FTC 2025

Book of Abstracts of the 4th International Conference on Functional Textiles & Clothing

Edited by
Deepti Gupta, Abhijit Majumdar & Sanjay Gupta

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PREFACE

Welcome to the Book of Abstracts of the International Conference on Functional Textiles and Clothing, FTC2025. This compilation represents the cutting edge of textile research and innovation, showcasing groundbreaking work from researchers, scientists, and industry professionals worldwide. The textile and clothing sector stands at a fascinating crossroads of tradition and innovation. As we face unprecedented global challenges—from climate change to resource scarcity—the sector is responding with remarkable ingenuity and responsibility. This collection of abstracts reflects this dynamic evolution, spanning diverse domains from advanced materials to circular textile systems.

Within these pages, readers will discover the latest developments in sustainable raw materials, demonstrating our collective commitment to environmental stewardship. The growing intersection of technology and fashion is evident in contributions exploring digital fashion and smart textiles, while our dedication to inclusivity shows through research on adaptive clothing for special needs.

The abstracts strike a fine balance between innovation and heritage, as demonstrated by studies on traditional textiles alongside cutting-edge protective and technical textiles. The breadth of topics covered—from composite materials to circular textile systems—underscores the interdisciplinary nature of modern textile research. These abstracts represent not just academic exercises but practical solutions to real-world challenges, from enhancing user comfort to reducing environmental impact.

The FTC conference series, initiated in 2018 as a collaborative event of IIT Delhi and WUD Sonipat, has established itself as a premier global platform. The previous editions of FTC have witnessed the participation of an average of 80+ universities worldwide, drawing 225+ delegates from 20 odd countries, presenting ~150 research papers. This unique collaboration has created a platform where engineers, designers, researchers, and industry leaders can engage in meaningful dialogue and forge partnerships. As we continue to push the boundaries of what's possible in functional clothing, FTC 2025 promises to be a catalyst for collaborations that will define the next generation of textile innovations.

As you explore these abstracts, we invite you to envision the future of functional textiles and clothing – a future where technology, design and textiles work in harmony to enhance human potential. We extend our deep gratitude to all contributors, reviewers, and participants who make FTC a vibrant platform for knowledge exchange. We also acknowledge the help of Dr. Vidushi Vashishtha in putting this volume together. Special thanks are due to the A2K+ program of DSIR for supporting the conference and the publication of the Book of Abstracts.

Welcome to FTC 2025, where we continue our journey of innovation, collaboration, and discovery.

Deepti Gupta   Abhijit Majumdar   Sanjay Gupta
Editors

सत्यमेव जयते

वैज्ञानिक और औद्योगिक अनुसंधान विभाग

Department of Scientific and Industrial Research

The Department of Scientific and Industrial Research (DSIR), under the aegis of the Ministry of Science and Technology, GoI was set up through a Presidential Notification, dated 4th January, 1985 (74/2/1/8 Cab). The mandate of DSIR is to promote industrial research for indigenous technology development, promotion, utilization and transfer. The Department of Scientific & Industrial Research (DSIR) operates the Umbrella Scheme on "Industrial Research & Development (IRD)" consisting following four sub-schemes : (i) Common Research and Technology Development Hubs (CRTDHs); (ii) Patent Acquisition and Collaborative Research & Technology Development (PACE); (iii) Access to Knowledge for Technology Development and Dissemination (A2K+) and (iv) Promoting Innovations in Individuals, Start-ups and MSMEs (PRISM). Access to Knowledge for Technology Development and Dissemination (A2K+) 'Support to Events' (seminars, workshops, conferences, exhibitions etc.) - provides a platform for exchange of views leading to useful insights on issues relating to industrial research DSIR has partially supported the conference under Event Program of Access to Knowledge for Technology Development and Dissemination (A2K+) Scheme of DSIR.

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Biomimicry: An Approach to Innovation in Textiles

Tushar K. Ghosh
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Abstract

The natural world around us provides excellent examples of functional materials, structures, mechanisms, and systems that have evolved to adapt highly sophisticated problem-solving methods. The practice of learning from nature, or biomimicry, has been explained as “the conscious emulation of life's genius.” [1]. Biomimicry is the incorporation of these natural principles by designers and engineers to create something efficient in its raw material usage that functions optimally. This approach is not just about drawing inspiration from nature, but about creating tangible benefits. The foundation of biomimicry is based on the belief that nature follows the path of least resistance and consumes the least energy while using the most common materials available to perform a task. Throughout time, nature has evolved to develop highly sophisticated and efficient solutions, such as superhydrophobicity, self-cleaning, self-repair, energy conservation, drag reduction, dry adhesion, adaptable growth, and many others, in response to contemporary needs. Some of these solutions have inspired humans to achieve outstanding outcomes; fishing nets mimicked after spiders' webs have been in use for thousands of years, and the strength and stiffness of the hexagonal honeycomb shape have been adopted for use in lightweight structures required in airplanes and in other applications [2]. Whether it be specialized riblets on the surface of a shark's skin to help them achieve high swimming speeds [3] or functionally gradient materials found in animal and plant species with remarkable properties to meet demanding functional requirements for many contemporary engineering problems [4], nature can provide scientists efficient, time-tested and unique ideas of achieving a goal. There are numerous examples of functional surfaces, fibrous structures, structural colors, self-healing, thermal insulation, etc. that offer important lessons for the textile products of the future.

While the paper underlines the need for sustainable design (and manufacturing) and consumption of textiles, It examines specific examples of a few bio-inspired textile structures. The paper argues the need for biomimicry by highlighting a few inherently sustainable biological systems that may be adapted to fit current textile technologies/products. The subsequent discussion focuses on the continuing effort at the SMARTextiles laboratory at NC State University toward developing multifunctional fiber and textiles. These include fiber-based actuators and mechanically gradient composites [5,6].

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Towards a Data-driven Modelling of Textile Recycling Value Chain: Applying a Three-dimensional Concurrent Design Perspective

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Recycling as a circular manufacturing option has gained prominence in the textile industry within the scope of circular economy, due to the growing volume of post-consumer textile flow that is unfit for reuse, and to avoid landfill [1]. Globally <13% of post-consumer textiles are being recycled, and current valorisation is hindered by challenges at product-process-supply chain levels. Pivotal to scaling up textile recycling is designing a well-functioning system that can handle the growing volume of textile waste flows [2], and its logistics, improve feedstock and process quality through standardization and optimization, and align demand and supply in conjunction with end market needs; in other words, design and configure a complex textile recycling supply network optimally. Crucial to designing such optimal system and configuring its supply network is a three-dimensional concurrent engineering (3-DCE) perspective, which presumes that product, process, and supply chain variables should be identified and designed simultaneously, including concurrent development of required capabilities [3]. Previous research (e.g. [4]), have highlighted the significance of developing and designing data-driven supply network models in context to circular manufacturing, unveiling the need to detect the main categories of data, i.e. product, process, stakeholder management, and technology, and understand how to structure it, to support the underlying decision-making process.

Considering, the essentiality of understanding data categorizes underpinning the supply network design, the purpose of this paper is to explore and map the specific supply chain, product and process data contingencies and their inter-relations, in context to textile recycling. A new conceptual data model has been developed taking in account and integrating the extant literature to provide a holistic view on textile recycling from a supply network design perspective. First step of the model development involved identifying the supply network design aspects. Given the sparse literature on textile recycling practices and the specific characteristics, from a supply chain management perspective, an inductive interview study with semi-structured questions was deemed to be an appropriate and relevant approach. 20 semi-structured interviews were conducted online during spring 2022 with textile recycling supply chain players from Europe, that included collectors, sorters, recyclers, with substantial activities with respect to textile recycling, including a variety of different collection modes, automatic sorting, and chemical recycling. As a second step, a data mapping model was established by forming a matrix of the identified supply network design aspects from step 1 and the 3-DCE levels (product, process and supply chain). For developing the reference conceptual data model, a literature review was employed to adopt an interpretative approach to detect and categorize different data types, and through an inductive reasoning position them under different categories in the

matrix. A final step involved validation/refinement of the data model through empirical study conducted as experts' interviews and Delphi. From the first step of the study via interviews, 11 supply network design aspects evolved. While several of these design aspects were specific to a particular stage in the supply chain (collection, sorting or recycling), such as collaborative collection, efficient sorting operations, or matchmaking recycling and market requirements, other aspects were multi-stage and related to determining geographical scoping and location of different actors, creating traceability and information management systems, and scaled infrastructure and transportation network management.

The second step, based on the extant literature, enabled identification and categorization of different data types at the product, process and supply chain (3-DCE) levels. Among the different data categories, the most crucial ones are: (i) number of supply chain tiers and members, and geographical distances in-between; (ii) inventory/stock and material flow at each tier; (iii) process yields and conversion rate based on sorting/recycling technology; (iv) demand volume and feedstock variety and variability in terms of material, colour etc, and (v) costs and prices based on market conditions. Other external data categories relate to textile waste export-import mechanisms, such as taxation and recycling standards. This paper defines and develops a conceptual model underpinning a data-driven designing of textile recycling supply network from a 3-DCE perspective. Such a conceptual data model can enable to organize and structure data and information covering the textile recycling business needs, and aid in solving complex decision-making problems inherent to novel supply networks as observed in textile recycling context due to the ongoing reconfiguration/configuration due to the demands of scaling textile circular manufacturing. In circular manufacturing context, some attempts to structure data and integrate different data sources have been done before (e.g. [5]). However, by applying the 3DCE perspective to categorize the different types of data required to design 11 different aspects in textile recycling networks we offer a more modular and granular understanding of systems through data models and ontologies, as also highlighted by [6].

Our study partly adopts a design science approach, where the research process started with inductive interviews to interpretatively 11 supply network design aspects in textile recycling context, followed by literature review performed to detect and categorize the data types required to design a modular and granular textile recycling system. However, we did not follow-up with the final phase of design science approach, that is validating and refining the model through experts' interviews. Future research is required to perform empirical validation of the data-driven model proposed and use it further for decision-making purpose. The conceptual data model developed in this paper can guide the stakeholders (collectors, sorters, recyclers, manufacturers, and retailers) in getting more nuanced understanding of how to design textile recycling supply networks, and what data types are crucial to improve process efficacy and optimize recycling networks and align with market needs. The model offers an ontological framework that can be applied to designing recycling networks in other comparable industrial value chains.

Keywords

Supply network design, 3-DCE, Textile recycling, Data model, Circular manufacturing.

Acknowledgments

We would like to thank (i) Formas (a Swedish Government research council for sustainable development) (registration number: 2022-02222) and Department of Science and Technology (DST), Government of India, for jointly funding the work and research presented in this paper, within the scope of RESORTEX project.

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DIGITAL FASHION

Digital Sports Fashion as a Successful Concept of Physical Self-Optimization

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Research Problem

Physical sports clothing provides its users with a variety of functions to perform certain movements and activities. At the same time, the textile material offers a visible surface that can be enriched with other features that play a particularly important role in digital sports fashion. This article focuses on virtual sportswear, i.e. images of clothing shapes that are used in training apps to visualize the avatars of the people exercising. Freedom of movement through elastane components, wearing comfort through cutting and seam processing, and sweat transport through synthetic fiber blends or ventilation inserts are also simulated on the screens [1]. With the help of virtual reality tools during a training session, digital sports clothing is used to represent the needs of the people exercising in a way that is more responsive and visible to the community.

Aim of Research

This article argues from a media and social science perspective how reality with its physical properties and the immersive world are connected through the representation of digital sports fashion and its simultaneous perception on a screen. Can the visible simulated attributes of digital sports fashion influence the real training experience and which additional tools enable the support of physical self-optimization? [2]

Materials and Methods

Screens are analyzed by using the online user platform Zwift [3] for virtual cycling and running training as an example. With the help of a multi-level image context analysis according to selected categories, it is shown that the specific functions of the physical textile functional clothing can be found in the display of the virtual jerseys on the screens. This analysis is complemented by exploratory qualitative interviews with active users of the training app who are asked about their user experiences and the effects of their training routines.

Results

Real-time, computer-generated, interactive virtual environments serve to combine physical body action and immersive experiences. The virtual jerseys are independent products that are mass-produced in a radically shortened supply and value chain [4], but still based on the material conditions of the textile jerseys. This new constellation allows online users not only to look at their own moving avatar and training performance, but also at those of the other users. The virtual jerseys are now located in unreal places, in social spaces and in artificial situations. However, the decoding of the simulated jerseys is still based on traditional conventions of representation and perception. The users are subject to the conditions of the unreal space because they have to follow the given instructions and accept the narrative framework so that the training action can take place online. The article discusses how the use and reception of the virtual jerseys not only creates an online community for mutual observation and control [5], but also makes immersive experiences and active recreation possible as a result of the technical and economic framework conditions.

Related Discussion

The virtual jersey is fundamentally ambiguous. Its range of meaning is tied to the production and use of the app. Promises made to users for using the app result in expectations intended by the provider. These include a personalized training program, a varied training track and an interested online community [6]. At the same time, the virtual jersey occupies the largest screen area of the avatar and is therefore the most visible element. When avatars are dressed in the same virtual jerseys, this leads to social moments of exchange, confusion, rejection or belonging on the screens.

Conclusions

Digital sports fashion derives from familiar and traditional consumer practices and socio-cultural patterns of action in several ways. Finally, this article proves that, just like the functional textile material, its simulation on the screen is also geared to physical usage scenarios, enables belonging and distinction in the community and drives the human organism to physical self-optimization, self-care and performance improvement.

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Advent of Digital Fashion and Virtual Prototyping

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Abstract

Fashion operates at the crossroads of art, technology, and cultural expression, continuously evolving to reflect and shape societal values. At its core, fashion is a medium that interacts with the human form, drawing on fabric characteristics, draping techniques, and silhouette creation to craft narratives that captivate and provoke. While traditional methods of garment construction rely heavily on physical materiality and craftsmanship, contemporary advancements in digital tools have opened new frontiers for experimentation, redefining the interplay of form, function, and aesthetics.

Digital fashion is rapidly emerging as a transformative force in the fashion industry, driven by advancements in technology and shifting consumer behaviours. The term describes a practice that involves creating three-dimensional virtual clothing, which can serve as prototypes or simulations for potential physical garments, data-driven digital representations, or digital-only fashion.This paper explores the intersection of digital fashion and technology, focusing on the 3D design development, simulation, real time experience, augmented reality, virtual photography, material digitisation and more.

We analyse how digital fashion is reshaping design practices, altering consumer interactions, and addressing sustainability concerns. By reviewing current industry trends, technological innovations, and case studies from leading digital fashion platforms, the research provides a comprehensive overview of the field's growth and potential.

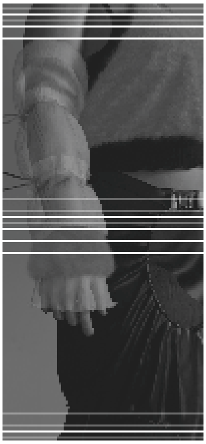

Figure 1: Digital Grament designed by Yasmin Koppe for The Interline DPC report 2024

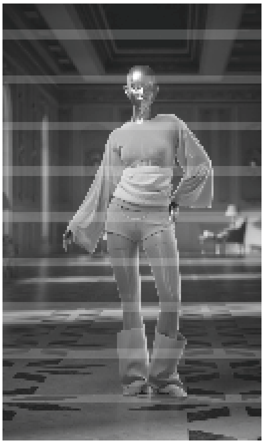

Figure 2: Designed by Diane Wallinger, for The Interline DPC report 2024

The integration of digital tools is enabling designers to simulate realistic drapes and textures with unprecedented accuracy. Sayem et al. (2023) define digital fashion as a fusion of technology and design that tracks developments in 3D modeling, virtual reality (VR), and augmented reality (AR). These innovations not only enhance the precision of garment simulation but also broaden the scope for experimentation with fabrics and forms. CLO3D, a virtual fitting software, exemplifies these advancements, as highlighted by Huang and Huang (2022), who investigated its application in simulating down jackets. Their research underscores the dynamic interplay between cloth behavior and digital environments, reinforcing the importance of understanding material characteristics in virtual design processes.

The apparel 3D software's are built around simulating "Ready to Wear", which means their tools and algorithms are aimed at representing basic structured fabrics and silhouettes. Integrating tactile experiences into digital fittings, is still at a nascent stage in order to create a complex silhouette or a true digital twin.

To test the boundaries of design development in digital fashion The CLO3D (version CLO2024.1) 3D design and simulation software is used to tests the ability of digital simulation to move beyond two-dimensional patterns-based design development to a more complex and evolved fashion silhouette, crafting sculptural, spatial structures around the body that are otherwise achieved by complex pattern manipulations or draping techniques by hand (Fig. 5).

Figure 3: Draped Design by hand

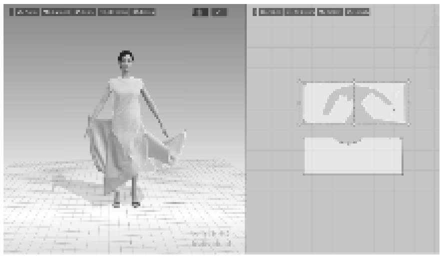

Figure 4: CLO3D workflow

Figure 5: CLO3D Animation, enhanced using Leonardo AI

According to the latest Interline DPC report of 2024, the digital product creation beyond fashion has been more widely adopted compared to digital fashion. Although currently a lot of emphasis is being put on to integrate or keep the digital platforms in open formats for interoperability, there is still a technology gap. In the design of hard products, files are created for production that use surface or volumetric 3D modelling, while rendering and animation 3D technologies are based on polygons. There will be some point in the process where we will need to convert between formats. The research will delve into use of digital product creation tools specially the animation & gaming software's ability to support, contribute and collaborate with digital fashion software's to check interoperability, integration and achieve desired results in terms of fashion silhouette.

