

## A Review: Sustainable Practices in Specialty Yarn Manufacturing

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**Received:** 09-03-2025

**Revised:** 10-04-2025

**Accepted:** 21-04-2025

**Published:** 24-04-2025

### ABSTRACT

*The specialized yarn sector is swiftly evolving to accord with sustainable methods propelled via ecological issues and customer desires for ecologically safe resources. Specialty sustainable yarns unite aesthetics, functionality, and ecological awareness [7]. Innovations feature using certain green fibers such as cotton, hemp, and reused things [16], with specific new spinning ways like air jet spinning and 3D knitting. Yarn's clever technologies and AI customization increase performance and reduce waste, while circular initiatives promote recycling and closed-loop output [16]. These yarns have applications throughout industries, from high fashion and home textiles to vehicular and medical fabrics. Even with problems such as high expenses, supply chain difficulties, and green-washing, the market for sustainable yarns keeps growing because of increased consumer awareness as well as regulatory pressure. A portion of the industry's future lies in certain biotech innovations and diverse regenerative fibers. Another portion of the industry's future lies in certain smart functionalities, with increased emphasis on digital transparency and zero-waste manufacturing. By incorporating sustainability in each phase of production, the specialty yarn sector is designed to change textiles via a greener and more advanced approach.*

**Keywords:** Sustainability-Recycling-Low waste-Fancy yarn-Innovation

### INTRODUCTION

**Specialty yarn:** Yarn having a specialized decorative or aesthetic effect other than conventional yarn. Fancy yarn is known for its creative textures and unique fiber blends.

The textile industry has long been identified as being a meaningful contributor toward ecological degradation, raising issues such as excessive water consumption in addition to chemical pollution along carbon emissions from factories. As a response to many increasing ecological concerns, the industry is now prioritizing sustainability to a much greater extent. That prioritization is happening notably in the sphere of the production of specialty yarns. Stylish threads, known for their showy qualities as well as odd surfaces, now lead this change. This review discovers how sustainable practices are restructuring the specialty yarn sector and their impacts for the future.

Sustainable specialty yarns emphasize the use of environmentally friendly fibers that are low in cost and need less processing, such as organic cotton, Banana, Hemp, and Pineapple fibers that are usually taken as agricultural waste, utilizing these fibers into textile industry will lessen the environmental impact and will be taken as an initiative toward sustainability. These fibers offer sustainability and aesthetic touch. The production process is further enhanced through innovations by using yarn manufacturing through air jet spinning, rotor spinning, and 3D knitting, which reduce waste and enhance productivity. Smart textile like moisture detector conductive yarns are being manufactured that accommodate the emergent applications in functional textile.

The Circular Economy model helps in describing waste percentage, effectively utilized resources, and input material efficiency. Recycling of the fibers, up-cycling of the used textile product material, adoption of eco-friendly material, and creation of a close-loop manufacturing system are key policies that move industries toward advancement. Digital technologies like AI, block chain, and software systems are improving supply chain transparency and permitting customized production of innovative products, minimizing material wastage and overproduction.

Despite these advancements, challenges occur. Higher fabrication costs, recycling limitations, and consumer misinformation obstruct widespread adoption. However, these challenges also present opportunities for innovation, particularly in bioengineering, AI optimization, and sustainable material development. As demand for eco-friendly textiles grows universally, the specialty yarn industry is uniquely positioned to lead the shift toward a greener, more sustainable future.

## **METHODOLOGY**

A systematic Literature review was undertaken, research on market trends of fancy yarn, industrial visits, and experts interviews were conducted.

### **Adoption of sustainable fibers**

The fancy yarn section includes many eco-friendly fibers like organic cotton and recycled bamboo, Tencel™, hemp, flax [13], and innovative agricultural waste fibers. This material can create balanced sustainability and aesthetic appeal. Green-conscious production techniques introduced biodegradable raw materials like PLA (thermoplastic polyester), banana fibers, and recycled cotton, wool, and PET (Polyethylene). A combination of textile waste and new fiber to produce yarns is introduced by zero-waste approaches [12]. Carbon nanotubes and graphene are also used in specialty yarn production.

**Advanced fiber and material innovation:** Bioengineered fibers, such as lab-grown silk and bacterial cellulose, decrease environmental influence, while algae-based yarns offer biodegradable and antimicrobial properties. Upcycled fibers, including recycled cotton, wool, and agricultural waste fibers (like bananas and pineapple), subsidize landfill waste reduction. Textile-to-textile recycling further permits the recycling of old textiles into new fibers.

**Challenges in adoption:** In the way of embracing closed-loop methods, fibers face many hurdles like identifying good eco-friendly material, higher production cost, consumer awareness, and quality maintenance in texture [13].

