



A Review on Advancements in Functional and Sustainable Textile Finishing Technologies

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The textile industry is undergoing a transformative shift, driven by innovations in finishing technologies that aim to balance performance, sustainability, and functionality. This paper explores the latest developments in textile finishes, including sustainable dyeing techniques such as supercritical CO₂ and microbial dyeing, bio based and plasma treatments, and functional enhancements through smart textiles. It highlights the integration of wearable technology and health-monitoring features, as well as advancements in textile recycling and closed-loop systems that support circular economy goals. While these innovations offer promising solutions to environmental challenges, they also introduce implementation hurdles such as cost, infrastructure demands, and regulatory gaps. The study concludes by emphasizing the need for continued research, investment, and standardization to facilitate widespread adoption and future innovation in textile finishing.

Keywords: Infrastructure demands, microbial dyeing, wearable technology.

1. INTRODUCTION

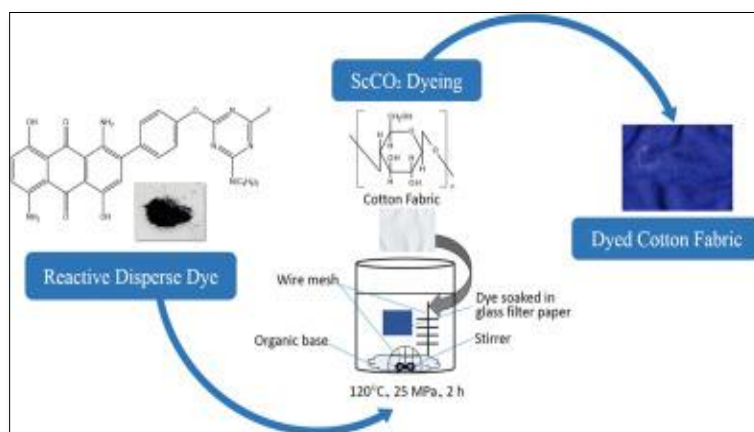
The textile industry is undergoing a significant transformation, driven by advancements in finishing technologies that prioritize sustainability, functionality, and aesthetics. This paper delves into the latest innovations in textile finishing processes, highlighting their environmental impact, performance enhancements, and the challenges manufacturers face during implementation.

2. RESEARCH METHODOLOGY

2.1 Sustainable Dyeing and Finishing Technologies

2.1.1 Waterless Dyeing with Supercritical CO₂

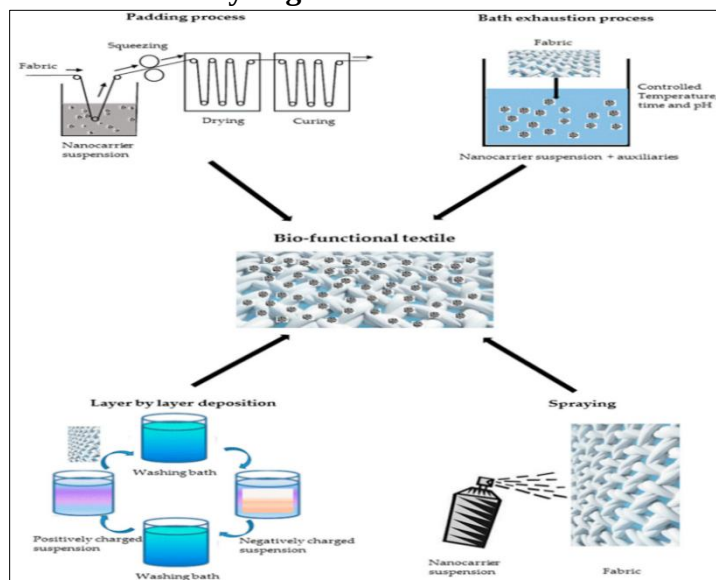
Traditional dyeing processes are notorious for their high water consumption and chemical usage. In response, waterless dyeing technologies utilizing supercritical carbon dioxide (CO₂) have emerged.



(Fig 1)

This method eliminates the need for water, reducing consumption by up to 80%, and minimizes energy usage by up to 60% compared to conventional methods. The process also allows for more vibrant and uniform color application, enhancing fabric quality while promoting environmental sustainability.