Softwares like Autodesk Maya, ZBrush and Marvellous allow you to sculpt and render desirable shapes without being restricted by principles of garment construction, enabling designer to be creative with ideation. Ability of these softwares to the integrate sculpting, topology design, and garment simulation is looked into to achieve a streamlined workflow for creating custom garments. Clo3D requires its avatars to adhere to predefined measurement systems, limiting its flexibility with custom body meshes(Fig. 6).The body avatar from CLO3D is replicated by sculpting using Autodesk Maya (Fig. 7) and body contours are created (Fig. 8) by making a mesh on the body (Fig. 9). The 3D patterns for these contours are created using extraction tool on Maya.

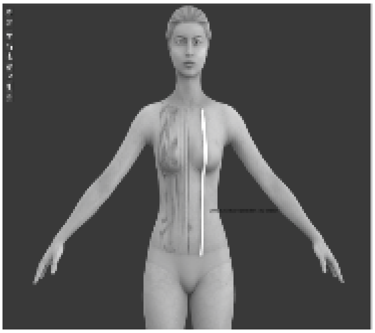

Figure 6: CLO3D experiments to develop body mesh to generate vertical body contours.

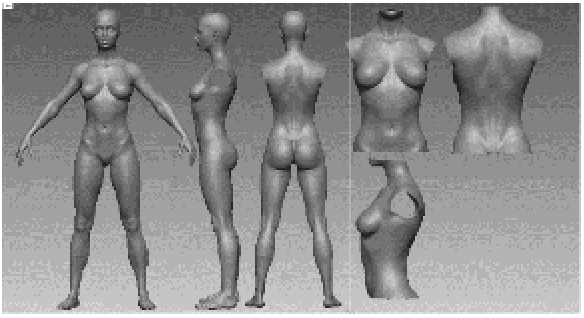

Figure 7: Model sculpted in ZBrush

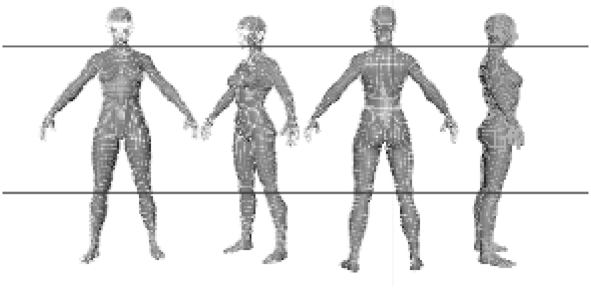

Figure 8: Body contours grid developed using Autodesk Maya

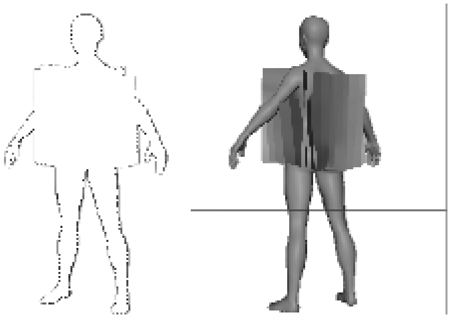

Figure 9: Contour Patterns development using AutoDesk Maya

While software like ZBrush, Maya, and Marvelous Designer provide robust features, the transition between these platforms requires nuanced understanding and meticulous execution to overcome technical limitations.This research highlights the process of building a custom human figure, adapting its topology for garment patterns, and simulating garments in a digital environment while addressing limitations in edge flow, compatibility, and design flexibility.

Our findings highlight the opportunities and challenges presented by digital fashion, including design development, environmental impact, and the future role of physical garments. This research contributes to a deeper understanding of digital fashion's role in the evolving landscape of fashion and its implications for designers, consumers, and the industry at large.

Keywords

3D virtual fashion design technology, Digital Fashion, Digital Product Creation, CLO3D, Virtual Garment Simulation, 3D Contour Patterns, Sustainable Fashion Design, Digital Draping Techniques, Sculptural Aesthetics in Fashion.

Weblinks

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Keywords

3D virtual fashion design technology, Digital Fashion

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AI in Fashion System- Design to Customer Feedback

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The fashion industry is rapidly embracing artificial intelligence (AI) technologies to streamline processes, enhance creativity, and improve customer experiences across the entire product lifecycle. This paper provides a comprehensive overview of AI applications in the fashion system, from trend forecasting and design to production, marketing, retail operations, and customer feedback integration. The role of AI in trend forecasting through data mining and predictive analytics is explored, along with its contribution to the design process via generative design, virtual prototyping, and design ideation. The paper explores how AI driven techniques such as demand forecasting, supply chain optimization, and intelligent automation are transforming apparel production and inventory management. Furthermore, the paper investigates AI's impact on marketing strategies, including targeted advertising, customer segmentation, and personalised recommendations. It also delves into AI-powered in-store experiences, such as smart fitting rooms, visual merchandising, and real-time inventory tracking. Importantly, the paper highlights the potential of AI in facilitating a closed-loop system by incorporating customer feedback and preferences into the design and development processes. Finally, it provides insights into the future of AI in fashion, addressing challenges and opportunities for further integration and innovation. Overall, this paper offers a holistic perspective on the transformative power of AI in reshaping the fashion industry, from design inception to customer engagement, and its potential to create a more sustainable, responsive, and customer-centric fashion ecosystem.

Keywords

AI, fashion, trend forecasting, generative design, virtual prototyping, market analysis, demand forecasting, supply chain optimization, intelligent automation, targeted advertising, personalised recommendations, smart fitting rooms, closed-loop system, sustainable fashion, customer-centric design.

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Modelling a Sustainable Mass Customization Apparel Development System Integrating Dynamic Target Sizing and Automated CAD Generation Using Malaysian Anthropometric Data

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Research Problem

In the globalized market environment, the sizing systems within the apparel industry exhibit significant differences between brands and countries. Despite the existence of international sizing standards and the increasing practice of brands including size conversion charts for different countries on their product labels, the sizing standards used in mass production fail to accurately reflect the actual needs of the brand's target market and customers. This discrepancy arises because consumer body shapes are more diverse and complex than the size ranges established by brands. Due to the lack of sizing standards that are closely aligned with the target market and customer groups, brands face two key issues: first, the size ranges produced do not match the actual needs of consumers; second, brands cannot avoid producing sizes that are unsuitable for their target customers. This lack of precision not only exacerbates inventory buildup and overproduction but also leads to resource waste and environmental pollution, thereby hindering the sustainable development of the apparel industry. Furthermore, traditional apparel product development models are inefficient and lack flexibility. During the development process, repeated modifications to designs and patterns often necessitate multiple revisions and remakes of prototypes. This iterative process results in the wastage of significant amounts of paper, fabric, and labor, which not only increases production costs but also extends the time required to bring products to market. This inefficient development model makes it difficult for brands to respond quickly to changes in market demand, placing them at a disadvantage in the highly competitive market.

Research Objective

This study aims to develop a sustainable mass customization apparel development system that integrates dynamic target sizing and automated CAD technology. The research will utilize Malaysian anthropometric data.

RO1: To investigate the diversity of consumer body shapes and the relationship between body shape and sizing.
RO2: To develop a dynamic sizing model tailored to the target market and customer groups.
RO3: To integrate automated CAD technology with the dynamic sizing system.
RO4: To model a sustainable mass customization product development system.
RO5: To evaluate the efficiency of the new product development system.
RO6: To assess the impact of the new product development system on sustainable development.

Research Contribution

The core of this research lies in developing a mass customization apparel development system that integrates dynamic target sizing with automated CAD technology to more accurately meet the diverse body shape needs of consumers. Traditional sizing systems struggle to accommodate the complexity of different markets and customer groups, whereas the dynamic sizing system developed in this study can flexibly adjust size ranges based on actual data, thereby improving garment fit and consumer satisfaction. Additionally, the research utilizes Malaysian anthropometric data, providing more tailored sizing standards for the local market and offering valuable insights for other similar markets. By optimizing the apparel development process, this study effectively reduces the resource waste caused by repetitive design modifications and prototype iterations, while also shortening the time to market. This efficient and flexible development system contributes to reducing resource consumption and environmental pollution, thus promoting sustainable development in the apparel industry. Consequently, this research not only advances apparel customization technology but also makes a significant contribution to the industry's sustainable development. By constructing a sizing system based on Malaysian anthropometric data, the study fills a gap in regional body shape research, enhancing garment fit and consumer satisfaction. Furthermore, by integrating automated CAD technology with dynamic sizing for the first time, it significantly improves the flexibility and efficiency of apparel development, while also providing an innovative approach to reducing resource consumption and environmental impact through the minimization of unnecessary production and inventory.

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Examining Already Established Mass Customization Set-up in the Apparel Industry: Suggestion and Case Study

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Research Problem

Currently, academic research is limited in examining mass customization in terms of the technologies [1] [2] [3] [4] [5] [6], challenges and critical successful factors [7] with the providing of a set-up for mass customization in fashion industry [8] not so much recent research has been done specifically in the field for apparel industry. Additional limitations of previous LTR research include the failure to measure the process modularity of mass customization that has been suggested for years, hence a lack of examination in terms of the feasibility of the process with respect to the suggestion of some improvement. The purpose of this study is to explore the already established mass-customization of one the top apparel manufacturers of India and provide a comparison on the basis of mass production and mass-customization along with some suggestion on the observation based in the industry.

The remainder of the paper is organized under Literature Review on mass-customization, Industrial Case: Raymond Ltd. (Made to measure), Improvements to be Considered for current MC, Future improvements, Summary and Conclusion.

Aim of the Research

Based on suggestions made over the years to ensure that mass customisation is successful for an organisation, this paper examines mass customisation for one of the top manufacturing company in India that is Raymond Ltd. in terms of process adaptability, product design, and customisation in the supply chain. Through the use of a real-world case study, we examine if the terms that have already been suggested for a successful mass customisation are actually applied. If not, we explore what steps have been taken and what may be improved going forward. We point up the obstacles and vital elements of success for putting garment MC into practice. Fashion MC Systems have several key technologies that we identify. Additionally, we suggest possibilities for future investigation of MC operations with the changing technologies in the apparel industry.

Keywords

Mass-customization, case study, Custom-fit, co-design, system dynamics, modularity

Method

A detailed review of Raymond's made-to-measure section outlining the measures taken to achieve mass customization with respect to custom-fit has been provided. Raymond Ltd. is considered a pioneer in mass customization, having established a stable new supply chain for MC, while Arvind, a well-known brand, struggled to make a significant profit. The following section of this article outlines enhancements that should be taken into account for the existing MC based on observations made regarding the manufacturing process's adaptability, the product mix and design, supply chain modification, and performance measurement via data analysis. At last, based on the upcoming terminology and technology, future improvements have been provided.

Conclusions Insights Future Research Direction

The study presented in this paper provides us a good picture that helps us to differentiate between what was proposed and what has been implemented actually. There might be some limitation which definitely needs to be addressed that is, since the paper focuses on a single MC fashion company, the results of the case study may lack generalizability. Due to this, we can only concentrate on a limited number of informants.

According to the findings derived from literature review and suggestions provided for existing methods, future research directions have also been suggested. However, it is important to keep in mind that after applying the proposed changes, the operations consequently change a bit or even turn to another way, which requires more attention.

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Consumer Tech-gagement in Fashion Retailing in Online & Offline Purchases Using Augmented Reality in Delhi

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Online shopping has become more and more popular, influencing almost every type of business in the globe. Online brands' ability to successfully implement modern technologies will determine their future success. Although online platforms offer a quicker and more convenient way to shop, they have not been able to provide users with the actual shopping experience. Technology like augmented reality (AR), which gives online as well as offline selling platforms a whole new dimension, are moves in the right direction. How extensively customers in Delhi will adopt this technology and what factors influence their relative preference for AR are just a few of the unanswered concerns. The purpose of this study is to identify the variables impacting the customers' adoption of augmented reality while buying online & offline. The elements that include personality, a willingness to innovate, technological savvy, and shopping experience Measurements of seeking behavior were made with the 125 participants in the online survey. Standard deviation was employed for the analysis of the gathered data. According to the findings, those who enjoy making regular online purchases and who are gadget lovers are more likely to experiment with augmented reality.

Keywords

Augmented Reality, online, offline, technology, consumer behavior

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Fashion's Digital Renaissance: AR as a Catalyst for Cultural Preservation

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Research Problem

The contemporary fashion industry frequently encounters challenges in effectively conveying the cultural significance and intricate design elements of garments to consumers. Traditional methods, such as physical stores and online platforms, often fall short in providing a comprehensive and immersive experience. This limitation hinders consumer engagement and understanding, ultimately impacting the industry's ability to connect with its audience.

Research Aim

This research endeavored to develop a novel approach that would bridge the gap between consumers and the rich cultural heritage embedded in fashion design. By harnessing the capabilities of augmented reality (AR), the primary objective was to create a virtual platform capable of offering a detailed exploration of garments, elucidating their cultural significance, and fostering a deeper connection between the consumer and the fashion industry.

Methodology

To achieve this ambitious aim, a multifaceted methodology was employed. Cultural motifs and techniques from diverse regions of India were meticulously selected to serve as the foundation for unique and culturally resonant garment designs. Advanced 3D modeling software was utilized to meticulously craft realistic and detailed 3D models of the garments, capturing their intricate designs and textures. An AR application was subsequently developed using a suitable platform, enabling users to interact with the 3D models in real-time and access supplementary information through their smartphones. QR codes were strategically integrated into the garment designs, acting as gateways to the AR experience. Audio descriptions were meticulously crafted to accompany the AR experience, providing in-depth insights into the design elements, cultural significance, and historical context of the garments. Finally, pertinent retail details, such as price and availability, were incorporated into the AR interface to offer consumers a holistic shopping experience.

Findings

The research culminated in the successful development of an innovative AR-based platform that offers consumers a comprehensive and engaging experience. This platform empowers users to:

Explore Garments in Depth: Users can meticulously examine the 3D models of garments from various perspectives, zoom in on specific details, and appreciate the intricate craftsmanship.

Learn About Cultural Significance: Audio descriptions provide invaluable insights into the cultural context and inspiration behind the garment designs, fostering a deeper connection between consumers and the fashion industry.

Engage with the Fashion Industry: The platform offers a personalized and interactive shopping experience, encouraging consumers to explore diverse options and make informed decisions.

Discussion

The findings of this research unequivocally demonstrate the transformative potential of AR technology in the fashion industry. By providing consumers with a more immersive and informative experience, AR can significantly enhance engagement, foster a deeper appreciation for cultural heritage, and drive sales. The platform developed in this research serves as a pioneering model for future AR applications within the fashion industry.

Conclusion

This research successfully developed an AR-based platform that offers consumers a comprehensive and engaging means of accessing knowledge about garments and their cultural connections. By synergizing 3D modeling, AR technology, and audio descriptions, the platform provides a holistic and immersive experience that significantly enhances consumer engagement and satisfaction. The findings of this research underscore the transformative potential of AR in reshaping the fashion industry and creating novel opportunities for both brands and consumers alike.

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AI-Powered Design: Boosting Sustainability and Cost Efficiency in Kids' Garment Manufacturing

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In the realm of children's garment manufacturing, the integration of AI tools presents a transformation opportunity to enhance sustainability and cost efficiency. This research investigates the impact of AI-driven design optimization on reducing waste, thereby mitigating manufacturing costs while benefiting both manufacturers and customers. Focused on age groups 1-3, 4-6, and 7-10, this study examines the current manual cutting and sewing operations in the garment industry and identifies the substantial waste generated during these processes. By implementing AI tools for design optimization, significant reductions in cutting waste are achieved, leading to a noteworthy decrease in manufacturing costs. This paper explores the mechanisms through which AI facilitates precise material utilization, pattern optimization, and customization, resulting in improved resource efficiency and profitability. Moreover, the economic benefits accrued from reduced manufacturing costs are passed onto customers, enhancing affordability and accessibility to high-quality children's garments. The findings of this research underscore the potential of AI-driven solutions to revolutionize garment manufacturing practices, aligning with sustainability goals and fostering economic advantages for both industries.

Keywords

AI tools, Children garments, Reduce waste, Cutting, Design, Garment manufacturing

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EDUCATION AND ERGONOMICS

Declining Demand for Professional Textile Design Programs in Indian Higher Education Institutions

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The evolution of formal education in Arts and Design in India reflects a rich tapestry of cultural heritage, colonial influences, and time-to-time responses to contemporary global trends. In ancient India, artistic and design education was predominantly informal, with skills and knowledge passed down through generations within families or guilds. Traditional arts such as sculpture, painting, textiles, and architecture were closely tied to religious and cultural practices. Educational systems were largely based on apprenticeships and master-apprentice relationships, where students learned through direct practice and observation. The advent of British colonial rule marked a significant turning point in formal education in Arts and Design in India. The colonial period introduced Western-style education and established institutions that began to formalize and systematize art and design education. After India gained independence in 1947, the focus shifted towards creating an indigenous educational framework that reflected India's cultural heritage while integrating modern practices. Several state-level art and design institutions were established, catering to local artistic traditions and contemporary needs. There was a concerted effort to preserve and revitalize traditional Indian arts and crafts through formal education. Institutions like the National Institute of Design incorporated traditional techniques into modern design curricula, promoting a fusion of old and new.