**Industry initiatives and certifications:** Certifications like GOTS, OEKO-TEX® Standard 100, GRS, and FSC validate the sustainability of materials and processes in the industry [16]. These initiatives ensure adherence to eco-friendly practices and support the movement toward a greener textile future. [12]

### **Properties of sustainable specialty yarn**

In the production of fancy sustainable yarns, we are adding softness and style and also embracing a nicer way to create them. By choosing sustainable fibers from renewable and biodegradable materials, waste is reduced automatically cost is also reduced. It is a small but advantageous step towards a sustainable future. Main aims for the production of sustainable fancy yarn is their ethical production, aesthetic and functional properties and reduced environmental impact; ethical production lies in using low impact dyeing, energy efficient processing that minimizes the carbon footprint; aesthetic qualities involves novelty effects, adding softness and durability; making the process environment friendly by minimal waste production, using non-toxic finishes and ensuring biodegradability

### **Innovative yarn production techniques**

Sustainable practices and innovations can be introduced in the spinning and functionality of fancy yarns that minimize the usage of natural resources like water and energy. Modern spinning techniques avoid water-intensive methods, minimize pollution.

**Rotor spinning** increases production, which ultimately reduces energy consumption while maintaining yarn quality. **Air-jet spinning** uses compressed air, diminishing the step of mechanical twisting, reducing water and harsh chemical usage. It creates soft, lightweight yarns ideal for sustainable fibers like Tencel™. Zero-waste knitting and solar or wind-powered mills support energy-efficient processing, while waterless dyeing and digital printing lessen environmental destruction during manufacturing. [16].

**Digitalization production** such as AI optimizes procedures like fiber blending and dyeing, reducing waste and resource usage. Digitally engineered yarns and 3D printing allow for tailored, supporting on-demand production and cutting overproduction in fashion.

### **Specialty effect in fancy yarn**

Metallic fancy yarns and lightweight hollow-core fancy yarn can be prepared by sustainable methods, reducing chemical use. Gradient and speckled effects on yarns can be obtained in eco-friendly ways. These new technologies help to add aesthetic beauty and, at the same time, maintain ecological integrity. Effects such as **Slub effects** are introduced using innovative digital controls in spinning to escape unwanted fiber waste. **Loop effects** are produced using reused fibers and closed-loop systems to lessen the use of chemicals. **Core-Spun Yarns** use a natural core fiber with an outer layer of recycled fiber for strength and sustainability. Core-spun yarn spinning adds elasticity and strength, enabling biodegradable or recycled components [10]. **Sustainable impart of novelty effects** focuses on the use of natural dyes and low-energy twisting methods to impart unique textures. Creativity in fancy yarn production can be achieved by AI-driven engineering and 3D printing techniques. By using advanced technologies, these methods allow customization while supporting eco-friendly practices.

### **Application of specialty yarn**

These eco-friendly specialty yarns are used across several industries, ensuring minimal environmental effects.

**Fashion and apparel:** Specialty yarns enhance luxury, activewear, and casual wear in an eco-friendly fashion. Organic cotton slub and recycled silk fibers add texture and luster to high-fashion garments, although recycled polyester and hollow yarns sustain moisture-wicking and lightweight designs in active wear. Hemp-blended and Tencel™ yarns are preferred for their rural charm and luxurious touch in knitwear.

**Interior Décor and home textile:** These yarns convey eco-friendliness and texture to home goods. Organic cotton and slub yarns are generally for upholstery and cushions, recycled wool works well in blankets and carpets, and banana and bamboo fibers are meant for sustainable curtains and rugs.

**Industrial and technical application:** Specialty yarns meet functional demands in several sectors. In automotive textiles, recycled PET and flax-blended yarns are utilized, while conductive fancy yarns and bioengineered fibers provide smart textiles and wearable technology. In medical uses, bamboo charcoal and chitosan-infused yarns offer antibacterial and moisture-wicking aids. [14]

**Handicraft and DIY sustainable fashion:** These yarns are ideal for crafting and decorative projects. Recycled cotton yarns are communal in knitting and embroidery, although eco-friendly ribbon and tape yarns are used for macramé and other art forms.

### **Smart & Functional Yarns**

**Thermo-regulating yarns** that use phase change materials (PCMs) regulate temperature. **Anti-bacterial fibers** are infused with bioactive material coatings or nanoparticles for prolonged freshness. **Light-responsive yarns** dyed with photochromic dyes

### **Consumer Preferences for Sustainable Fancy Yarns**

Modern consumers demand eco-friendly, ethical, and high-performance yarns with aesthetic appeal. Consumers increasingly prefer biodegradable, plant-based fibers like organic cotton, hemp, and agro-waste fibers. There is also major awareness of recycled materials such as recycled cotton, wool, and regenerated fibers like Econyl®. Transparent supply chains supported by blockchain and certifications like GOTS and OEKO-TEX® are becoming essential to meet ethical sourcing demands. [15]

