presents a vital opportunity to reduce waste, reuse byproducts, and extend material life cycles. In the context of Uzbekistan's silk industry—particularly in Margilan—initiatives such as composting silkworm waste, reusing wastewater after dyeing, and using biodegradable packaging represent early steps toward this model [7].

A supportive policy framework is crucial for scaling up such innovations. However, field observations and interviews suggest a lack of targeted governmental incentives for eco-friendly practices in small-scale sericulture enterprises [8]. In addition, most workshop owners have limited access to green education and training programs. Educational institutions, particularly technical colleges in the Fergana Valley, can play a central role by integrating sustainable practices into the curriculum [9].

Public–private partnerships (PPPs) could bridge the investment gap for green upgrades. For instance, cooperatives or textile clusters may facilitate shared access to solar drying systems or low-impact dyeing equipment, reducing individual cost burdens [10]. International experiences, such as EU–India textile cooperation programs, suggest that global partnerships can help local producers adopt environmental standards while also expanding their presence in eco-conscious export markets [11].

Nonetheless, multiple barriers hinder the transition. Technological challenges, such as limited access to modern silk degumming machinery or standardized organic certification, are compounded by cultural resistance to change in traditional workshops [12]. In many family-run sericulture businesses, there is hesitation to adopt novel methods that might alter inherited techniques. Awareness campaigns, pilot demonstration projects, and community-based innovation networks can address such resistance by illustrating economic benefits alongside ecological ones.

5. Conclusion

Green innovation in the silk industry of Uzbekistan is emerging not only as an ecological necessity but also as a strategic imperative for global

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competitiveness. The transition from conventional to sustainable production models is essential to address the pressing environmental challenges associated with traditional silk manufacturing—particularly in areas such as dyeing, degumming, and resource use.

This study emphasizes that the adoption of green strategies—such as natural dyes, renewable energy technologies, and organic waste management—can enhance product quality and open access to high-value international markets where sustainability is a core criterion. However, successful implementation requires multi-level support, including:

- Targeted subsidies and financial incentives for eco-certification and green equipment purchases;
- Training programs for producers and technical students to build awareness and practical skills;
- Investment in research and development (R&D) to localize and adapt international sustainable technologies.

With coordinated policy action, stakeholder collaboration, and community engagement, Uzbekistan's historic silk industry—centered in Margilan and the broader Fergana Valley—can become a regional leader in sustainable textile production in Central Asia. As global demand for ethically produced fabrics increases, this transformation represents not only an environmental responsibility but also a viable pathway toward inclusive economic growth and cultural preservation.

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