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**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH
TECHNOLOGY****KNITWEAR THROUGH THE LENS OF SUSTAINABILITY****Dr Sabrina Sareen**Assistant Professor, Fabric and Apparel Science (Department of Home Science), Lakshmibai College,
University of Delhi.**ABSTRACT**

The fashion industry is witnessing a growing demand for sustainable practices and eco-friendly materials in recent years. Knitwear, as a prominent sector within fashion industry, is undergoing a transformative shift towards sustainable strategies and technological advancements to address environmental concerns. This review article examines the use of organic and recycled materials, sustainable dyeing & finishing processes and waste reduction initiatives in knitwear manufacturing. It emphasizes the importance of circular economy models and explores how technological advancements, such as 3D knitting and virtual prototyping, are revolutionizing the sustainability aspect of knitwear industry. The article showcases the successful knitwear brands implementing sustainable strategies and technological innovations, resulting in reduced environmental impact and increased consumer appeal.

Keywords: Technological advancements, Sustainability, Smart Knitwear, Circular economy, Innovation.

1. INTRODUCTION

Knitwear and sustainability can become intertwined as the fashion industry increasingly recognizes the importance of circular economy principles [1,2,3]. As the demand for more responsible and environmentally conscious practices grows, knitwear brands are embracing sustainable approaches to address the needs of the circular economy. The circular economy model focuses on designing garments for longevity and recyclability, ensuring that materials and resources are utilized efficiently, and waste is minimized [4]. Knitwear, with its inherent versatility, durability [5], and potential for innovation, is well-suited to align with circular economy principles, by incorporating sustainable material. For sake of ease, the review article has been divided into four areas, reasoning out the appropriateness of knitwear for sustainability:-

The knitwear industry has witnessed several innovations in recent years

Ray demonstrates the growth of knitwear and how the knitwear industry has witnessed several innovations in recent years, driven by advancements in technology, sustainability concerns, and evolving consumer preferences [6]. Here are some notable innovations in the knitwear industry:

Seamless Knitting: Seamless knitting technology allows for the production of garments without traditional seams, resulting in a more comfortable and flexible fit [H]. Seamless knitting machines use computer-controlled processes to create garments in one piece, reducing material waste and improving overall efficiency. This innovation has led to the production of seamless sweaters, leggings, and other knitwear items.

3D Knitting: 3D knitting, also known as additive knitting or whole garment knitting, is a technique that enables the creation of fully-formed knitwear garments in one continuous process. Using specialized computerized knitting machines, complex designs and structures can be created with minimal waste, in coherence with sustainability. 3D knitting allows for customization, precise sizing, and intricate patterns, eliminating the need for cutting and sewing [7].

Smart Knitwear: The integration of smart textiles and wearable technology into knitwear has opened up new possibilities. Knitwear can now be designed with embedded sensors, conductive yarns, and interactive features.



Smart knitwear can monitor biometric data, regulate body temperature, provide haptic feedback, or even incorporate lighting elements [8]. These innovations offer enhanced functionality, comfort, and connectivity in knitwear garments. Some examples of companies embracing the technology to produce smart knitwear are Hexoskin, AiQ Smart Clothing.

Sustainable Fibres and Materials: Innovations in sustainable fibres and materials have transformed the knitwear industry. Organic cotton[9], recycled polyester[10], and regenerated fibres like Tencel® are gaining popularity as eco-friendly alternatives. These materials reduce reliance on non-renewable resources, minimize waste, and promote circularity in the fashion industry. Additionally, bio-based fibres derived from renewable sources like bamboo or hemp are being explored as sustainable knitwear options [11].

Digital Design and Production: The adoption of digital design tools and computer-aided knitting machines has revolutionized the knitwear production process. Designers can create intricate patterns, textures, and colour variations using software programs, which are then translated into machine-readable instructions. Digital design reduces the need for physical samples, accelerates the prototyping process, and enables more efficient production [12]. Research has brought forth examples of companies that have adopted the technology to minimise wastage –Nike Flyknit, Wool and the Gang, the Fabricant, Shima Seiki, Unmade, etc.