In the above context, Textile design has held a pivotal role in the Indian design education sector since its inception. India has a rich tradition of textile arts, from intricate handloom weaving to vibrant embroidery. Textile design education has always helped preserve and promote the rich textile traditions, ensuring that they continue to thrive in a modern context. The landscape of arts and design education in India has expanded significantly in the past few decades, with numerous private and public institutions offering specialized programs in design. In recent years, Indian higher education institutions have witnessed a significant decline in the demand for professional Textile Design programs. Aspiring designers are increasingly drawn to more popular design fields such as fashion design, product design, and graphic design, leading to a decline in enrollment for Textile Design courses. As a result, many institutions have either discontinued their Textile Design departments or are in the process of phasing them out. This research paper aims to delve into the reasons behind this change, exploring the changing career preferences of design students, the evolving needs of the design industry, and the perception of limited career prospects within the textile sector. By analyzing quantitative data on enrollment trends and gathering qualitative insights from educators, industry professionals, and students, the study aims to find out the key factors driving this decline. The paper shall examine the broader implications of this trend on the future of textile design education. It also discusses potential strategies to revive interest in Textile Design programs, such as updating the curriculum, strengthening connections between academia and industry, and raising awareness of the diverse and dynamic opportunities that exist within the textile design field.

Keywords

Textile Design, Design Education, Higher Education Institutions, Declining Demand, Career Prospects.

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AI in Design Education: Human Machine Symbiosis for Success

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Fashion and Textiles are very closely related to latest trends and technologies and it is very predictable that these domains will be the most intimately influenced by the Artificial Intelligence (AI) revolution. And design pedagogy related to Fashion and Textiles has to keep up with the advancements happening globally, AI being the most impactful. Though AI has its different forms and applications, we are looking at Generative AI and how design education is being reset by the advent of the Generative AI applications. As humans and machines work closely together, the synergies can result in pathbreaking creativity, in Design as a practice and in the Design Education realm. Taking cues from Blooms Taxonomy and its many digital iterations, this paper looks at how AI can be introduced to the learning and teaching process and what are the impacts and outcomes in Design education. Can the outcomes be assessed for their creativity and effectiveness? Will the interactions deal with cognitive decline or progress in students? The use of AI is not without its drawbacks and we discuss in this paper two class room projects that used AI and what was the role of the mentor, the student and the influence of AI on these projects.

Introduction

In the year 2001 renowned artist David Hockney teamed up with physicist Charles Falco and published the paper "Secret Knowledge: Rediscovering the lost techniques of the old masters". Hockney convincingly demonstrates that, starting around 1430, artists used optical devices to capture figures and landscapes realistically. This raised a storm in artistic circles, prompting Hockney to make the statement "the artist makes the picture not the lens", agreeing that art is not diminished by the use of technology. Now, nearly six centuries later generative AI is pushing at the frontiers of creation and ideation as an important tool in the hands of creators and designers and the effects of this symbiosis is having deep repercussions, in not only the design in itself but also how this is taught. Is AI just a passing fad or will this be an important tool in defining the creativity of the future generation of designers. And can AI be integrated into the curriculum, compensating for the concerns of bias and hallucinations that are inherent in the models that generate the outputs.

Project

This paper records the activities of two group of students in the School of Fashion at the World University of Design, Sonipat, India. The objective of the activity of the first group was to see how they could visualize a garment made out of a smart textile and present it as a mock up. The activity of the second group was to visualize traditional printed textiles in Modern Interiors. They used AI primarily for two main purposes. One was to do research and other to visualize and present mock ups and renders. The first group was a batch of 10 students who were new to the Textile and Fashion domain. The Second group was a batch of 5 students who were well introduced to the subject (3rd Year students of Bachelors Course in Textile Design). The study aims to gauge their learning curve and make inferences regarding whether the creative skills of the students have been enhanced by comparing the presentations with and without the AI intervention. The projects also threw up some interesting aberrations associated with AI use like hallucinations and bias. The study reports how these aberrations were overcome. The first project was a part of the course entitled "Future Textiles". This course is taught as an elective and aims to introduce Future Trends in textiles with particular accent on sustainability to students outside the Textiles and Fashion domain. A brief introductory session covered smart textiles, functional textiles, and technical and non-conventional textiles. Artificial intelligence (AI) was suggested as one of the tools for visualizing innovative ideas. Only one student utilized AI, while others relied on traditional methods. Given the limited timeframe, the student using AI quickly visualized a garment made of algal textiles, known for their antifungal properties.

Figure 1: AI generated representation of dress made of Algal material

Figure 2: AI generated mock-up of Algal head gear

The Second Project was part of a course "Home and Interior Textiles, Exhibition and Display Design". This project engaged 3rd year textiles students in a comprehensive study of globally recognized

European and African textiles, aiming to visualize these rich cultural designs in contemporary living room and bedroom settings. Each student was provided with specific size and design specifications for the textiles and furnishings. They were tasked with developing prompts that could effectively translate the traditional and cultural essence of these textiles into visualizations that reflect contemporary aesthetics.

Figure 3: AI generated visualization of African print inspired interior

The outcomes of the project were strikingly beautiful images that captured the essence of each textile in contemporary setting. Programs like Playground, Dall E, Leonardo were used here.

Methodology

Methodology was based on the process as outlined below and making the observations and assessments on the assignments submitted.

1. Learning Process and Knowledge data set.
2. Timeframes
3. Comparisons between the outputs of the different students.
4. Bias, Hallucination in AI in textiles and fashion design and correction.

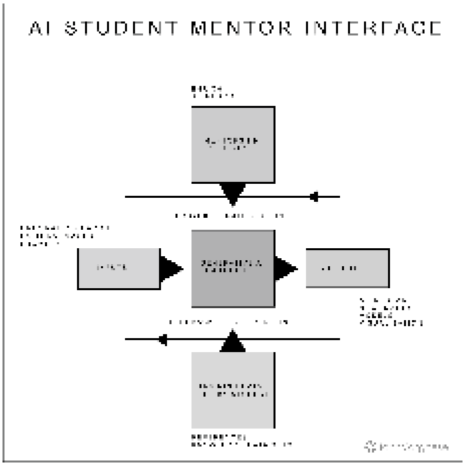

Figure 4: AI Student-Teacher Interface

Mentor/ Teacher: Tutorial instruction - Study Materials and Other Aids, Reinforcement- of Important Concepts, Feedback for Students based on Initial Concepts, Cues and explanations and Knowledge Set

Student: Classroom participation and morale, Student time on task- observation of Timeframes**,** Improved learning skills**,** Cooperative and Interdisciplinary learning – Initial cognitive prerequisites, Exploration and Representation of Concepts, Articulation and Presentation

Observations

Some striking outcomes were observed in regards to Bloom's Taxonomy and Churches' Digital Taxonomy Phases (recording only two levels here).

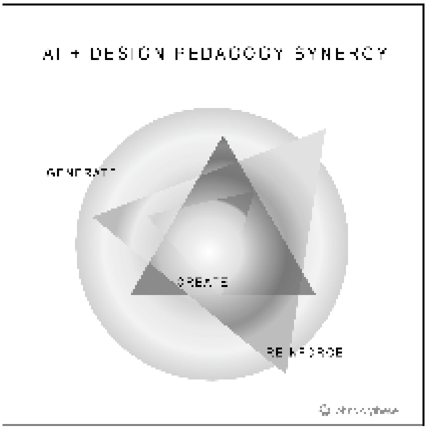

Figure 5: AI in Design Pedagogy Synergy Map with Student and Teacher

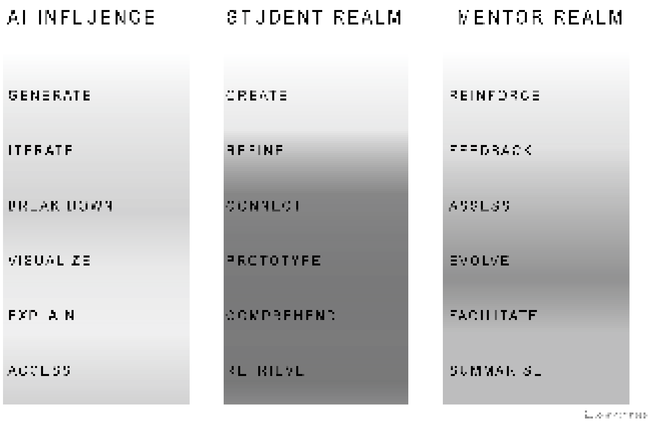

Figure 6: Influence of AI, Students and Teachers in their respective realms

The rigid layers of the leaning pyramid gave way to a more informal map where various realms in which the influences of AI, and roles students and teachers were diffused and blended.

1. Remembering:

Traditional Phase: Recall facts and basic concepts.
AI Influence: Instant access to extensive databases; automated summarization of information.
Teaching: Teachers provide guidance, and enriched content and resources
Learning: Students quickly retrieve relevant facts.
Example: Students used AI to gather detailed information on the properties and history of various textiles.

2. Creating:

Traditional Phase: Produce new or original work.
AI Influence: AI tools enable the rapid creation of innovative designs and visualization capabilities. Creative prompts, generative design tools are at the disposal of students.
Learning: Generation of innovative and original designs.
Teaching: Encouragement of creativity and innovation through AI-enhanced tools.
Example: Students created novel garment and interior designs using AI, combining traditional and contemporary elements.

It was observed that when combining research with design and synthesis, then the best results were observed. The Project also gives us an idea about how generative AI models whether LLMs for Research or GANS for Image Generation can be optimized for correcting Bias and Hallucination through rudimentary process, observations and study. Whenever the system appeared to go off track corrections were provided in terms of better prompts and image references to correct.

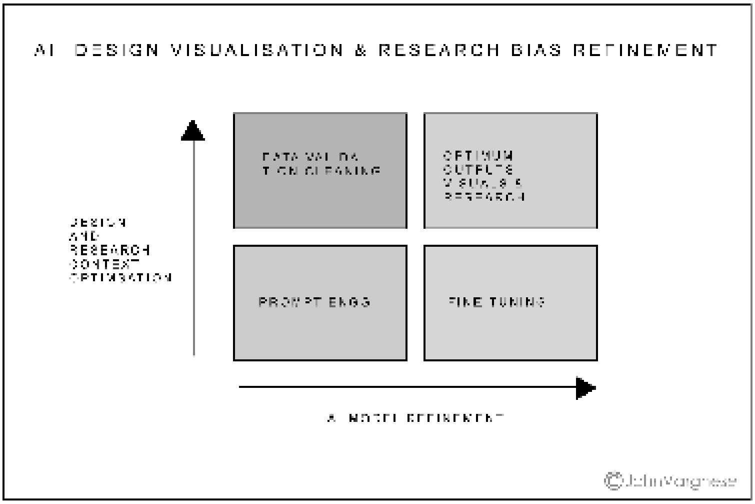

Figure 7: Bias Refinement process for the Design and Research process in AI

Limitations of the Study

The Projects were of short period ranging from one week to two months; also, better methods of optimization and bias correction could be used by using custom designed programs;

Conclusion

The cognitive and creative faculties are peaking when teachers' attention and guidance provides knowledge set that is required to overcome the pitfalls of Bias and Hallucinations. By integrating Generative AI technologies into Textile and Fashion design education within a framework that prioritizes critical thinking, creative expression, and ethical considerations, students can harness the potential of these tools while retaining the integrity of their artistic practice. This approach empowers students to utilize technologies purposefully, rather than chasing trends, and equips them with the skills to navigate the evolving landscape of design with confidence and agility. Overall, AI has the potential to augment the capabilities of educators and provide students with personalized and engaging learning experiences. By harnessing the power of AI, education systems can evolve to meet the diverse needs of learners in an increasingly digital and interconnected world.

Acknowledgments

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Pattern Engineering Framework for the Design of Contemporary Functional Officewear

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Functional clothing is distinct from conventional garments due to its ability to offer enhanced performance characteristics, tailored to specific activities in context with their respective environments. Fashion clothing on the other hand is primarily designed with aesthetic appeal and current style trends in mind, focusing on visual impact and self-expression rather than specific performance characteristics. Unlike functional clothing, fashion wear prioritizes appearance, social signaling, and cultural relevance over tailored functionality for particular activities or environments.

Functional clothing is designed with a thorough understanding of human physiology, biomechanics, ergonomics, and psychology (D Gupta 2011), ensuring that it effectively responds to the body's needs during various physical activities. Practically, functional clothing offers enhanced performance characteristics compared to regular garments, providing superior benefits in activities where specific functionality is required, thereby elevating the wearer's experience and effectiveness in those environments. Systematic classification of functional clothing has been done (D Gupta, 2011) to organize garments according to their specific functions and the environments in which they are used. This field is broad and diverse, with each category requiring distinct specifications, material requirements, technologies, and processes. As per Functional clothing classification system there are: Protective, Medical, Sports, Vanity, cross-functional and clothing for special needs, as a result, a wide range of functional clothing types emerges, each tailored to serve particular purposes and enhance user performance in targeted scenarios.

Officewear is mostly viewed as just another mainstream clothing category, primarily focusing on trends and aesthetics. However, modern office workplace has undergone significant changes due to evolving work environments, extended hours, the growing complexity of office tasks, and a greater emphasis on employee well-being, hence, reimagining officewear as functional clothing has emerged as a necessity. The modern office workplace demands a new approach to office wear design that prioritizes performance, efficiency, convenience, and health benefits over time (Braganca, 2015). In this context, work-life as a "social sport" highlights the integration of professional and social activities, requiring adaptable, stylish, and functional office attire (Simmel, 2020).

Pattern Engineering for Functional Garment Design

Pattern engineering as a technique is crucial in functional clothing design. Pattern engineering involves working with a 2-D medium, such as paper or fabric, to create a blueprint for garments that will drape a 3-D body, ensuring the desired fit while optimizing resource use. This process is pivotal in the design of any type of clothing, as it translates conceptual designs into practical, scalable blueprints for production. Pattern engineering serves as a vital link between design ideas and their tangible realization, enabling efficient and effective garment creation.

The patterns of ergonomic garments must align with the 3D contours and physiology of the human body, accurately corresponding to the user's size and posture. As such, functional clothing patterns are best designed in 3D (Gupta, 2011). However, even 2D pattern engineering can, in certain cases, contribute to the ergonomics, physiology, biomechanics, and psychology of the body through functional clothing design.

In pattern engineering, specific components are pivotal in rendering clothing functional. Each of these components functions like mechanisms, selected and adjusted to ensure the garment fulfils particular performance criteria—be it comfort, protection, mobility, or other specialized requirements. Proper pattern engineering ensures the garment's fit, enabling it to function as intended while allowing the wearer to perform tasks efficiently (Boorady, 2011).

Traditional Classification of PE Components

Pattern engineering components are traditionally classified based on their specific function in a garment, ensuring that the garment meet diverse functional and aesthetic requirements, contributing to both form and utility in clothing design.

- Structural components: are foundational elements like seams, darts, and pleats that create the garment's shape and ensure proper fit.
- Functional components: enhance usability and include features like pockets, zippers, and closures that add practicality.
- Aesthetic components: are added for visual appeal, incorporating decorative details such as unique collar shapes or hem designs.
- Supportive components: provide reinforcement, maintaining garment structure and shape with elements like interfacing, lining, and padding.
- Adjustable components: allow for fit customization and style flexibility, accommodating different body types and sizes with features like adjustable straps, elastic bands, and drawstrings.

Functional Requirements of Officewear

Officewear is proposed as a new category bridging the gap between functional clothing and fashion wear, combining elements of both categories to meet the practical demands of the workplace while adhering to professional aesthetics and social norms. It occupies a middle ground, balancing functionality (like comfort for sitting long hours, breathability, and ease of movement) with fashion considerations (such as adhering to dress codes, projecting professionalism, and allowing for some personal style expression).

Considering contemporary officewear as an emerging category of functional clothing, this study examines the effectiveness of 2D pattern engineering in optimizing functional office attire. This study demonstrates the appropriate application of pattern engineering components to achieve enhanced productivity. The study will focus on the integration of the four human needs identified by Gupta, 2011 i.e. human physiology, biomechanics, ergonomics, and psychology within the design ideation process, adapting pattern engineering components accordingly to deliver effective results.

New Proposed Classification of PE Components for Officewear

New proposed classification of PE components is based on their potential to serve multiple functions aligned with - physiological, biomechanical, ergonomic, and psychological body needs are proposed. By mapping these components to the multifunctional capabilities, they can impart, designers can create office attire that meets diverse demands, such as comfort, support, adaptability, and aesthetics thereby enhancing the overall functionality and user experience of the clothing.

Following is mapping of PE components is most important for designing of functional Office workwear to possible functions reflecting their multiple-functional capabilities:

FUNCTION	MOBILITY	FLEXIBILITY	FIT	CONCEALING	STRETCH	SIZING	FASTENING	ADAPTABILITY	EXCESS	FORMING	STORABILITY	SAFETY	SUPPORT	VENTILATION
PE COMPONENT														
DARTS	✓		✓							✓			✓	
ARTICULATED SEAMS	✓	✓			✓									
GUSSET	✓	✓	✓						✓				✓	
GODETS	✓							✓	✓	✓				
ADJUSTABLE FITTING			✓			✓		✓		✓			✓	
OPEN CUTS / SEAMS	✓								✓		✓			✓
OVERLAPPING	✓	✓	✓	✓					✓				✓	
PLEATS	✓					✓			✓	✓	✓			✓
GATHERS	✓					✓			✓	✓	✓			✓
YOKES														
FLAPS				✓			✓	✓		✓			✓	
COMPRESSION / -VE EASE			✓		✓								✓	
SLITS	✓							✓	✓			✓		✓
ATTACH AND DETACHABLE	✓							✓			✓			
POCKETS										✓	✓		✓	
PANELS	✓		✓	✓		✓			✓	✓			✓	✓
EASE	✓	✓							✓			✓		

Figure 1: PE components mapped to their multiple-functions

Identification of Functions, PE Component Should Impart to a Functional Officewear

A. ***Physiological Needs:*** Body shape, Thermo-Physiological comfort, Tactile comfort.
B. ***Biomechanical Needs:*** Kinematics, Strength & Safety, Support.
C. ***Ergonomic Needs:*** Body-form, comfort (Access & Excess), Fit & Adjustability.
D. ***Psychological Needs:*** Aesthetics, Transformability.