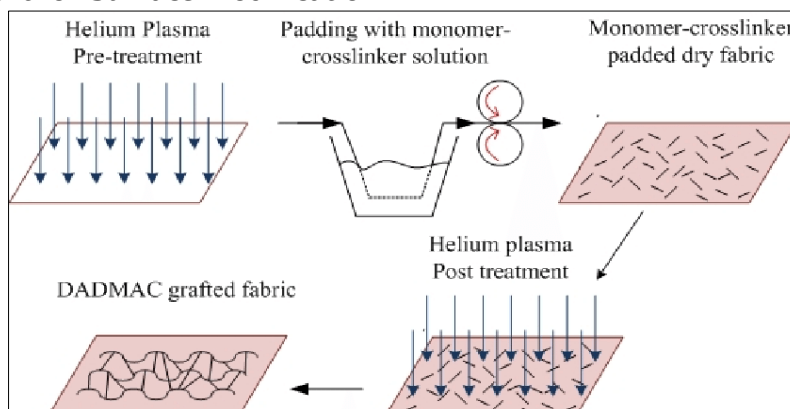
2.1.2 Bio based Finishes and Microbial Dyeing



(Fig 2)

Biobased finishes derived from renewable resources offer an eco-friendly alternative to conventional chemical treatments. These finishes provide natural properties such as antibacterial effects, UV resistance, and moisture management. Additionally, microbial dyeing techniques employ genetically engineered microorganisms to produce pigments, reducing the need for toxic chemicals and heavy metals in the dyeing process. These innovations contribute to a significant reduction in the environmental footprint of textile manufacturing.

2.1.3 Plasma Treatment for Surface Modification

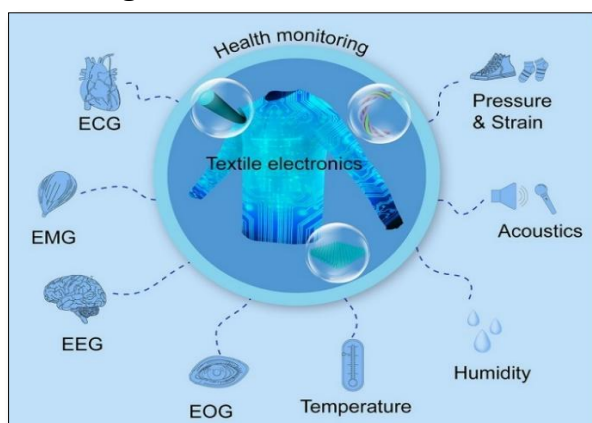


(Fig 3)

Plasma treatment is a non-chemical method that modifies the surface properties of textiles, enhancing characteristics like hydrophilicity, adhesion, and dye uptake. This technology improves fabric performance without altering its bulk properties, making it an attractive option for manufacturers seeking sustainable finishing solutions.

2.2 Smart Textiles and Functional Finishes

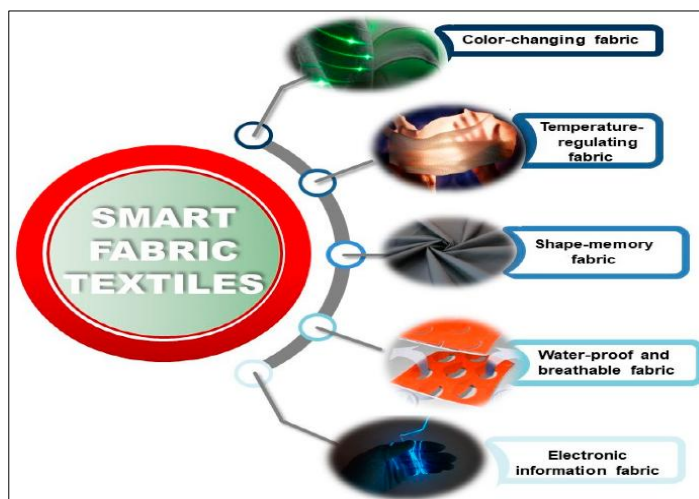
2.2.1 Integration of Health Monitoring Features



(Fig 4)

The incorporation of sensors into textiles has led to the development of smart fabrics capable of monitoring vital signs such as heart rate, respiratory rate, and temperature. These textiles offer continuous health insights without the need for bulky devices, paving the way for advancements in wearable healthcare technologies.