Sustainable Dyeing and Finishing Techniques: Traditional dyeing and finishing processes in the knitwear industry often involve the use of harmful chemicals and excessive water consumption. Innovations in sustainable dyeing and finishing techniques are being developed, including waterless dyeing, natural dyeing, and eco-friendly finishing processes [13]. These innovations aim to reduce the environmental impact of dyeing while maintaining high-quality and vibrant knitwear products. Patagonia, an outdoor clothing brand, has been a pioneer in sustainable practices. They have implemented waterless dyeing techniques in their knitwear production[14]. One of their initiatives is the use of a Carbon dioxide-based dyeing process [15] called ColourDry, which eliminates the need for water in the dyeing process, significantly reducing water consumption and pollution. Another example is the knitwear range of Eileen Fisher, that places a strong emphasis on sustainability. They have explored natural dyeing methods for their knitwear, by using plant-based dyes derived from sustainable sources, such as indigo, madder root, and turmeric dyeing process, significantly reducing water consumption and pollution.

Circular Economy Initiatives: The concept of a circular economy is gaining traction in the knitwear industry. Brands are exploring initiatives like take-back programs, upcycling, and recycling of knitwear garments. Some companies are designing garments with disassembly in mind, making it easier to separate different components for recycling or repurposing. These efforts aim to minimize waste and extend the lifespan of knitwear products. Research shows companies like Patagonia [14] encourage customers to extend the lifespan of their knitwear by providing free repairs for damages such as holes or loose seams. This initiative helps reduce waste and promotes the longevity of their knitwear garments. Additionally, Everlane clothing brand provides a recycling program called "ReNew" for customers to return their worn-out knitwear for recycling into new products. Finistree, a British apparel brand, prioritizes the use of recycled materials in their knitwear production, such as recycled wool and recycled synthetic fibers.

These innovations demonstrate the ongoing efforts to improve sustainability, functionality, and design in the knitwear industry. By embracing technological advancements and sustainable practices, the industry continues to evolve to meet the demands of a more conscious and discerning consumer base.

Knitwear, as a category of clothing, has the potential to be more sustainable

Knitwear can be regarded as a more sustainable choice for several reasons. Firstly, it utilizes materials efficiently, as yarns can be measured and tailored precisely, reducing waste and minimizing environmental impact. Additionally, knitwear is known for its durability, with well-constructed garments lasting for years, reducing the need for frequent replacements and decreasing overall consumption. The versatility of knitwear allows for multiple styling options, promoting a more minimalist wardrobe and reducing the demand for excessive clothing production [6,15]. Furthermore, many knitwear materials, such as wool and cotton, are recyclable and biodegradable, enabling garments to be repurposed, recycled, or naturally decomposed at the end. Here are some reasons why knitwear can be considered more sustainable:

Versatile and Durable: Knitwear garments, such as sweaters or cardigans, are often made from natural fibres like wool or cotton, or even from sustainable synthetic materials like recycled polyester. These fibres tend to be more durable, which means the garments can have a longer lifespan compared to some fast-fashion items. By lasting longer, knitwear reduces the frequency of replacements and contributes to a more sustainable wardrobe.

Efficient Production Process: The production process for knitwear typically involves fewer steps compared to other types of garments, such as woven fabrics. Knitting machines create the fabric directly, reducing the need for cutting and sewing multiple pieces together. This results in reduced waste of fabric and energy during the manufacturing process [17].

Recyclable and Biodegradable Fibres: Many knitwear garments are made from natural fibres like wool, cotton, or linen. These fibres are often recyclable or biodegradable, which means they can be repurposed or returned to the environment at the end of their life cycle. Recycling or composting these materials can help reduce waste and minimize the environmental impact.

Thermal Insulation: Knitwear, especially those made from natural fibres like wool, provide excellent thermal insulation, keeping the wearer warm and reducing the need for excessive heating in colder climates. This can contribute to energy conservation and lower carbon emissions.

However, it's important to note that the sustainability of knitwear also depends on other factors, such as the production practices, dyeing processes, and supply chain transparency of the specific brands and manufacturers. Additionally, while knitwear can be more sustainable, it's essential to consider the overall lifecycle impacts, including fibre sourcing, dyeing, transportation, and end-of-life disposal.

To make informed sustainable choices, it's advisable to look for brands that prioritize ethical and sustainable practices, consider the materials used, and evaluate the durability and care instructions of the knitwear garments.

Sustainability being embraced by Tirupur and Ludhiana knitwear manufacturing units -

Tirupur, located in the state of Tamil Nadu, India, and Ludhiana in Punjab [18] are known as a major centres for the production of knitwear garments. Sustainability has become an increasingly important focus within these manufacturing centres, driven by the need to address environmental concerns [19,20], improve working conditions, and meet the demands of conscious consumers. Here are some key aspects of sustainability in the Tirupur and Ludhiana knitwear industry:

Water Management: One of the significant sustainability challenges in the textile industry is water usage and wastewater management. Tirupur has made substantial progress in this area by implementing various measures. Effluent Treatment Plants (ETPs) have been established to treat wastewater generated during the dyeing and printing processes. Additionally, water recycling and rainwater harvesting systems are being adopted to minimize water consumption and reduce reliance on freshwater sources.