Physiological Needs: Research on the impact of restrictive garments, such as skinny jeans, has shown that prolonged wear in certain postures can exacerbate these issues, as demonstrated by cases of rhabdomyolysis and neuropathies caused by fabric compression (Wai, 2016). Comfort plays a crucial role in body image, especially at work, where clothing significantly influences the perception of comfort.

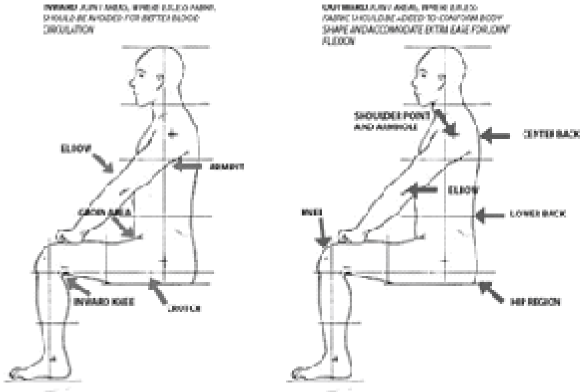

Figure 2: Body Postures in sitting position in Office environment

In the context of designing functional office workwear, a thorough understanding of body physiology is critical to ensuring the garment conforms to the body's contours while promoting, thermo-physiological and tactile comfort. Analyzing the human body in both static postures (sitting and standing) allows for the identification of body curves and forms, which informs garment design to accommodate these anatomical features. Additionally, considering the extent of body stretching and expansion in various postures is essential for ensuring functional ease in clothing design (Boorady, 2011).

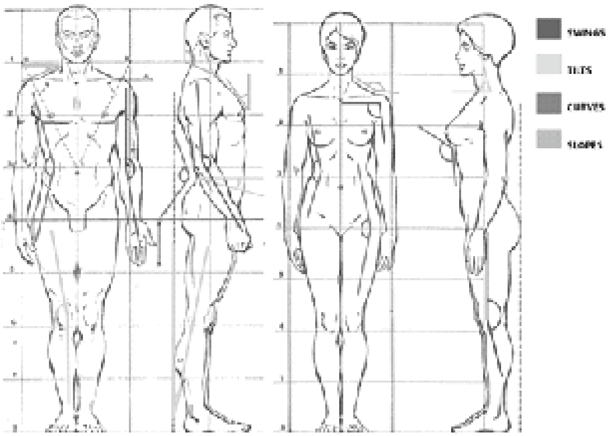

Figure 3: Physiology of Body in Ideal Standing position.

Biomechanical Needs: Clothing designed for users engaged in biomechanical activities must ensure the provision of ease for allowing unrestricted movement essential for professional tasks, often referred to as "functional ease". The configuration and dimensions of garment components, established during the design phase, play a pivotal role in determining efficiency of the wearer. During dynamic activities involving motion, the measurements of the involved body segments undergo significant changes compared to their static state. These variations induce tension within the garment along both the longitudinal and transverse planes (Avădanei, 2023), simultaneously the interaction between the skin and fabric is significantly influenced by the gap between them. Smaller gaps result in earlier contact and increased stress levels, while larger gaps alter the stress dynamics experienced during movement (Xing, 2011), this suggests the importance of integrating body biomechanics into the development of clothing pattern geometry (Avădanei, 2023). Body in motion well accommodated by functional clothing also renders user with safety and corrective support.

The body segments and the types of movements that they can execute are:

BODY SEGMENT	TYPE OF MOVEMENTS
The Upper Limbs	Flexion/ Extension, Abduction/ Adduction, Rotation, Circumduction
The Trunk	Flexion/ Extension in the sagittal plane, Lateral tilts in the frontal plane, Rotations in the transverse plane
The Head & Neck	Rotations, Lateral Flexions Medial Flexions
The Shoulder Area	Raising Lowering
The Lower Limbs	Flexion/ Extension, Abduction/ Adduction, Rotation

In these positions, the values of the body measurements change according to the type and amplitude of the movement, (M Avădanei, 2023).

Ergonomic Needs: Ergonomics here is the interaction of functional clothing with the body in context to office workwear. Ergonomic considerations in functional clothing emphasize the importance of garments conforming to the body's natural form, thereby enhancing both comfort and functionality (Gupta, 2011). Designing clothing to align with the body's contours ensures unrestricted mobility while maintaining an appropriate aesthetic fit. A critical ergonomic requirement is the provision of comfortable access to garment features, such as pockets and fastenings, which should be strategically positioned for ease of use during specific tasks (Boorady, 2011). Including the pockets being placed in a way that arms can rest utilizing them as well. Additionally, allowing for excess material in areas requiring greater mobility, such as joints or regions involved in frequent flexion and extension, is essential for supporting dynamic activities (Malcolm Xing, 2011). Features that enable adjustability, including elastic inserts, drawstrings, or adjustable fasteners, further enhance the micro-adaptability of garments to diverse body shapes and occupational needs (Avădanei, 2023). By addressing these ergonomic principles, clothing designs can improve user performance, reduce discomfort, and promote satisfaction in functional environments, underscoring the integration of human-centred design with occupational requirements.

Psychological Needs: The psychological aspects of functional clothing prioritize aesthetics, adaptability, and user satisfaction, addressing physical, emotional, and social needs. Balanced proportions, cohesive seams, and harmonious fits enhance confidence and professionalism. Convertibility allows seamless transitions between professional and social settings, adding value and versatility. Minimalistic designs conceal functional elements for refined aesthetics, while transformable features, such as detachable components, provide adaptability. These considerations elevate user experience, blending utility with personal expression (Gupta, 2011; Bragança, 2015).

Conclusion

The study proposes a new framework of 2D PE components based on their potential to serve multiple functions aligned with physiological, biomechanical, ergonomic, and psychological body needs, particularly in the context of officewear. Such functionality in officewear not only provide comfort, mobility, protection, and support, but also enables the clothing with enhanced productivity, effectivity, convenience and performance, thus converging function and fashion.As the field of functional clothing continues to evolve, the role of PE in bridging design concepts and practical applications will remain crucial, driving innovation and advancing the capabilities of modern workwear.

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Evaluation of Compression Points for Designing Zumba Bra

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Introduction

Activities like jumping/dancing can cause breasts to move up and down as much as 12 cm. (Sports Medicine Australia, n.d.). Cooper's ligaments in the breasts are connective tissue that helps maintain structural integrity, but during the movement that comes with exercise, these ligaments can stretch, causing breast pain or sagging. Studies have shown that vigorous activity can cause strain on breasts, and can lead to back, neck, or shoulder pain over time. A compression sports bra holds your breasts against your body to reduce movement and bounce. Wearing a compression sports bra during workouts limits the breasts' movement, helping to prevent injuries and giving you a more enjoyable exercise experience (CW-X 2024).

Need

1. The human breasts can be heavy. The force created by them can pull the trunk forward, making one slouch. This can negatively affect athletic or sports performance, and lead to headaches and neck, back and arm pain (Sports Medicine Australia, n.d.).
2. A compression bra can reduce movement during exercise. (CW-X, n.d.)
3. Compression reduces vertical and lateral breast movements, which can cause discomfort during exercise.

Literature Review

Shapewear compression is typically categorised into four levels [2]:
1. Light - Offers gentle shaping and smoothing for everyday comfortable wear.
2. Medium - Provides moderate shaping and contouring for special occasions.
3. Firm - Is ideal for more intense shaping and support.
4. Extra firm - The highest support level for maximum control and shaping.

Triathlete (2024) placed Electromyography sensors on the chest and shoulders to measure changes in muscle activity in response to the sports bra. Using a 3D scanner and a force platform, the forces, volume and shape of the breast were tracked while a woman ran on a treadmill.

Objective

1. To develop and evaluate compression bras specifically designed for Zumba dancers.
2. To identify critical compression points that ensure stability during vigorous activities

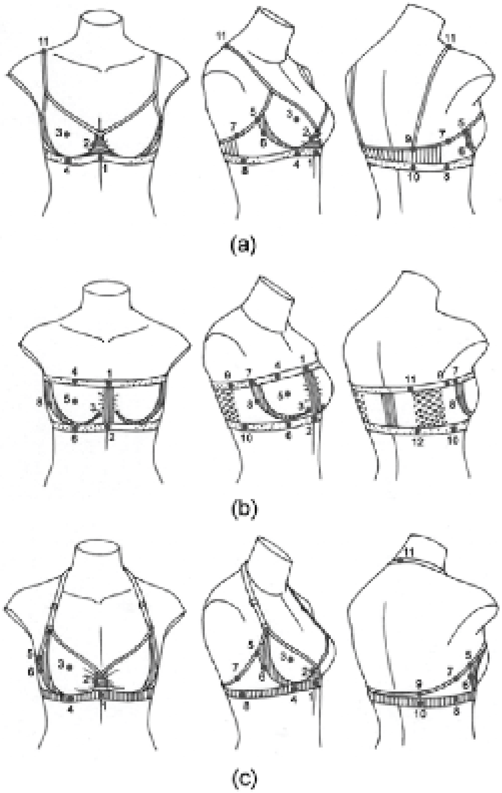

Figure 1: Pressure points on different bra styles (Winnie Yu, n.d.); (a) style 1-regular bra and other 4 commercial bras, (b) style 2- strapless bra, and (c) style 3-halter neck bra

Methodology

Finding the Compression points across the bust area

↓

Electromyography sensors are placed on the chest and shoulder to know the compression points

↓

Measure changes in muscle activity

↓

Developing the compression bra according to the compression points

↓

Ability to reduce movement during dancing which causes breasts to move up and down and damage the breast tissue

Expected Deliverables

1. The study aims to establish design guidelines for creating optimal compression bras that meet the demands of dynamic, high-intensity activities like Zumba.
2. It explores the development and evaluation of compression bras specifically designed for Zumba dancers.
   a. Compression bras offer a solution by stabilising breast tissue and reducing excessive movement during exercise.
3. This research investigates the materials, design, and functionality of compression bras tailored to the unique needs of Zumba dancers.
4. The research identifies critical compression points that ensure stability and minimise movement during vigorous activities.
5. Key factors such as breathability, moisture management, fit, and support are analysed to determine their effectiveness in providing comfort and performance enhancement.

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Decolonizing Textile and Fashion Education: Problematizing the Fashion Curriculum in Higher Education in South Asia

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This paper problematizes the Eurocentric and colonial system of textile and fashion education in South Asia at a higher education level. The fashion education policy emphasizes the technological and the design aspects at the surface level only without any reference to the underlying educational process then we run the risk of getting trapped at the surface level of fashion education. Textile and fashion education for that matter is an iceberg, whose visible top, be it product or media, irrespective of the limelight it might attract, for sure miss out on the substantive intent and content of fashion education. It is not that these concerns have not been addressed, for instance, clothing/dressing has been intricately linked with the praxis of prevalent power structure in a society. Likewise, textiles and fashion have been addressed at the surface level of compatibility or otherwise of body type, skin colour, and so on. Such discourses, by their very nature, are susceptible to repulsive and counter-willing movements of the fashion industry.

Decolonization includes the process of questioning and deconstructing colonial ideologies of the white Western thought and approaches and acknowledging indigenous processes. One definition of fashion suggests that it is a system of power and industry of capitalism, which is colonial in nature (a noun). However, fashion has always been a movement, a radical change, an act of resistance through fashioning one's body and creating ways to respond to environmental changes. Academicians involved in fashion education create spaces to deconstruct and suggest new methods of “diversification, decolonization and eradication” (Hogans and Shaw, 2024, p. 2) of dominant oppressive structures. Adopting a decolonized perspective in fashion education is crucial, as these spaces are centred around teaching, thinking, and writing about fashion. Higher education fashion programs, in particular, provide an ideal environment for this approach due to their focus on critical thinking and the professional development of the next generation's workforce. While not all fashion professionals undergo formal education in a fashion program, those who do gain the knowledge, skills, and networks necessary to enter the industry (Ranavaade, 2021).

Decolonization does not always need to focus on the ills of the industry but it also means acknowledging and engaging with one's own cultural identity and participating in discourses about the lack of representation of ethnic cultures in the fashion system. Decolonization fashion and textile education should offer spaces for appreciation and acknowledgement of “traditionally excluded thought processes, theoretical framing and present realities” (Hogans and Shaw, 2024, p. 3) that nudge the system into a direction of evolution and appreciate fashion instead of appropriating. In this context, fashion and textile education in higher education establishments should encourage the learners to research and practise (practise-based research), and to understand the elements of a process instead of inheriting a mainstream fashion/ or design process.

In this scenario, the paper also problematizes the curriculum design and content in fostering fashion consciousness by adopting problematization as a critical method, viewing knowledge as an issue and challenging the prevailing patterns and structures of the system. So the question of the related issue is whether the fashion education policy and curriculum continue to be driven by Eurocentrism or whether there has been a serious attempt to integrate indigenous textile clothing and fashion practices into the mainstream of fashion education. I intend to problematize the extent approach of appending indigenous textile approach and fashion to the Eurocentric fashion education system and make a case for its embedding in the ethos, technologies, processes, marketing and consumption of technical and textile fashion products to the Indigenous and global markets.

This also reminds me of the concept of "decolonial love as a praxis" by Justine Woods which suggests fostering the possibilities of lived experiences and identities that are practised "beyond the parameters and limitations of the colonial; an alternative consciousness of identity". It encourages acknowledging the intersectionality within a decolonial context and engaging in progressive "other thinking, freeing, sensing, being, knowing, doing and living" (Walsh, 2018, p. 102). In addition to promoting progressive thinking, it is crucial to foster a dialogue that addresses cultural exchanges and histories that have been distorted or erased as a result of post-colonial tensions and xenophobic forms of nationalist rhetoric.

What will be the contours of this bi-centric or even poly-centric approach to textile and fashion education wherein there will be an opportunity to engage in non-judgemental dialogues and conversations on the entirety of the education and practise of textiles and fashion? Will it be embracing Indigenous diversity or embracing Indigeneity in celebration of diversity and inclusion, in the context of *Vasudeva kutumkumbh* (the world is one) as a corollary? What shall be the modes of dialogues and conversations in global-local and vice versa textile and fashion discourses and practises? While the paper resists the traditional textile and fashion curriculum and centers on decolonization and South-Asian values and representations in Western education, it also attempts to lay a foundation for my pedagogical ideology in the future.

Keywords

Fashion discourses, Eurocentric, fashion consciousness, indigenous practises, decolonization, xenophobia, fashion appreciation, appropriation.

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Development of Ergonomically Designed Mastectomy Bra and Breast Prosthetics for Indian Breast Cancer Survivors

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Background

In 2020, there were 2.3 million women diagnosed with breast cancer, globally. As of the end of 2020, there were 7.8 million women alive who were diagnosed with breast cancer in the past 5 years, making it the world's most prevalent cancer. In India also, as per the Breast Cancer Organization of India, the population of breast cancer patients are increasing by approx. 1.6 lac cases every year, i.e. 1 in every 28 women. Fortunately, these patients' life expectancy has increased due to medical advancements. However, there is a scarcity of affordable and well-researched apparels that address various women's health concerns. As per (Hojan K. a., 2017) it has been estimated that about 90% of women undergoing mastectomy use a breast prosthesis permanently. The standard full external breast prosthesis, which is moulded to the natural shape and weight of the woman's breast and worn in a special bra, called a mastectomy bra, should be used as a first choice after total mastectomy, (Baron, 2000).

Problem Statement

Although mastectomy bras and prosthetics are essential for post-surgery recovery, the Indian market lacks affordable, aesthetically pleasing, and medically approved options. Patients undergoing chemotherapy or recent surgery are especially vulnerable and need garments that are safe and comfortable. International options are expensive, local options are basic, and NGOs often provide subpar-quality products.

Objective

This study aims to develop an ergonomically designed, full range of mastectomy bras and a versatile breast prosthetic that are both affordable and stylish, addressing the gaps in the current market for Indian breast cancer survivors.

Methodology

The Following methodology followed for the development of mastectomy Bra and Breast prosthetics **(Figure 1).**

Products

The introduced product range successfully combines style, function, and affordability, meeting the needs of breast cancer survivors in India. This initiative not only provides practical solutions but also contributes to improving the quality of life for patients by addressing both medical and psychological needs post-mastectomy. The newly developed mastectomy bras offer a variety of designs catering to different preferences while ensuring full coverage, durability, and comfort. The foam-based prosthetic is lightweight, versatile, and compatible with all bra designs, enhancing the overall experience for users.

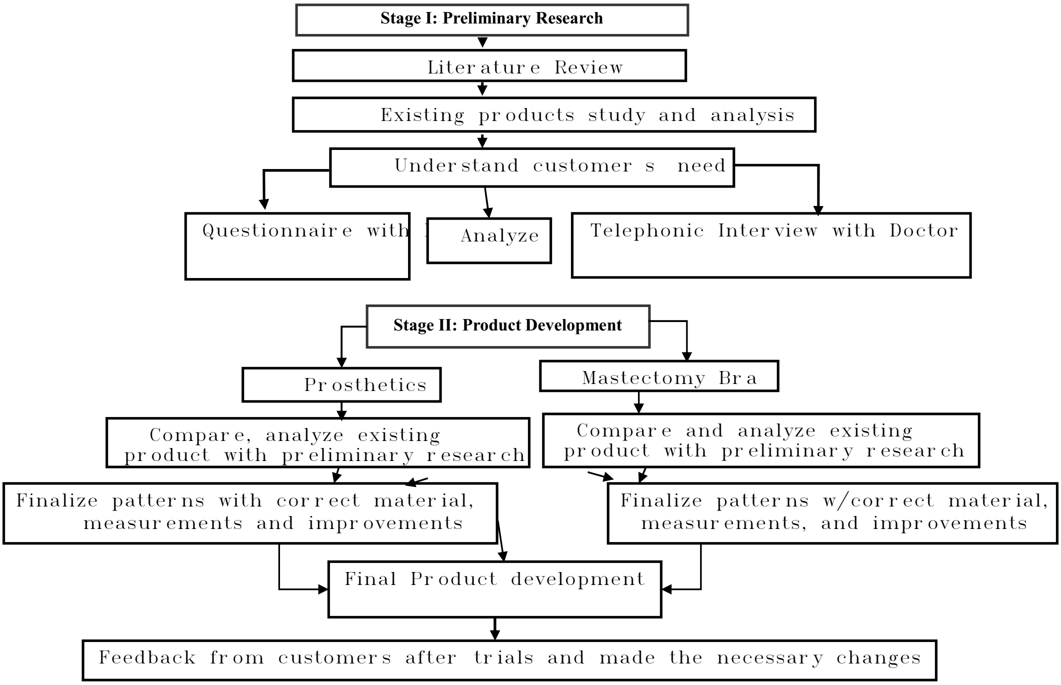

Figure 1: Methodology for the development of Mastectomy Bra and Breast Prosthetics.