2.2.2 Wearable Technology Advances

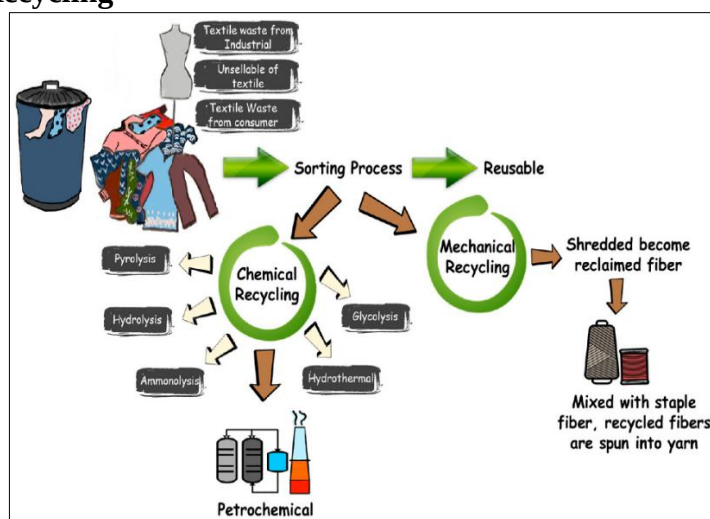


(Fig 5)

Advancements in nanotechnology and electronics have enabled fabrics to incorporate functionalities traditionally associated with gadgets. Smart fabrics can now include interactive elements, such as touch-sensitive surfaces and color-changing features activated by environmental cues or user inputs. Potential applications extend into smart work wear that boosts productivity with connectivity capabilities or safety gear with integrated communication systems for industrial use.

2.3 Circular Economy and Recycling in Textile Finishing

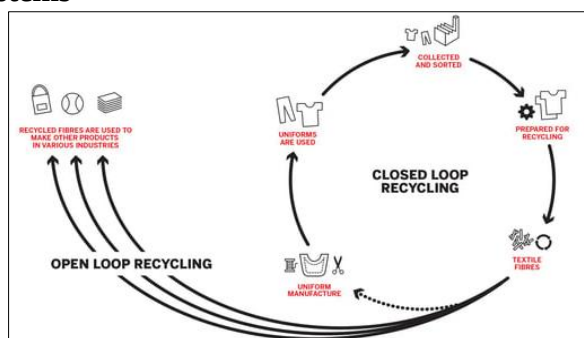
2.3.1 Textile-to-Textile Recycling



(Fig 6)

The concept of a circular economy in textiles emphasizes the importance of recycling and reusing materials to reduce waste. Innovations in textile-to-textile recycling processes allow for the recovery and reuse of fibers, minimizing the need for virgin materials and reducing environmental impact. Companies are investing in advanced sorting and recycling technologies to promote a more sustainable textile industry.

2.3.2 Closed-Loop Dyeing Systems

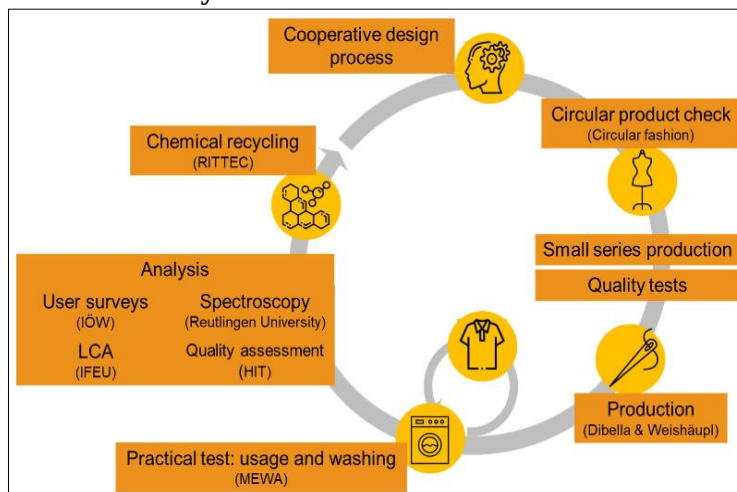


(Fig 7)

Closed-loop dyeing systems aim to minimize water and chemical usage by recycling and reusing dye baths. These systems not only reduce environmental pollution but also lower operational costs for manufacturers. The adoption of such systems is a step towards achieving sustainability goals in textile production.