Consumers concentrate on fully appreciable and transparent supply chains, and they prioritize permanence to reduce waste. They demand luxurious, soft, and breathable yarns with a natural feel and prioritize hand-spun and crafted fancy yarns. Nowadays, there are some innovative yarns in the market that have temperature regulation, UV protection, and moisture-wicking properties. Customers prefer lightweight materials for all-season wear. Increasing consumer consciousness and regulatory actions continue to fuel demand for sustainable innovations. [24]

### **Circular economy and waste reduction**

The industry holds circular economy principles by planning durable yarns, recycling textile waste, and minimizing resource use. Recycled fibers like PET and Econyl® are repurposed into high-performance yarns, while decomposable materials, such as PLA and hemp, decompose naturally. Techniques like 3D knitting and zero-waste spinning further reduce material loss. [17]

The circular economy is an essential concept in the textile industry, concentrating on sustainability, efficient resource utilization, and waste reduction. Specialty yarn manufacturing can implement circular economy principles by using recycled materials, closed-loop production, and eco-conscious processing. One of the key strategies in sustainable processing is using recycled fibers, such as post-consumer textile waste, plastic bottles (PET), and industrial remnants, to create superior-quality novelty yarn. By utilizing such materials, manufacturers reduce the usage of virgin fibers and lessen waste that would otherwise end up in landfills. Additionally, **closed-loop systems**, where used textiles are collected and processed again, it help in extending the lifespan of raw material and minimize resource exhaustion.

Another acute aspect of sustainability in yarn manufacturing is waste reduction. Implementation of zero-waste manufacturing techniques, such as lean production and digital automation, controls the efficient quality product. Re-spinning and Upcycling techniques further add to waste reduction. Another step toward sustainable practice is developing ecological and compostable yarns sourced from natural fibers such as cotton, bamboo, and hemp, which decompose naturally by the end of their lifecycle. By selecting sustainable materials and accountable manufacturing, the fancy yarn industry can reduce its ecological footprint while maintaining high quality innovative designs. These strategies along with circular economy principles, promote a more sustainable future for textile industry.

### **Market trends for sustainable yarn**

The global drive for sustainability is reshaping market trends, with consumers demanding eco-friendly specialty yarns. Brands are centering on transparency, novelty, and functionality to meet these outlooks.

North America and Europe chief the sustainable yarn movement, focusing on carbon-neutral textiles. Africa and South America emphasize locally sourced, fair-trade artisanal yarns, while Asia-Pacific shows growth in eco-friendly industrial yarn production

The market is flowing toward bio-based and lab-grown yarns, driven by better regulation and government directives. AI and automation investments are expected to elevate efficiency and sustainability in yarn production further.

### **Challenges and opportunities**

While manufacturers aim to embrace sustainable practices, they surface challenges such as high production costs, recycling margins, and consumer awareness, but these also present opportunities for revolution.

Sustainable yarns often cost more due to pricey raw materials and energy-efficient technologies. Mixed fiber fabrics are challenging to recycle, and inadequate infrastructure hinders textile waste processing. Supply chain transparency remains an issue with limited blockchain adoption. Additionally, consumer deception and greenwashing complicate awareness efforts.

Bio-based and lab-grown fibers, like lab-grown wool or agro-waste-based yarns, are gaining power. AI and automation enhance production efficiency, while efficient, sustainable yarns with properties like conductivity or self-cleaning meet rising consumer demands. Stricter government regulations and sustainability policies encourage investments in circular textiles and recycling creativities. Performance-focused sustainable yarns, offering antimicrobial, moisture-wicking, or smart functionalities, are rising in demand. Customization through AI-driven dyeing and 3D knitting enables unique textures, while the slow fashion and DIY movement lifts interest in natural hand-dyed and vintage-effect yarns.

## CONCLUSION

In this article, the greener future for the specialty yarn is focused. Sustainable raw material is the backbone for the sustainability of any product, so the sustainable fancy yarn industry is focusing on utilizing waste material and post-consumer waste. Innovations in fancy yarn production are altering the industry by accumulating sustainability, aesthetics, and functionality as a whole. The merger of eco-friendly materials, advanced spinning technology, smart yarn manufacturing, low-cost formulas, and digital technologies modernized the yarn manufacturing and introduced appealing effects and textures that enhanced consumer demand. Sustainable specialty yarns offer a perfect blend of fanciness and high performance, with valuable applications in wearables, home textiles, the automotive industry, smart textiles, and medical textiles.

As a Sustainable practice, eco-friendly dyeing and finishes should be used, such as waterless dyeing, natural dyes, and nontoxic finishes should be They will have a low environmental effect while giving high performance and quality standard.

The market for sustainable fancy yarn continues to increase in demand as consumers' preference for eco-friendly, high-performance, and ethical materials is increasing. For the industrial transformation, Companies start prioritizing regenerative economy, smart textile technologies, and discoverability. While meeting sustainability, industries start facing challenges like high costs, supply chain barriers, and technological limitations, which also make paths for novelty, growth, and efficiency. Brands would change the entire infrastructure of the textile industry's future if they focused on making eco-friendly products, circular solutions, and digital transparency. [9, 13, 16].

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