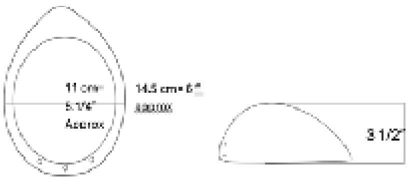

Figure 2: Flat sketch of Asymmetric poly-fill breast prosthetics

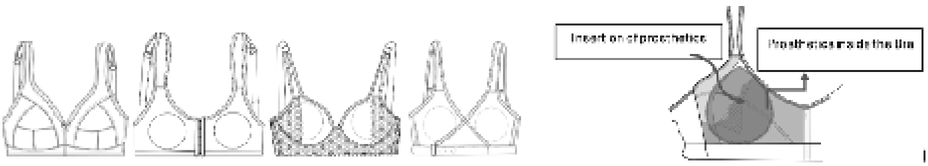

Figure 3: Flat sketch of various designs of mastectomy bra

Conclusion

The introduced product range successfully combines style, function, and affordability, meeting the needs of breast cancer survivors in India. This initiative not only provides practical solutions but also contributes to improving the quality of life for patients by addressing both medical and psychological needs post-mastectomy.

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Analyzing Body-garment Distance Through 3D Scanning for Enhanced Apparel Fit Evaluation

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Literature Review

The literature review highlights the increasing importance of objective methodologies in evaluating garment fit, emphasizing the limitations associated with traditional assessment methods, which are often influenced by subjective bias and human perception [1,2]. Traditional approaches to fit evaluation, which typically involve visual inspections and physical try-ons, can be time-consuming and cumbersome, particularly when evaluating multiple sizes and styles [3,4]. Recent advancements in 3D body scanning technology have emerged as promising tools to enhance fit analysis by providing accurate measurements and facilitating a deeper understanding of the body-garment relationship [5,6]. Moreover, research suggests that fabric properties, particularly drape characteristics, play a critical role in garment fitting, necessitating an integration of these technological advancements with studies on fabric performance to achieve improved consumer satisfaction and garment design efficiency [7,8].

Research Problem and Aim of the Research

The efficient fit of apparel remains a significant challenge in the fashion industry, often necessitating subjective assessments that can lead to inconsistencies and user dissatisfaction. This research aims to objectively evaluate and enhance garment fitting by analyzing the relationship between body shapes and garments using 3D scanning technology. The focus is on developing a predictive model that quantifies the body-garment distance, taking into account various fabric types and fit specifications.

Materials and Methods

The study involved the creation of multiple sheath dresses, crafted from five distinct fabric types and five different fits shows in figure 1. Using 3D scanning technology, generated detailed point cloud

Figure 1: Sheath dress with fit A in different fabrics

data for analysis. 3D scan models are aligned then Geomagic ControlX software used to find the min, Max and Average distance at Bust, waist and hip refer figure 2.

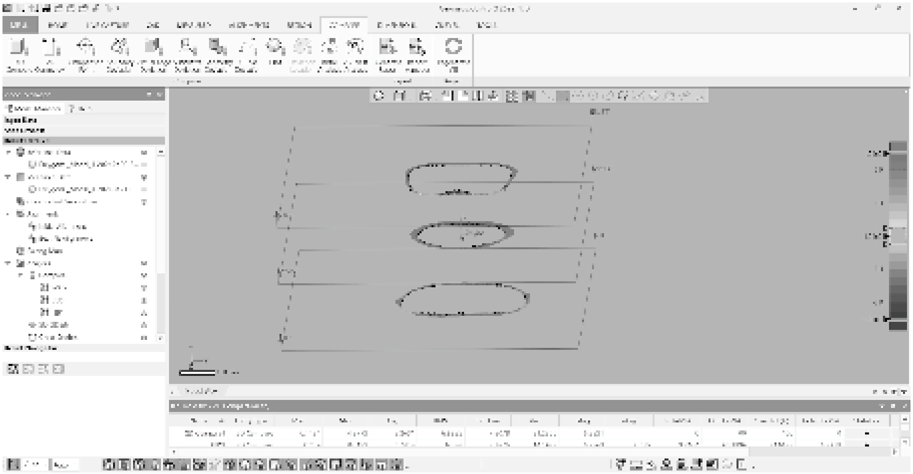

Figure 2: Cross Section of Bust, Waist and Hip

The collected data underwent rigorous statistical analyses, including single-factor Analysis of Variance (ANOVA), to identify significant relationships between fabric drape coefficients and body-garment distances. The research was conducted using dress forms to achieve consistency and precision in measurements.

Results and Discussion

The findings highlighted a significant correlation between the fabric drape properties and the fitting accuracy of garments. Variations in body-garment distance were observed when different fabrics were applied, even under identical fit conditions.

Table 1: Average distances of scans of each trial for different drape coefficient for fit A.

Fabric	Fit	Trial	Bust Min (mm)	Bust Max (mm)	Bust Avg (mm)	Waist Min (mm)	Waist Max (mm)	Waist Avg (mm)	Hip Min (mm)	Hip Max (mm)	Hip Avg (mm)
Fabric A	Fit A	1	0.00	14.76	2.80	1.21	18.70	5.44	0.04	23.54	3.28
Fabric A	Fit A	2	0.00	13.55	3.61	2.75	15.50	5.91	0.00	15.75	2.75
Fabric A	Fit A	3	0.00	13.25	3.43	3.48	17.51	9.67	0.00	24.93	3.68
Fabric B	Fit A	1	0.00	30.79	4.74	0.36	15.34	9.79	0.00	22.71	6.31
Fabric B	Fit A	2	0.09	30.84	4.49	2.43	15.85	10.19	0.00	35.03	6.13
Fabric B	Fit A	3	0.00	30.92	4.43	2.78	18.21	10.14	0.00	22.81	5.78
Fabric C	Fit A	1	0.10	24.88	4.98	1.16	17.49	11.07	0.09	32.84	6.60
Fabric C	Fit A	2	0.00	24.77	5.37	2.65	18.79	11.44	0.05	31.04	6.37
Fabric C	Fit A	3	0.00	24.79	4.97	2.40	20.17	11.70	0.01	31.42	6.66
Fabric D	Fit A	1	0.00	14.54	5.03	3.54	21.37	11.47	0.02	45.83	9.07
Fabric D	Fit A	2	0.00	14.1[illegible]	4.78	2.56	21.79	10.95	0.00	[illegible]	[illegible]
Fabric D	Fit A	3	0.00	14.84	5.51	2.47	22.21	10.94	0.00	29.28	7.91
Fabric E	Fit A	1	0.00	18.26	4.87	[illegible]	23.19	[illegible]	[illegible]	14.85	[illegible]
Fabric E	Fit A	2	0.00	24.72	5.41	2.82	21.50	10.63	0.09	24.15	6.93
Fabric E	Fit A	3	0.1[illegible]	24.8[illegible]	[illegible]	2.8[illegible]	24.8[illegible]	10.71	[illegible]	[illegible]	6.4[illegible]

The predictive model developed showed a high accuracy rate (>85%) in estimating garment fit across varying fabric types, emphasizing the role of fabric characteristics in determining clothing fit. This study presents a substantial advancement in the methodology for assessing garment fit, offering a more standardized and objective approach than traditional methods.

Conclusions

In conclusion, this research bridges the gap between traditional fit evaluation methods and innovative technological applications, paving the way for enhanced garment fitting processes. The integration of machine learning with 3D scanning not only improves the accuracy and efficiency of assessments but also elevates customer satisfaction by addressing fit issues proactively.

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Participatory Ergonomics for Mitigation of Musculoskeletal Disorders Among Silk Hank Dyers in Western Parts of Tamil Nadu India

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Research Problem

Silk yarn dyeing is an essential preparatory operation in the handloom silk saree weaving industry. The operation is being done separately by dyers as a cottage industry business. The current silk yarn dyeing practice is an age-old labour-intensive method. The process is primitive and no technological development is observed in the sector. The number of dyers practicing the art is diminishing because of the requirement of intense physical labour and low wages. A detailed study on the multicolour silk yarn dyeing process and the corresponding musculoskeletal disorders have not been reported earlier.

Aim of the Research

The aim of the present study is to observe the current silk yarn dyeing process for multicolour silk saree handloom weaving, and to study the musculoskeletal disorders associated with the practice. The study aims to establish an insight into the process, so as to realise the scope for technological advancements in the process to enhance the efficiency and profitability of the business.

Methodology

Silk yarn dyeing cottage industries along the banks of Bhavani river have been selected as the sample population for the study. A questionnaire was drafted in the local language (Tamil) to collect demographic information and analyze the technical aspects of the dyeing practice followed Health survey was done using modified Nordic questionnaire to identify the musculoskeletal disorders in various parts of the body during dyeing process. The working posture during silk hank processing was analyzed using Ovako Working Posture Analysis system (OWAS) [1] and Rapid Upper Limb Assessment (RULA) system [2].

Results and Discussions

The dyeing process was analysed and the effect of the process on the health of dyers showed that the dyers faced musculoskeletal issues especially pain in arms, shoulder, neck, and back. Observation using OWAS system showed that postures maintained during silk yarn processing were categorized under Action Codes 2 and 3, implying that corrective measures are required in near future and as soon as possible respectively. It is concluded from the posture analysis by RULA system that the warp yarn preparation, dyeing and washing processes affected the muscles leading to musculoskeletal disorders. The postures were classified under Action Level 4, insisting that investigation and changes in postures were required immediately.

Conclusion

This survey with questionnaire as a tool has been done to analyze the silk dyeing practices followed for dyeing silk yarns for multicolour silk saree handloom weaving. From the response received, it is inferred that silk dyeing is being done as a household business and the dyeing units are scattered around. Intensive manual labour required for silk yarn dyeing is the reason for musculoskeletal disorders, especially in shoulders, arms and lower back leading to general weakness and body fatigue among the dyers. Low profit margin is forcing the dyers to shift to other business and jobs. The poor work environment and manual labour has created an aversion to silk dyeing among the millennials.

Indicative Literature

Handloom products are famed for being distinctive and attractive with intricate designs [3]. Handloom workers are generally classified as weavers and allied workers. Handloom weavers are the people engaged in weaving activity while allied workers are involved in preparatory processes. On comparing the first, second, third and fourth handloom censuses, a steady decline in the people engaged in handloom sector is noticed. The reason proposed is due to the advent of powerlooms and its mass production [4]. According to the observed silk yarn dyeing units in Western Tamilnadu, dyeing units are supported with poorly equipped technologies. The current process followed is very primitive. Silk dyeing process is still being practiced manually with high amounts of physical labour involved. The dyers practicing the art are prone to musculoskeletal disorders (MSD) due to long working hours with repetitive actions and postures.

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CLOTHING DESIGN FOR SPECIAL NEEDS - I

Analysis of Chinese Elderly Women's Lower Body Shape from Anthropometric Data

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Anthropometric measurements are essential for ergonomic design, serving as a foundation for creating user-friendly, safe, and comfortable products [1]. In China, Qian et al. (2014) and Liu and Zhang (2014),collectively provide a detailed analysis of body shape variations and classifications across different age groups of women[2-3], highlighting the need for updated body type classifications and offering insights into the evolution of body shapes. Liu (2016) classified the lower body shapes of young women, but there is limited research on the classification of lower body shapes in elderly women aged 60 and above. The clothing industry faces a challenging and important question: what is the appropriate body shape classification that would enable consumers to easily identify their body types and assist garment manufacturers in producing well-fitting clothing? This study aims to classify and analyze the lower body shapes of Chinese women aged 60 to 80 using anthropometric data. The research data were collected from 345 women in Zhejiang Province. This paper proposes a lower limb body shape classification method based on hierarchical clustering. Through factor analysis and correlation analysis, we found that height, waist circumference, and the hip-to-waist ratio are the key dimensions for representing lower body shapes. Using the hierarchical clustering method, we classified the lower body shapes of elderly women into three categories. The results indicate that the hierarchical clustering body classification method can more accurately reflect body information without increasing the number of body shape types. Compared with the national standard for women's clothing sizes, elderly women tend to have shorter heights, larger waist circumferences, and increased hip circumferences. Anthropometric data is the basis of garment pattern design, and body classification is a necessary prerequisite for developing a garment size system. These research findings will provide valuable references for the pattern design of lower body clothing for elderly women, the development of new sizing systems, and related industries.

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Designing Fashionable Functional Clothing for Diabetes Patients on Insulin Treatment

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Diabetes is a chronic disease that occurs due to two main reasons. It can happen when the pancreas does not produce enough insulin (a hormone that regulates blood sugar) or when the body cannot effectively use the insulin produced by the body. An increase in blood sugar or hyperglycemia is a common effect of uncontrolled diabetes and over time leads to serious damage to many of the body's systems. According to the World Health Organization (WHO) almost 77 million people above the age of 18 years are suffering from diabetes (type 2) and nearly 25 million are prediabetics (at a higher risk of developing diabetes in the future) in India. Another type of diabetes is gestational diabetes, which happens during pregnancy in women. In a study published in 2023 by the Indian Council of Medical Research - India Diabetes (ICMR INDIAB), the prevalence of diabetes is 10.1 crores in India. More than 50% of people are unaware of their diabetic status which leads to health complications if not detected and treated. Adults with diabetes have a two- to three-fold increased risk of heart attacks, strokes, and other complications [1-3]. Therefore, facilitating effective treatment for diabetes patients is important in India. Diabetes treatment is through medication and also through injection of insulin when the medicinal therapy alone is not effective or sufficient, in addition to exercise and lifestyle modification. Therefore, according to the physical condition of the diabetic patient and the blood sugar levels, medical healthcare professionals may recommend insulin injections to the diabetic patients for effective treatment [3]. During the pilot study, it was observed that insulin injections are to be taken 2- 4 times per day, depending on case to case. The insulin is injected through an insulin pen with generally a 4 mm needle by most of the adult patients themselves or through insulin syringes. The insulin injections are required to be taken mostly before meals when it is a quick-acting medication. Therefore, patients on insulin therapy often carry the insulin pen for administering the injection wherever they are. The insulin injection is easy to self-administered, but the major obstacle faced by patients is when they are traveling on flights and trains, at workplaces, and social gatherings. The main reason is that as the insulin is self -administered in the abdomen or thighs, the clothing interferes with taking the injection while traveling on a flight or train. This has led to patients not being able to travel. Taking the injection through clothing may lead to infections, as reported in the literature [4]. The other option of an automatic insulin pump is a costly treatment for most diabetes patients in India [6]. Therefore, this research aimed to design and develop functional and fashionable clothing for diabetes patients on insulin therapy.

The methodology used was user-centered design research with an ethnographic study of diabetes patients on insulin of different age groups among males and females. The ethnographic research focused on different design research methods like the day in the life of the patients, empathy mapping, and user journey mapping to understand their needs, requirements, and pain points. Additionally, expert feedback has been taken from endocrinologists, diabetologists, and nurses specializing in diabetic care. The data collected from the ethnographic research was used in conceptualizing, designing, and developing the clothing prototypes. After the user trial, the designs were further refined to meet the needs of the diabetes patients. The research findings revealed that most of the diabetes patients prefer to self-administer the insulin injection in the thighs as it is convenient for them. This was also true for women with gestational diabetes who self-administer. The main difficulty for them was that they had to find a suitable place as they had to doff the lower (trousers and pants) or lift the lower like skirts for injection. As this was not possible, especially in inflight, in trains, in buses, or within the workstations at offices, diabetes patients were looking for fashionable lowers with comfortable concealed zippers and design features to enable taking the injection with an insulin pen, themselves. The research led to the development of a range of designs of suitable lowers with concealed zippers for men and women under insulin therapy according to their needs and aesthetics.

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Assistive Inclusive Clothing Design for Visually Impaired People

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Globally, at least 2.2 billion people have a near or distant vision impairment. Before buying, people use various senses to assess colours, patterns, textures, sizes and pricing to select appropriate clothing. The selection is primarily made based on one's fashion sense and social status. However, if any individual has any disability in identifying these features of clothing, this may be a major hurdle in buying and wearing clothing appropriately. Moreover, people with special abilities are often neglected in the mainstream society. In case of visual impairment, one has to rely on family members to help the individual in buying and wearing the clothing. Hence, this research project seeks to design and develop inclusive clothing for visually impaired people, which can help them in buying and using clothing conveniently. Two blind schools in Punjab and Himachal Pradesh were visited and respondents were surveyed on the issues faced by them in purchasing clothing and selecting a garment from their wardrobe. It was observed that there was a lack of options available in the market with no design consideration. Moreover, it was challenging for them to identify a particular colour, print, size, fabric, price etc in the store. As part of the design process, initially brainstorming was done to identify possible techniques and materials to incorporate suitable design interventions. Various materials like pompoms, Swarovski crystals, beads, sequins, quilted beads, hand embroidery, and machine embroidery were explored for making braille codes. The developed swatches were tried on people with visual impairment. After trial and receiving feedback from the user group, it was found that hand-done French knots were preferred by them. Crucial details like style name, colour, size, care instructions, and price were written on the different parts of the product in varying lengths and colours for visual appeal. The clothing designed can used by both sighted and visually affected people. It will help in normalizing visual impairment and sensitize the common people towards people with disability. Hence, it can be concluded that designing clothing for visual impairment can go a long way in making these people self-reliant in their day-to-day activities and reducing their dependency on other people. As a result, it would also help in ensuring their emotional and social well-being.