Energy Efficiency: The Tirupur and Ludhiana knitwear industry have been taking steps to improve energy efficiency and reduce greenhouse gas emissions. Manufacturers are investing in modern machinery and technology to optimize energy consumption during the production processes. Implementing energy management systems and adopting renewable energy sources[W], such as solar power, are also becoming more common practices.

Chemical Management: The knitwear industry has been working to reduce the use of hazardous chemicals in textile processing. This involves adopting safer alternatives, implementing strict chemical management practices, and ensuring compliance with international standards and regulations, such as the Restricted Substance List (RSL) and Zero Discharge of Hazardous Chemicals (ZDHC) guidelines.

Social Compliance: Sustainability in the Tirupur and Ludhiana knitwear industries also encompass social aspects, such as ensuring safe and fair working conditions for the labour force. Efforts have been made to improve worker welfare, including providing proper training, ensuring fair wages, and establishing grievance

mechanisms. Several knitwear manufacturers in Tirupur have obtained certifications like Fair Trade, SA8000, to demonstrate their commitment to social compliance.

Organic and Eco-friendly Materials: The knitwear industry has witnessed an increasing demand for organic and eco-friendly materials. Tirupur has responded by promoting the use of organic cotton, which is grown without the use of synthetic pesticides or fertilizers. The cultivation of organic cotton helps to reduce environmental impact and support the livelihoods of farmers.

Sustainable Certifications: Many knitwear manufacturers in Tirupur and Ludhiana are obtaining sustainability certifications to demonstrate their commitment to responsible practices. Certifications like GOTS, OEKO-TEX, and WRAP (Worldwide Responsible Accredited Production) are being pursued to ensure compliance with specific environmental and social standards.

The Tirupur and Ludhiana knitwear centres have made significant strides towards sustainability, addressing various environmental and social challenges [21,23]. However, it is an ongoing process that requires continuous improvement, innovation, and collaboration among stakeholders. By adopting sustainable practices, the industry aims to mitigate its environmental impact, improve worker welfare, and meet the evolving expectations of conscious consumers worldwide.

Emerging knitwear brands focussing on sustainability

In recent years, the fashion industry has witnessed a rise in emerging knitwear brands that prioritize sustainability as a core value. With their innovative designs and dedication to principles of circular economy, these emerging knitwear brands are paving way for a more sustainable future in the fashion industry. Here are a few examples of knitwear companies that have started their sustainable journey:

Wool and the Gang: Wool and the Gang is a knitting brand that began in 2008 but gained significant traction and popularity around 2016. They offer sustainable knitting kits and ready-to-wear knitwear made from eco-friendly yarns, such as recycled denim and sustainable alpaca wool [22].

Study NY: Study NY is a sustainable fashion brand founded by designer Tara St. James. While the brand encompasses a broader range of clothing, they have incorporated sustainable knitwear into their collections since their inception in 2009. Study NY focuses on ethical production, uses natural and organic materials, and promotes slow fashion principles.

Jan 'n June: Jan 'n June is a German fashion brand that started in 2014 but gained recognition for its sustainable practices around 2016. They offer a range of knitwear garments made from organic and recycled materials. Jan 'n June places emphasis on transparency, fair working conditions, and responsible production.

Reformation: Reformation, a sustainable fashion brand, expanded its offerings to include knitwear in its collections in the mid-2010s. While the brand was established in 2009, its focus on sustainable practices became more pronounced around 2016. Reformation utilizes eco-friendly materials, implements sustainable production techniques, and emphasizes transparency in their supply chain.

These examples highlight a few knitwear brands that either emerged or intensified their sustainable practices over the last decade. It's important to note that the specific focus on sustainability and the timeline of each company's journey may vary.

2. CONCLUSION

The redefinition of knitwear through sustainable strategies and technological advancements represents a promising pathway towards a more environmentally conscious fashion industry. By embracing organic and recycled materials, implementing efficient manufacturing processes, and fostering a circular economy, the knitwear sector can contribute to the overall sustainability goals of the fashion industry while meeting consumer demands for responsible and stylish clothing.

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