2.4 Challenges in Implementing Sustainable Finishing Technologies

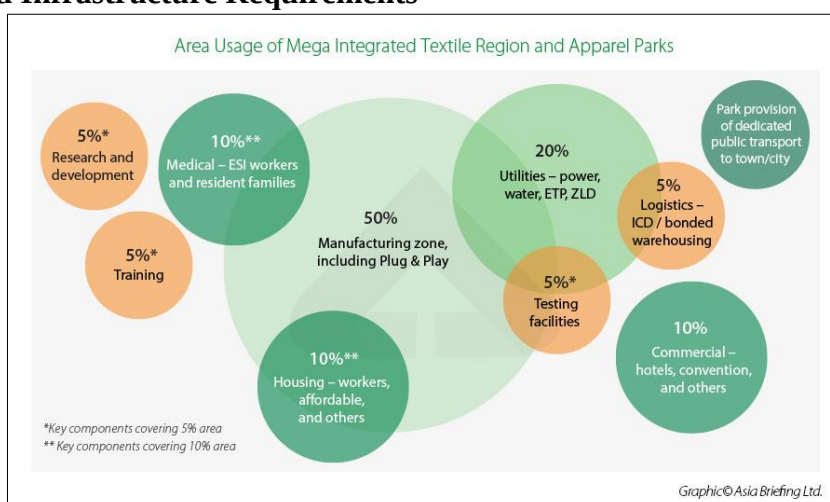
2.4.1 Trade-offs Between Sustainability and Performance



(Fig 8)

While sustainable finishing technologies offer environmental benefits, they may present challenges in terms of performance. For instance, bio based finishes may not always match the durability or functionality of traditional chemical treatments. Manufacturers must balance sustainability goals with the need to meet performance standards.

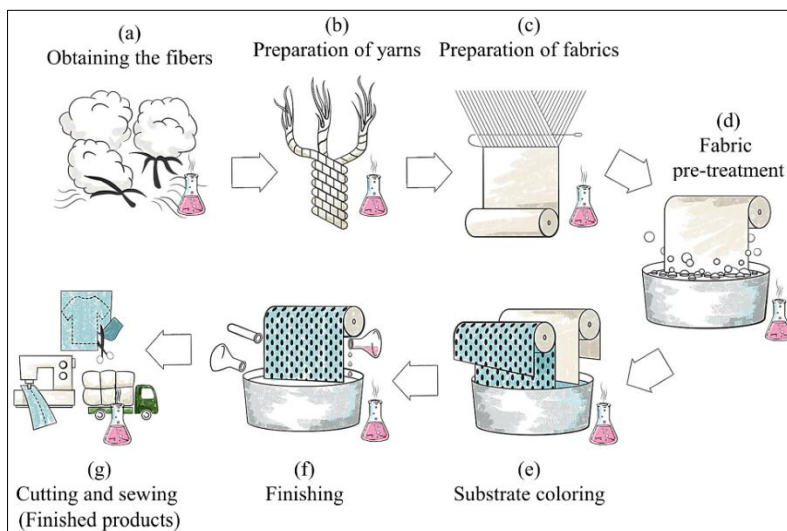
2.4.2 Investment and Infrastructure Requirements



(Fig 9)

Implementing advanced finishing technologies often requires significant investment in new equipment and infrastructure. Small and medium-sized enterprises may face financial constraints in adopting these technologies. Additionally, training personnel and adapting existing processes to accommodate new technologies can pose challenges.

2.4.3 Regulatory and Standardization Issues



(Fig 10)

The lack of standardized regulations and certifications for sustainable finishing processes can create uncertainty for manufacturers. Establishing clear guidelines and standards is essential to ensure the credibility and effectiveness of sustainable practices in the textile industry.

3. RESULT AND DISCUSSION

The review indicates that textile finishing technologies have undergone significant advancements toward improving fabric functionality while reducing environmental impact. Conventional finishing methods are increasingly being replaced or modified through the use of sustainable chemicals, bio-based materials, nanotechnology, plasma treatment, digital technologies, and low-water or waterless processing techniques.

4. CONCLUSION

The review highlights the growing shift from conventional textile finishing to functional, sustainable, and eco-friendly technologies. Advancements in nanotechnology, biotechnology, plasma, ozone, enzymatic, and bio-based finishes improve textile performance while reducing water, energy, and chemical consumption. Although challenges such as cost, scalability, durability, and environmental safety remain, continued research and innovation can promote sustainable, efficient, and high-performance textiles for future applications.

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