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Tailored for Ability: User-centric Adaptive Wear Solutions for Cerebral Palsy

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Cerebral palsy (CP) is a neurological disorder that affects movement, muscle tone, and posture, often resulting in significant physical disability. Individuals with CP face daily challenges, particularly in managing tasks such as dressing, which can impact their comfort, independence, and overall quality of life [1]. This research addresses these challenges by designing adaptive clothing tailored specifically to the needs of individuals with cerebral palsy. The study employs a user-centered design (UCD) approach [2], aiming to enhance the functionality, comfort, and dignity of the wearers. The author has proposed a conceptual framework SPEED (Specific Purpose-based End-user-centric Evidence-driven Design), which emphasizes a structured approach to user-centered design. This framework is central to ensuring that the clothing solutions developed are both functional and empowering for the wearers.

Objective

The primary objective of this study is to develop adaptive clothing solutions that cater to the unique needs of individuals with cerebral palsy, thereby improving their daily dressing experiences. By focusing on ease of wear, comfort, and increased independence, the research seeks to create garments that not only meet functional requirements but also uplift the wearers' quality of life.

Methodology

The research adopts a qualitative, exploratory study method [3], engaging four participants with varying levels of motor function impairment due to cerebral palsy. The study begins with an empathetic assessment phase, where the specific challenges and preferences of the participants are identified through detailed interviews and observations. This initial phase also involves consultations with caregivers, physiotherapists, and occupational therapists [4,5] to ensure a holistic understanding of the participants' needs. Building on these insights, the study progresses through an iterative design and prototyping process [6]. Adaptive clothing prototypes are developed, tested, and refined based on continuous feedback from the participants. This iterative approach ensures that the designs are truly user-centric, with each prototype being evaluated for its effectiveness in reducing dressing time, improving comfort, and enhancing the participants' sense of independence. The selection of textiles and finishes is critical, focusing on factors such as breathability, flexibility, ease of maintenance, and durability, all tailored to the specific needs of the individuals [7]. Throughout the design process, the emotional and psychological impacts of the clothing on the participants are also considered. By integrating the users' feedback and personal preferences, the study aims to create garments that resonate with their identities and contribute to their overall well-being.

Conclusion

The research findings indicate significant improvements in the participants' dressing routines,

including a notable reduction in the time required for donning and doffing the garments. Participants reported increased comfort and a stronger sense of independence, while caregivers highlighted the ease of assisting with the adaptive clothing. The study emphasizes the importance of a user-centered design approach in developing adaptive clothing that not only meets the functional needs of individuals with cerebral palsy but also enhances their dignity and quality of life. By involving multiple stakeholders and prioritizing user feedback throughout the design process, this research demonstrates the potential of adaptive wear to transform the daily lives of cerebral palsy patients. The outcomes suggest that a tailored, empathetic approach to clothing design can lead to innovative solutions that address both the physical and emotional needs of users.
"When you design for everyone, you create a better world.", Dan Formosa

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Culturally Adaptive and Innovative Clothing Design for Male Parkinson's Patients in South India

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Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder predominantly affecting older adults, with motor symptoms such as tremors, rigidity, bradykinesia, and postural instability significantly impairing daily functioning [1]. As per the World Health Organization's recent report dated August 9, 2023, the global prevalence of PD has doubled over the past 25 years, with over 8.5 million individuals affected worldwide as of 2019 [2]. India, contributing to approximately 10% of this global burden, accounts for around 0.85 million cases [3]. PD is most commonly diagnosed in individuals around 70 years of age, with a higher prevalence in men. The risk factors for the disease include advanced age, biological sex, and heredity, with 15 to 25 percent of individuals having a known family history of the disease [4]. This research specifically focuses on the male population in South India, exploring the unique challenges posed by clothing and its use in this demographic group, which is overlooked in existing adaptive clothing solutions.

Research and Aim

The limited and slow motor movements, hand tremors, imbalance, and mood alterations associated with PD present significant challenges in performing daily activities such as dressing, undressing, and using the toilet independently. The aim of this research is to incorporate functional design elements into traditional South Indian garments, such as the lungi, vest, half-sleeve shirt, and veshti, without making major changes to their structure, aesthetic, and material feel. The objective is to ensure ease of adaptation for elderly patients, considering their comfort and cultural preferences while enabling greater independence in their daily lives.

Methodology and Materials

This research employed a human-centric design methodology, particularly the DTCD (Discovering, Translating, Creating, Developing) approach. The process began with discovering the specific needs of the target demographic through in-depth interviews with patients, caregivers, and other stakeholders. This need-based assessment helped identify the pros and cons of existing clothing options for PD patients. Secondary research involved a comprehensive review of literature on PD, global adaptive clothing designs for restricted movement-related conditions, and an analysis of their applicability to the cultural context of South India. The exploration also extended to innovative seam finishes, fabric technologies like Filium, which imparts fast-dry, breathable, odor-resistant, and stain-resistant properties to natural fibers [5], and knitwear technologies that enable the construction of seamless garments. Color psychology was also considered to design clothing that is mentally appealing and mood-enhancing.

Result and Discussion

The result of this research is a product line consisting of six garments tailored to meet the daily, outer, and inner wear needs of South Indian male PD patients. These designs incorporate innovative features such as a concept pleating technique that facilitates easier dressing through the use of drawstrings and strategically placed seams. Additionally, traditional garment closures were replaced with magnetic snaps to accommodate the hand tremors associated with PD, thereby enhancing user-friendliness and reducing frustration.

Conclusion

In conclusion, the proposed designs are currently being prototyped and subjected to user testing to identify areas for further improvement. Future work will focus on refining these designs based on feedback from extended trials and evaluating the scalability of the solutions for broader application across different demographics and conditions.

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Development of Commuter Jeans

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Introduction

Commuter jeans are urban-friendly denim crafted for comfort, durability, and functionality, ideal for active commuters with stretch fabric, reinforced stitching, and reflective elements.[1] As urban commutes transform, clothing must adapt to the growing urban demand. Commuter jeans, designed to navigate the urban landscape with comfort, breathability, and safety in mind. This project explores the material science, functionality, and design considerations making them the ideal companions for the modern commuter.[2]

This project aims to address these issues by developing a range of menswear commuter jeans that integrate functional design features. The research focuses on enhancing comfort, breathability, durability, and safety for active urban commuters.

Objective

The main objective of the research paper is to develop range of menswear commuter jeans.

Research Methodology

A mixed-method approach was employed, combining quantitative and qualitative research techniques:

1. Consumer needs analysis: A questionnaire was distributed to the target audience, followed by statistical analysis using Chi-square and regression tests to confirm the project's need.
2. Market study: Web scraping was performed on competitor and inspirational brands to gather market insights.
3. Concept ideation: Based on consumer needs, competitor analysis, and technical considerations, various design concepts were developed and refined.
4. Fabric selection: A fabric selection matrix was utilized to determine the optimal material composition, considering factors such as weight, strength, and performance characteristics.
5. Prototype development: Prototypes were created and subjected to wear trials, with feedback incorporated into the final design.

Research Findings

The research findings highlighted key issues with regular jeans, including discomfort, poor breathability, and limited mobility. Market research revealed a preference for mid to dark shades and cotton-elastane blends, with a strategic price point range of 4000-6000 INR. Lower Torso heat zones were front thigh, groin and calf. Also, the area along the outer leg seam can trap heat, especially when wearing fitted clothing.[3]

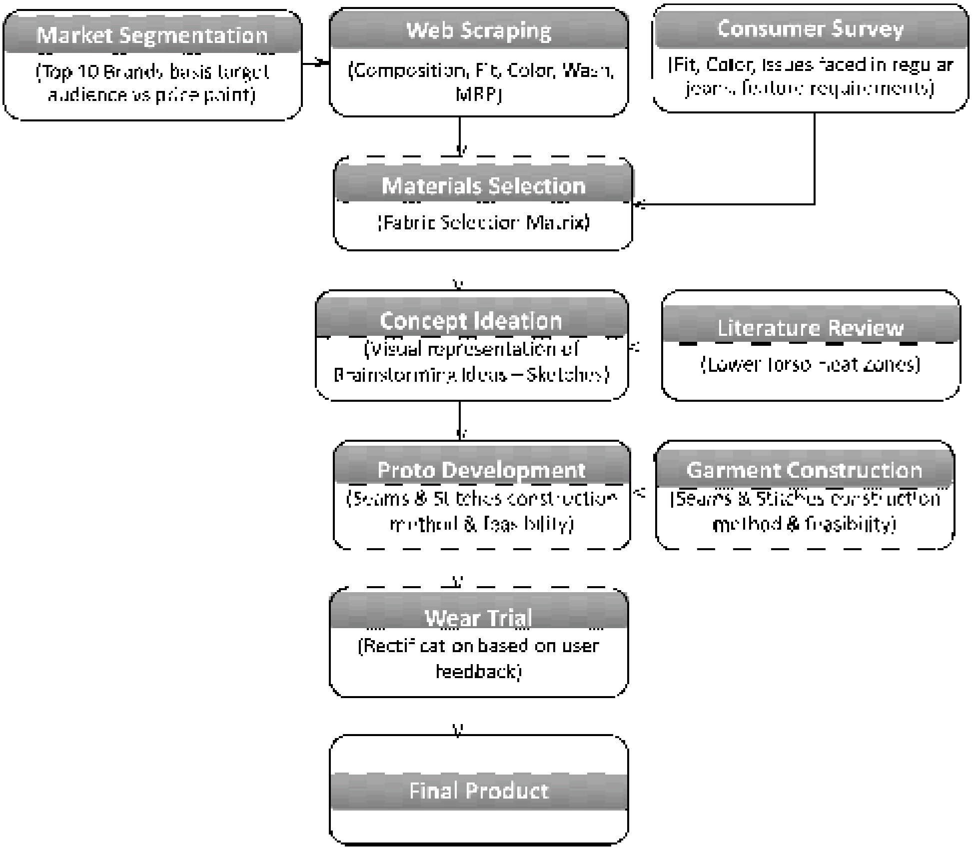

Figure 1: Theoretical Model.

Conclusion

The project successfully addressed the identified market gap for commuter jeans by developing a product that combines comfort, breathability, durability, and safety features. The final product features Lightweight fabric of 10-11 oz making it easy to carry with Cotton-elastane blend for improved comfort and flexibility, strategically placed rib panels for enhanced breathability, articulated knees for improved mobility, reinforced patches for increased durability, luminous thread and L-guard for visibility and safety in low-light conditions. The range of price points ensures accessibility to a broader consumer base.

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Exploration of Protective Properties in *Capparis decidua* for Kids Clothing

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Textiles with UV protection and antimicrobial properties offer significant benefits for health and safety. UV-protective textiles shield the skin from harmful UV rays, reducing risks such as skin cancer and premature aging. This protection is achieved through UV-absorbing agents, UV-resistant fibers, or protective coatings, and is measured by the Ultraviolet Protection Factor (UPF). Antimicrobial textiles, on the other hand, inhibit the growth of microorganisms, helping to prevent infections and reduce odors. These properties are achieved using chemical agents like silver nanoparticles or natural compounds. Both UV protection and antimicrobial features enhance the functionality of textiles, addressing important health and safety concerns through advanced materials science and technology. This study investigates the protective properties of *Capparis decidua* for children's health. Extracts from the plant's fruits and leaves were tested for antioxidant, antimicrobial, and anti-inflammatory activities. Preliminary results indicate that the ethanol extract shows significant antioxidant potential, with a 75% inhibition of DPPH radicals. It also exhibits broad-spectrum antimicrobial effects, especially against respiratory pathogens such as *Streptococcus pneumoniae*. Final results are pending for detailed validation and further analysis.

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Sustainable Apparels for Men and Women: Design Explorations Based on User Preferences

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State of art study of sustainable dyeing, apparels and brands in India and outside of India was conducted in depth to understand trends. A focus group user study was conducted with 15 male and 15 female young respondents between the age group 20-30 years from urban background. 20 were working professionals while 10 were college students. It was found that 60% of users bought sustainable apparels and accessories, 90% preferred cotton while others preferred silk, polyester, viscose and recycled polyester and recycled viscose. 75% would like to wear tie-dyed clothes, 90% would like patchwork technique while 80% would prefer embroidered clothes. 80% are willing to pay more for sustainable accessories. 68% said that they would like to buy from brands that provided repair and recycling services. Organic cotton basics and ethically made denim are more preferred than upcycled fashion articles. The budget for apparel purchase ranged between 200-2000 INR for both men and women. Based on user study following design directions were derived - Materials may be organic cotton or recycled textiles; Price may range between 200-2000 INR, Designs may include patchwork, embroidery, dyeing and tie-dye; and popular color choices include - white, black, blue, green, yellow and pink. A swatch file of organic cotton dyed with natural dyes - indigo, myrobalan, turmeric, catechu, madder, rhubarb - was generated in solid shades, tints and tie-dyed method. Traditional Indian Embroideries were made on swatches such as Kantha from West Bengal, Chikankari from Uttar Pradesh, Kasuti from Karnataka, Phulkari from Punjab, Applique from Rajasthan and Kashidakari from Kashmir. Unisex Patchwork shirt was made out of production waste. A design collection called - Sustainable Chic: Ethereal Elegance inspired from Flora, fauna and earthy elements was created digitally and made with sustainable clothing materials based on user study. The design philosophy behind the collection is using eco-friendly fabrics and artisanal craftsmanship for each apparel to imbibe the spirit of sustainability.

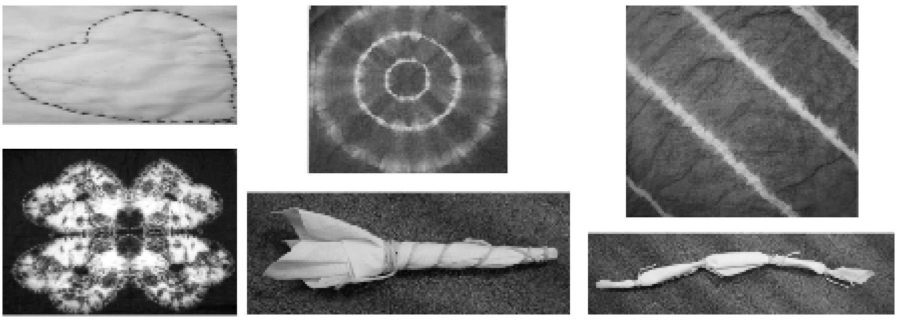

Figure 1: Tie and Dye swatches

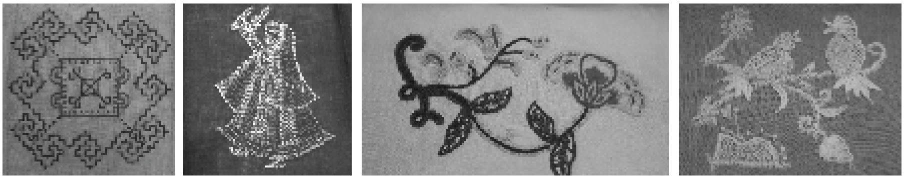

Figure 2: Traditional Indian embroideries on eco-materials

Figure 3: Design collection made on Procreate

Figure 4: Patchwork shirt designed by author for preferences study

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SUSTAINABLE & CIRCULAR TEXTILES

Biorefining Technology for the Valorisation of Textile Waste

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The global fashion industry is currently valued at over $3 trillion, with annual textile consumption exceeding 100 million tonnes. Managing textile waste poses significant challenge worldwide. In the UK alone, more than one million tonnes of textile waste are generated each year [1]. A 2016 UK survey showed that 55% of textile waste went to landfills, 26% was incinerated, and only 22% was recycled or reused. Among them, less than 1% of textile waste was recycled into new clothing materials [2]. In textile waste, it can be processed into reclaimed fibers for new yarn or nonwoven products. However, most recycling technologies are limited to pre-consumer textile waste, where pure materials are more easily obtained. While chemical hydrolysis to break down textile waste into monomers for polymerization and spinning new fibers has been explored, it is energy-intensive, degrades natural fibers like cotton and wool, and results in low-quality polyester fibers. Consequently, this process is often not economically viable for mixed textile waste due to the low-value end products.

Enzymatic hydrolysis is another option for the valorisation of textile waste. In a biorefining process developed by the research group, cellulase-producing fungus was cultivated in-house using textile waste and then the fresh enzyme extract was used to hydrolyse the textile waste [3]. A completed degradation of the cotton composition was achieved after 72 hours hydrolysis. The remaining PET fibre was then recycled and used for new PET fibre production, while the sugar released from cellulose was fermented lactic acid, which was subsequently converted to poly-lactic acid and biodegradable fibres.

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Sustainable Consumption of Clothing: Second-hand Clothing Use in the Australian Context

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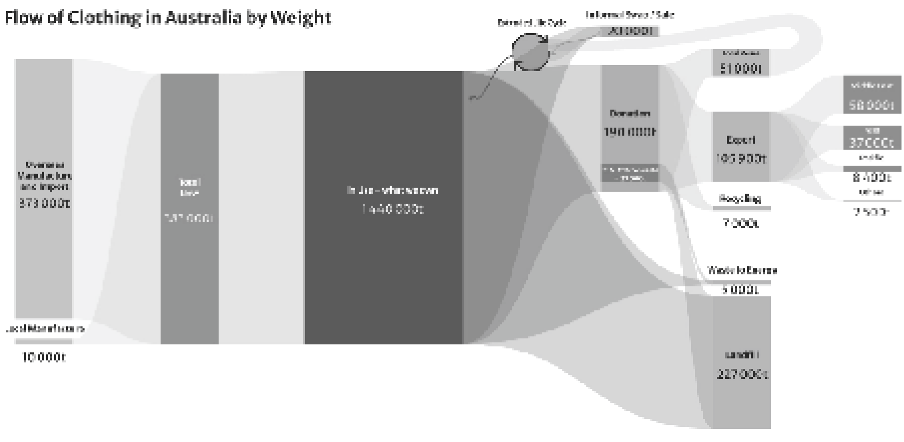
The unrestricted pace of fashion consumption, the environmental challenges and societal issues that it presents are known and discussed in research and industry. The use of second-hand clothing has evolved as one of the options for sustainable consumption within the reuse circular economy strategy. As reported by UNEP, 2023 [1] the seminal report by Ellen MacArthur Foundation, still provides the base for data for the unbridled consumption increase witnessed since 2000. Citing EMF's report, it stated that the textile utility or the number of times an item is used before disposal decreased by 36 percent in the past 15 years resulting in 85% of the end of life items being sent to the landfill or being incinerated [2]. One of the ways of decreasing the waste is reuse. Ellen MacArthur Foundation [2] reported that 6 million tonnes of clothing was reused globally in 2017, of which 2 million tonnes was for domestic use and the balance was exported. Of the 620,000 tonnes collected in the UK for reuse in 2018, charity shops accounted for 192,000 tonnes or 32% for domestic reuse [3]. The material flow analysis for Australia for 2018-19, Figure 1 showed that of the 190,000 tonnes donated to charities, only 51,000 tonnes or 26.84% was used locally [4].



Source: National Clothing Product Stewardship Scheme | Clothing Data Report 2022, pp 3
Figure 1: Flow of clothing in Australia by weight

The number of publications between 2010 and 2013 regarding consumers clothing disposal behavior exceeded the number in the last three decades, showing growing interest in research exploring sustainable behavior [5]. Clothing reuse, a sustainable clothing disposal option, enabled through inheriting products, borrowing, swapping, donating to charities and second-hand stores, trading and renting is the transfer of ownership of clothing to a new owner [6]. Consumption of second-hand clothing could help promote the transformation from the traditional linear approach of consumption to markedly more sustainable approach [7]. Additionally, legislation, changing customer choices, and increased customer awareness about sustainability are considered to be the reasons for this transformation [8,9,10] towards clothing reuse. Reports that secondhand online exchange had gained momentum [11], and that the secondhand market for clothes could outgrow fast fashion within the next 10 years [12], makes second-hand clothing an important area of research. In view of Australia being the second largest consumer of garments on a per capita basis, the consumption of second-hand clothing in the Australian market is worth investigating. On average per year, an Australian bought 56 garments that was second only to a consumer in the USA [11]. The average US consumer bought 69 garments per year [14]. Additionally, Australia being a well-developed economy and having environmentally aware consumers, presents a solid case for studying the complex link between buying second-hand clothes, sustainable fashion practices, and fashion circularity [15].

Several research gaps are evident despite growing research on second-hand clothes, sustainable clothing consumption and increasing consumer's interest in responsible consumption. Many studies use the terms clothing reuse and recycling interchangeably, leading to possible misconceptions. An understanding of the interface between Australian consumers, second-hand fashion and sustainable clothing consumption is missing. Additionally, there is a scarcity of significant research exploring if clothing reuse can serve as a pathway to sustainable consumption. To fill these gaps and contribute to literature on sustainable fashion, this study aims to explore the growth of research on second-hand fashion as a sustainable consumption choice. This paper utilised the systematic literature review method to review research conducted regarding use of second-hand clothing as a sustainable consumption choice in the clothing circular economy. This method is a replicable, less biased and an objective method [16]. Four researchers contributed to selection of keywords for a search string, inclusion and exclusion criteria to be applied, and the study of results obtained. The systematic literature review conducted using Scopus was further subject to bibliometric analysis using VOSviewer, a software tool. The network maps, density maps and analyses of text for keywords and terms used in the selected published papers were interpreted through a descriptive and content analysis.

The descriptive analyses revealed the number of articles published per year between 2018 and 2023, the articles per source, the methodology used by researchers, and the productivity by countries. The content analysis helped in drawing conclusions towards the lack of research in Australia, the focus on circular economy and consumer behavior in general, and the lack of consumers adoption of the 3R strategies. The results obtained pointed to lack of research in the clothing circular economy in Australia and the need to explore consumer behavior towards consumption of second-hand clothes.

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Effect of Accelerated Weathering on Sustainable Agricultural Mulching Using Sunnhemp and Banana Fibers

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Sustainable agricultural mulching involves covering the soil around plants with organic or biodegradable materials to enhance soil health, retain moisture, suppress weeds, and regulate soil temperature [1]. The need for sustainable materials and goods is growing as people become more conscious of environmental challenges. Banana fibers are renowned for their strength, durability, moisture absorption, thermal resistance, and UV resistance. Similarly, sunnhemp fibers are appreciated for their robustness and ability to withstand harsh environmental conditions. These fibers have potential applications in mulching, seedling mats, crop covers, and biodegradable packaging [2]. The extraction and characterization of these fibers have been conducted, including assessments of fineness, strength, and moisture regain [3]. In this research paper sunnhemp and banana fibres were used for development of Nonwoven samples with various GSM and thickness. Accelerated weathering is a laboratory simulation method used to test the durability of materials by exposing them to UV and xenon arc radiation, mimicking natural weathering processes (ASTM D4355 & IS 16202) [4]. The two types of weatherometers used in this study are shown in Figure 1. The QUV Accelerated Weathering tester and the xenon arc are the most commonly used accelerated weathering and light stability tester. These testers are based on two completely different approaches. Xenon arc tester, reproduce the entire spectrum of sunlight including ultraviolet (UV), visible light and infrared (IR). This method is effective as short wavelength UV is responsible for most of the damage to durable outdoor materials [5]. QUV tester do not attempt to reproduce the full spectrum of sunlight, but, rather, just the damaging effects of sunlight. This method is effective as short wavelength UV is responsible for most of the damage to durable outdoor materials. The use of varying exposure times and temperature cycles, as per standard test methods, ensures that the samples are subjected to a range of conditions to assess their performance. This approach helps to predict the degradation of materials under real-world exposure to sunlight, rain, and other environmental factors [6].

(a) UV-A (b) Xenon arc

Figure 1: Types of Weatherometer

The samples were exposed to alternating cycles of UV light and moisture under elevated temperature to simulate outdoor conditions of sunlight, dew, and rain. The change in thermal properties before and after accelerated weathering was investigated using thermo gravimetric analysis (TGA) and differential scanning calorimetry (DSC), weight and tensile strength using standard test methods. The properties of fibres are given in table 1.

Table 1: Properties of Sunnhemp and Banana fibres

Properties	Sunnhemp Fibre	Banana Fibre
Cellulose content (%)	69-71	60-65
Lignin content (%)	4-5	6-8
Density (g/cc)	1.22	1.28
Bundle Strength(g/tex)	35-45	20-28
Fineness (Denier)	30-40	25-35
Moisture Regain (%)	13.62	12.24

Three non-woven samples, using sunnhemp and banana fibres, were developed with different GSM and thickness using needle punch technology. Developed sample details are given in table 2.

Table 2: Developed samples using sunnhemp and banana fibres

Characteristic	Sunnhemp and Banana fibres nonwoven		
	Sample 1	Sample 2	Sample 3
Mass (g/m^2)	350	500	750
Thickness, mm	3	5	7

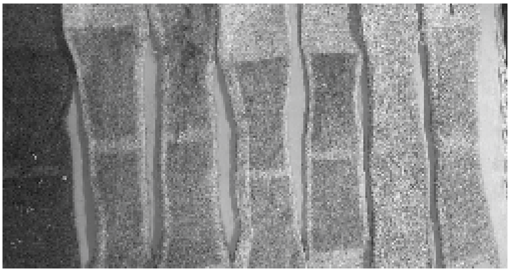

Figure 2: Nonwoven samples after QUV Accelerated Weathering Test

Following UV accelerated exposure testing method, the samples were assessed for percent strength retention, Min (After 144 Hour exposure) according to IS 16202:2014 (Annexure C). The results indicated that after 144 hours, the sunnhemp and banana nonwoven samples retained 69-71% of their strength. The weight loss of various structures under accelerated weathering conditions was monitored over three months. Despite the limited exposure time, some degradation was observed across the different structures. The weight loss in all developed samples ranged from 6-9%, demonstrating good resistance to UV and humidity cycles throughout the three-month study. The findings indicated that accelerated weathering led to a reduction in both weight and mechanical properties of the mulching structures. All three samples exhibited a decline in breaking force and elongation at break during the exposure period. Overall, the mulching mats made from sunnhemp and banana fibres demonstrated commendable resistance to accelerated weathering conditions, with minimal degradation, making them a promising sustainable alternative to currently used plastic films. Additionally, their substantial thickness may contribute to soil moisture retention and effective soil warming properties. Further research in agricultural fields is needed to evaluate the impact of these tested structures on plant and soil properties.

Acknowledgment

We are thankful to the National Technical Textiles Mission (NTTM), Ministry of Textiles, and Govt. of India for sponsoring a project on "Development of Crop cover, mulch, soil protection fabrics and other products using sunnhemp and Banana Fibre". Under this project, above study was carried out.

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Development of Circular Apparel with Good Handle Properties from Post-Consumer Denim Wastes

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Textile recycling is now inevitable for addressing environmental challenges arising from waste produced by the textile industry and can contribute to the achievement of Sustainable Development Goals (SDGs). Though mechanical recycling of textile wastes has lot of advantages, the quality of the recycled products has a long way to go. This research presents a novel approach for converting post-consumer textile waste (denim) into knitted apparels having good handle properties. To accomplish this objective, post-consumer denims were mechanically recycled and spun into rotor yarns (10 Ne). Then fabrics were produced using different ratios of recycled denim yarn (r-denim) and virgin cotton yarns (v-cotton), in the direction of course, in a flatbed knitting machine. Three different knitted structures i.e., rib, half cardigan and cardigan were produced. To improve the handle properties of the developed fabrics a silicone based softening treatment was given. Developed fabric samples were characterised for low stress mechanical properties, namely shear, bending, compression and friction, using Kawabata Evaluation System (KES). The experimental results were statistically analyzed using a three-way ANOVA. The results show that knitted fabrics are becoming a little stiffer and rigid with the increase in recycled fibre content. However, by course mixing and applying softening treatment comparable handle properties like those of virgin fabric were achieved even with 50% recycled fibres. Additionally, using 50% recycled fibres into the fabrics reduces environmental burdens significantly. Therefore, developed fabrics consisting of post-consumer textile wastes can not only reduce the requirement of producing virgin materials to a great extent and but also ensure the efficient use of natural resources and fossil fuels.

Keywords

Circular economy, Handle, Life cycle assessment (LCA), Post-consumer, Sustainability, Textile waste.

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Extending the Circularity Concept - An Exploration in Use of Shoddy Yarn in Premium Soft Furnishing Products

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Research Problem and Aim

This study addresses the pressing issue of textile waste in the industry by exploring the potential of shoddy yarn—a recycled material derived from discarded textiles—in the production of premium soft furnishing products, particularly home textiles and accessories. The aim is to assess the viability of incorporating shoddy yarn into mainstream textile production while adhering to the principles of circularity, thereby contributing to sustainable practices in the textile sector.

Materials and Methods

The research focuses on shoddy yarn primarily sourced from Panipat, India, where post-consumer garments and industrial textile waste are transformed into reusable yarn. To evaluate the properties of shoddy yarn, the study employs a comprehensive methodology that includes material analysis, carbon footprint assessments of various raw materials, and product development experiments. Additionally, case studies are conducted to examine the practical applications of shoddy yarn in soft line products. Physical properties such as yarn twist, hairiness, and imperfections are tested according to international standard methods, as outlined by Gupta and Saggu (2015). This foundational work highlights the fiber composition, revealing that wool rags and acrylic waste are predominant raw materials in shoddy yarn production. Further, Saini et al. (2018) provide insights into the socio-economic impact of shoddy yarn manufacturing, emphasizing its role in providing affordable products for low-income communities.

Results and Discussion

The findings indicate that while shoddy yarn presents certain challenges, such as variations in uniformity and strength, innovative blending techniques and modern manufacturing processes can significantly enhance its performance. Saini et al. (2020) support this by demonstrating that the physical properties of yarns and fabrics made from recycled fibers are comparable to those made from fresh materials, suggesting that recycled yarns can be effectively utilized in producing high-quality woollen apparel. The study also maps the stakeholders involved in the shoddy yarn industry in Panipat, identifying key players such as manufacturers, designers, and policymakers. This mapping is essential for fostering collaboration and innovation, ultimately driving the adoption of circular economy principles in textile manufacturing.

Conclusion

In conclusion, this research underscores the potential of shoddy yarn as a sustainable alternative in the textile industry, contributing to the reduction of environmental impact and promoting circularity. By integrating shoddy yarn into soft furnishing products, the study highlights the importance of recycled materials in achieving sustainable production practices. The findings advocate for further exploration of technological advancements in textile waste processing and increased consumer awareness of the benefits of recycled materials.

Indicative Literature

The research builds on existing literature, including Gupta and Saggu (2015), Saini et al. (2018), and Saini et al. (2020), which collectively emphasise the physical properties, socio-economic implications, and comparative analyses of shoddy yarn and its applications in the textile industry. These studies provide a robust foundation for understanding the potential of shoddy yarn in advancing sustainable practices within the circular economy framework.

Keywords

recycled yarn, circularity, soft furnishings, product exploration

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Implementation of Reeled and Spun Silk Yarns for Diversification of Handloom Products

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The silk industry is regarded as one of India's oldest industries and is also an important part of the Indian textile segment. India's silk and silk products are in high demand throughout the world. The reeling of silk cocoons and its spinning activities have shown its potential for diverse and innovative handloom silk products. In emerging silk scenario where India is consolidating its position as the 2nd largest silk producer, diversification of handloom products using silk yarns to address market needs is critically important. Product diversification and development has been a pressing need of the Indian silk industry. Indian silk industry has certain in inherent strengths that need to be projected in the right perspective and export market base needs to be widened and the range of products need to be broad based. Product diversification into casual wear and alternate end uses and focus on bringing the growing upper middle-income group in addition to the high-income group into the fold of silk products would lead to greater value addition in domestic silk production, product development and diversification efforts. Growing market awareness has been evidenced in the recent years for the Indian mulberry and non-mulberry silks especially spun silk yarns made by Eri silk or silk wastes in the domestic market. Development of handloom products and diversification by using Tasar, Muga and Eri silk yarns or its blend has been almost a virgin in hilly areas such as Ladakh, Himachal Pradesh, Uttarakhand, Jammu and Kashmir. India has regionally district variety of handlooms and its fabrics were exported to other parts of world. India is blessed with congenial situation to aid its production and it becomes the onus of the concerned, to create a sustainable market for the silk products both within and outside. The Indian Handloom Industry is deeply rooted in sociocultural traditions with a rich heritage of skills and talent that needs to be preserved and promoted. Traditional handloom products in India are making a comeback in fashion as consumers seek culturally authentic products.The implementation of silk yarns through schemes in handloom sector can also signifies a positive stride towards the economic opportunities and the promotion of sustainable practices within the post cocoon as well as handloom sector. The use of reeled and spun silk yarns on handlooms can bridge the gap between weavers and reelers, thereby increasing the diversification of handloom products which can retain their cultural significance while adapting to evolving fashion trends. This not only ensures the preservation of handloom products but also provides export opportunities for silk producers, fashion designers and weaver's communities. This paper presents the implementation of silk yarns through schemes for establishment of reeling/spinning units and support for weaving/dyeing sector for diversification of handloom products.

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Exploration of Indian Kurta Silhouette Through Zero Waste Pattern Cutting

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Problem Statement

The fabric is "the most critical factor in minimizing waste," with cut-and-sew waste being particularly significant among pre-consumer waste types, as fabric accounts for nearly half of the total garment cost [1]. The apparel-cutting process typically generates 10% to 15% cut-and-sew waste[2]. To address this, Zero-Waste Pattern Cutting (ZWPC) has emerged as a design philosophy that seeks to utilize the entire fabric area within a given length to create one or more garments[3][4][5]. This sustainable approach integrates design and patternmaking into a cohesive process that balances aesthetics and functionality[2]. Previous studies have successfully employed ZWPC in various Western garments, including skirts by Jalil and Hosseini, a denim coat and fitted dress by Saeidi and Wimberley, and western tops and dresses by [2][6][7]. Additionally, Italiano, Kauvauti, and Marcicano designed a Trapeze sleeveless tunic and spiral trousers[8], McKinney developed a children's denim jacket [9], and Carrico created hiking pants and jackets[10], all using the zero-waste approach. Despite these advancements, the application of zero-waste techniques to traditional garments like kurta has not been thoroughly explored, highlighting a critical gap in the literature that this study aims to address.

Research Aim

This study aims to design and develop a women's Kurta silhouette using Zero-Waste Pattern Cutting, optimizing the silhouette and its variations to minimize fabric waste and promote sustainability in the textile industry.

Methodology

This study systematically implements zero-waste design techniques in the creation of a women's kurta silhouette. Initially, a strategic framework was developed, focusing on the design, pattern-cutting, and marker-making processes. The research began with the identification of a research gap, followed by an analysis of marker placement in existing industrial patterns of the kurta silhouette. Subsequently, fabric optimization techniques were applied to create a zero-waste marker plan. A comparative analysis was then conducted between the existing marker plan and the newly developed zero-waste marker plan. Figure 1. demonstrates the methodology of the research. Marker plan efficiency, crucial for minimizing cut-and-sew waste(Aldrich, 2009; Cuc and Tripa, 2018) was a key metric in this study. The jigsaw and tessellation techniques were key approaches considered for zero-waste pattern making. While tessellation can lead to waste due to its limitations with curves, the jigsaw technique, described by Liu (2010), allows for flexible pattern shapes that interlock without waste[13]. A size 10 (US) kurta was developed using the manual jigsaw method, ensuring it was both aesthetically pleasing and suitable for mass production.

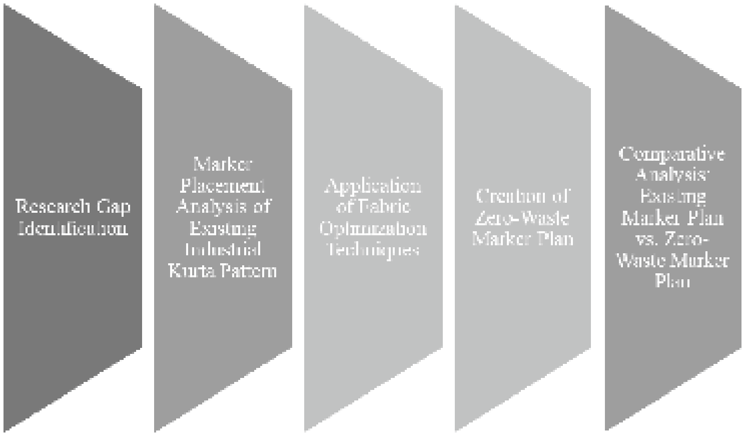

Figure 1: Methodology of the study

Result & Discussion

Figure 2 presents the flat sketch of the Kurta silhouette along with the traditional pattern placement on the marker, covering the front, back, top, bottom, sleeves, and pocket. Yellow-highlighted diagonal lines indicate areas of fabric wastage, with the marker placement using predefined dimensions of 181.6 cm by 106.7 cm. Marker efficiency will be calculated using computerized marker-making software.

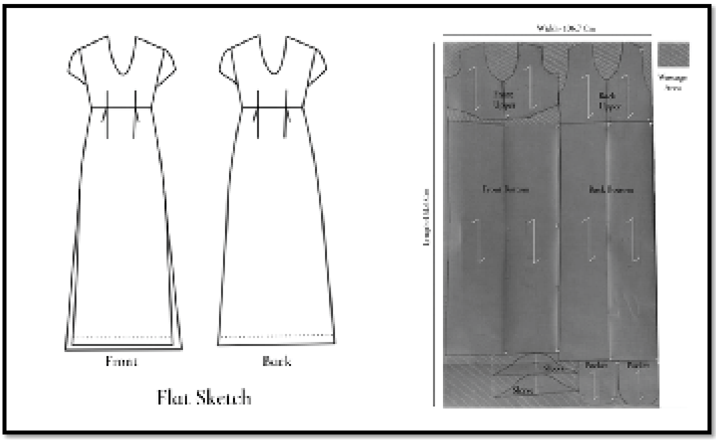

Figure 2: Flat sketch and Traditional method of pattern placement of Kurta silhouette

To address this fabric wastage, the jigsaw technique will be applied to create the same silhouette with zero-waste pattern cutting. Although zero-waste pattern making, which uses interlocking geometric shapes to optimize fabric[14], may pose aesthetic challenges, it offers significant sustainability benefits[4]. A comparative analysis between the existing and zero-waste markers will be conducted to evaluate waste reduction, with the study aiming to refine zero-waste techniques and advance their role in sustainable fashion design.

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PROTECTIVE TEXTILES

Developing Lightweight Extreme Cold Climate Clothing Using High *Clo* Calue Weed Fibres

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Defence clothing provides a scalable survival capability for soldiers from mild to extremely cold, life-threatening environmental conditions. Cold weather clothing assembly is manufactured using at least four main layers. These are wind resistance material, water resistance material, evaporative resistance material and thermal insulation material[1]. The thermal insulation layer in the clothing, one of the most important layers, resists heat transfer and is usually expressed in units of Clo. The insulation value mainly depends on fibre fineness, the thickness of the material, the ability of clothing to trap air and its drying ability. The air is trapped on the surfaces of fibres, and in the interstices between them. The thermal resistance of still air is about 25–30 times greater than that of fibrous polymers. An efficient insulation medium typically comprises about 5– 20% of fibres and 80–95% of air. The thermal resistance of air is eight times higher than that of fibres[2&3].

Defence forces need lightweight and compact insulation, so the efficiency of insulative properties is much more important[4]. Presently polyester-based microfibers, hollow polyester fibres, and Goose down are mainly used for manufacturing thermal layers of extreme cold climate clothing like sleeping bags, Jackets, etc. In this study, a weed fibre has been identified and analysed for fineness, density and hollowness properties. The study revealed that this fibre is 2.5 micronaire fine. The fibre density and hollowness are 0.89 g/c^3 and 20 to 30% respectively. After modification of the surface of this fibre, it was converted to nonwoven web samples of different thicknesses and areal densities. The different blends of polyester and weed fibres used to develop nonwoven fabric samples were 30:70, 50:50 and 70:30 keeping thickness and areal density constant. These nonwoven web samples were compared for thermal resistance (Rct) property with the commercially available hollow polyester nonwoven web of similar thicknesses and areal densities.

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Protection Against Arc-flash Fire: HPT Aracore Gloves

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Electric arc flash fires are a critical safety concern in electrical systems, particularly in industrial and commercial settings. These incidents pose a major risk to electricians and technicians involved in the maintenance and installation of electrical panels. Arc flashes occur when an electric current jump through the air between conductors or from a conductor to the ground, resulting in a high-intensity flash of light and immense heat. Factors such as dust, corrosion, or rodents contacting conductors can also trigger arc flashes. The intense heat & light, explosive force, sound are also generated during the arc-flash in just a fraction of a second. These hazards can cause severe skin burns and damage eyesight. This paper explores the recently developed HPT Aracore gloves, designed to offer protection against thermal hazards and arc flash incidents. The gloves were developed by utilising modacrylic blended with aramid and reinforced with glass at 10-gauge knitting machine. Later, the gloves were FR coated as shown in figure 1.

Figure 1: **(a)** HPT Aracore gloves (liner), **(b)** HPT Aracore gloves (after coating)

The gloves were tested for arc flash fire protection in accordance with ASTM2675/ASTM2675 M-23 under following test condition (Table 1).

Table 1: Test Condition

Parameter	*Detail*
Arc current	8 1 kA
Gap in between electrode (Stainless steel)	300 5 mm
Distance between electrode and sample	300 5 mm
Fuse wire	0.5 mm

The gloves were tested before (liner) and after coating. The arc thermal performance value (ATPV rating) was 9.2 cal/cm^2 for the coated gloves.

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Enhancing Thermal Insulation through Aerogel-Integrated Nonwovens

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Introduction

Sugar cane bagasse aerogel is a lightweight, porous material derived from sugar cane bagasse, which is the fibrous residue that remains after sugarcane stalks are crushed to extract their juice. Typically, bagasse is considered a waste product in sugar production, but it can be repurposed into valuable materials like aerogels. Aerogel in general are extremely lightweight and highly porous materials with very low density.

Aerogel Preparation

Creating aerogel from sugarcane bagasse involves several key steps. First, the bagasse is processed by cleaning and drying to remove impurities and moisture. Subsequently, alkali hydrolysis is performed to modify the bagasse structure. The processed bagasse is then converted into a gel through sol-gel techniques using a suitable solvent and cross-linking agent. After gel formation, solvent exchange is performed to replace the solvent with a drying agent to maintain the gel's porous structure. Freeze-drying techniques is employed to remove the solvent while preserving the aerogel's porous network.

Aerogel Characterization

Characterizing aerogels involves employing a range of analytical techniques to delve into their unique properties and structure. These materials, renowned for their exceptionally low density and high porosity, undergo meticulous scrutiny across various dimensions. Initial assessments include measuring bulk density by quantifying mass and volume, alongside determining skeleton density which focuses on the solid framework excluding pore volume. Understanding porosity is critical, with evaluations of open and closed pore volumes providing insights into accessibility and structure. Surface area and pore size distribution analysis further elucidate aerogel properties. BET analysis utilizes nitrogen adsorption/desorption to gauge specific surface area, complemented by the BJH method to discern pore size distribution. Mercury intrusion porosimetry adds depth by physically intruding mercury into the aerogel structure to measure pore sizes across a spectrum. Structural insights are gained through techniques like SEM and TEM, offering high-resolution images that reveal micro and nanostructure details.

Embedding the Aerogel into Nonwoven Materials

Integrating aerogel into nonwoven materials represents a significant advancement in the field of thermal insulation, offering a promising solution for enhancing energy efficiency and sustainability across various industries. Embedding the aerogel into nonwoven materials involves preparing the nonwoven substrate, integrating the aerogel using impregnation, where the aerogel particles or fibers are dispersed within the nonwoven matrix. The composite is then cured to ensure strong adhesion and compatibility between the aerogel and nonwoven fibers. This method enhances the thermal insulation capability of the nonwoven material significantly, making it suitable for thermal insulation applications

Conclusions

Sugar cane bagasse aerogel, derived from the fibrous residue of sugarcane processing, is a lightweight and highly porous material with excellent thermal insulation properties. However, challenges remain in scaling up production and ensuring cost-effectiveness, hindering widespread commercial adoption despite its potential benefits.

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A Novel Second-degree Test Protocol for Simulating Smoke Particle Exposure to Wildland Firefighter's Clothing for Wildland-oilfield Interface Fires

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Introduction

On duty wildland firefighters are exposed to various hazardous materials in their line of Although the thermal protection and comfort is a major issue, in recent years cancers among firefighters have been highlighted all over U.S. The firefighters are exposed to various smoke particles generated due to burning of various fuels. Exposure to these harmful smoke particles over a prolong period leads to various health complications, genetic modifications and even terminal cancer. As wildland gears are made up of single-layered fabrics the current wildland gear falls short of protecting the firefighters against these exposures. Owing to the severity of the profession, the International Agency for Research on Cancer (IARC) has classified the firefighting profession as Group 1, i.e., carcinogenic to humans. In recent years, various oil fields have been affected by encroaching wildfires, and the presence of hydrocarbons influences the type of carcinogen formed. As a result, in addition to wood, hydrocarbons serve as a potential fuel in wildland-oilfield interface fires. In our previous work, we developed a protocol for characterizing smoke particle exposure using a quartz tube setup ". Despite the severity of the hazards there is no standard protocol for simulating wildland firefighters' exposure to these carcinogens. Hence, in this study a protocol is developed that is replicable and reproducible, that is capable of simulating smoke particle exposure and transmission caused by fuel combustion in a wildland-oilfield interface fire in a laboratory setting. This will help firefighters to develop better understanding of textiles for particle protection and cancer prevention. Considering our previous studies, we investigated this exposure caused by wood burning. However, these studies were conducted on a small scale and could be considered a first-degree test, as the equipment was not suitable for liquid fuels and had limitations on the amount of fuel used during experimentation. Such first-degree test may not be enough to evaluate the protective performance of textiles from smoke particles.

Methodology

For this study, we burn the cellulosic and hydrocarbon substance in our laboratory. By considering the human body structure, we have developed a cylindrical torso having outer diameter of 30.0 ± 0.25 cm and length of 46.0 ± 0.25 cm, similar to ISO 18640-1. The fabric is wrapped around the surface of the torso to simulate the human beings wearing the clothing. The clothed torso is exposed to smoke particles generated from fixed amount of fuel. The smoke generated through burning of fuel is propagated using a fan, the schematic of the set up is shown in Figure 1.

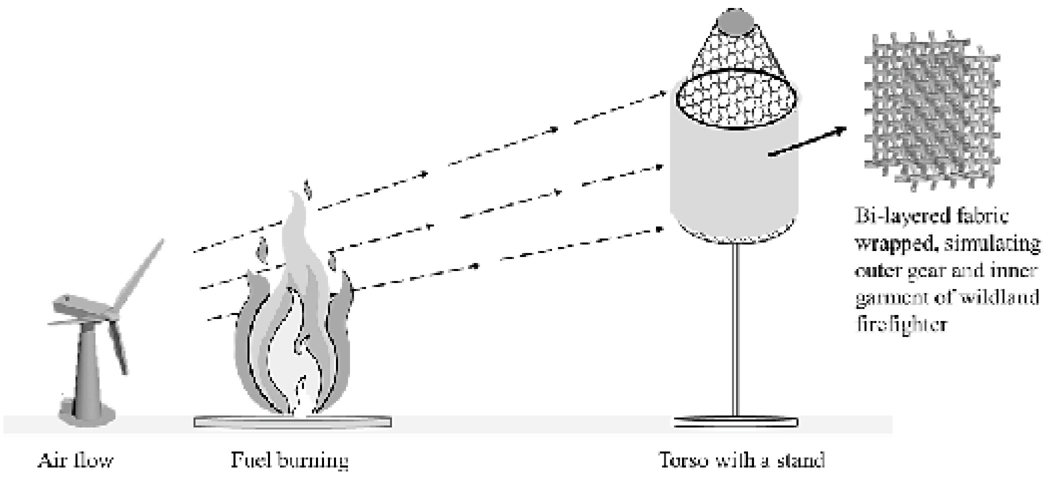

Figure 1: Schematic of test set-up

The smoke particles deposited on the fabric were extracted using hexane. After extraction, these particles were characterized using Gas Chromatography Mass Spectroscopy (GC-MS), SEM and TEM for determining the type of particle, size of aerosol and size of particles. For the study the protocol developed and tested for bi-layered commercial fabrics (Outer gear inner garment) at different air flow conditions.

Results and Discussion

It has been found that our developed protocol has been successfully performance under various condition. On the same fabric, it has been observed that the deposition of the particles was consistent for 3 tests. Based on the statistical analysis, it was evident that p-value is greater than 0.05. It means no significant difference was observed between the amount of particle deposition. Also, it has been observed that the different fabrics deposited different amount particles (p-values <0.05); so, by varying the fabrics it is possible to get different data set by using our experiment. Our preliminary studies have shown the effect of wind speed and wind direction as a significant factor in the deposition of smoke particles onto the fabric. Additionally, GC-MS showed presence of phenol, and oxidative aromatic hydrocarbon compounds on the surface of both the fabrics.

Conclusion

A novel protocol has been developed to simulate and characterize the smoke particle exposure to wildland firefighter's clothing in a wildland-oilfield interface fire. The methodology developed is reproducible in a laboratory scale setting with no significant variation in particle deposition under identical test conditions.

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Effect of Weave Pattern on Low-stress Mechanical Properties of Cut Protective Workwear Fabric

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Abstract

In the realm of cut protective workwear, sensory comfort is widely regarded as the most basic need. It is a significant problem to find a solution to the current difficulty of selecting the precise raw material and design of protective workwear to meet the requirements for protection against dangerous severe circumstances while preserving the comfort characteristics of wearing the products. The purpose of this study is to evaluate the impact of weaving patterns and materials on the sensory comfort of cut protective fabric. This will be accomplished by addressing the relevant issue. Throughout this study work, an effort has been made to determine the appropriate fabric pattern for cut protective apparel, together with the fibre material that should be used.Three distinct weave designs including plain, 2/2 twill, and 6-end satin were employed to fabricate the clothing specimen. The total number of nine sets of hybrid woven fabric samples was made by using para-aramid/modacrylic/stainless steel core spun yarn, ultrahigh molecular weight polyethylene (UHMWPE)/polyester/ stainless core spun yarn and para-aramid staple spun yarn which was denoted by A, B, and C correspondingly. The thread density of warp direction (34 ± 5 ends per inch) and weft direction (50 ± 5 picks per inch) was kept similar in all fabricated fabric samples. Four modules of the Kawabata assessment method for Fabric (KES-F1, KES-F2, KES-F3 and KES-F4) have been used to assess the low-stress mechanical characteristics including tensile, shear, bending, compression, surface friction, and roughness of each specimen objectively. The influence of weaving patterns on the sensorial comfort of cut protective workwear was studied and analyzed. It was noticed that the value of low-stress mechanical attributes is higher in warp compared to the weft way in each fabric specimen. Fabric weaving patterns have a significant impact on the low-stress mechanical attributes due to the different yarn floats in the weave. In this regard, the 6-end satin weave is considered the best weaving pattern for cut protective workwear in terms of sensorial comfort due to the longer yarn float in their weave design.

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Response Surface Methodology Analysis of the Outer Layer of Fire Protective Fabric at Different Angles of Heat Exposure

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Firefighters meet numerous forms of heat exposure from accidents happening worldwide every day. They usually require protection from direct fire threats or intense radiant heat exposure at different places and conditions during fire mishaps. It is extremely required to acquire a suitable outfit that can provide protection and comfort to the fire personnel, while it is extremely difficult to meet both characteristics. The outer shell of a multilayer fire protective gear greatly impacts the protection performance in various heat exposures. For the optimization of the para-aramid content %, microclimate thickness at varied angles of exposure has been explored in this study. The honeycomb weave structure was considered the outermost layer of the fire protection ensembles, and three various microclimate thicknesses (0mm, 6.25mm and 12.5mm) at 90, 135 and 180 degrees at a continuous heat exposure were tested. The box-Behnken model was evaluated to optimize the para-aramid yarn percentage (0 to 100 per cent) combined with meta-aramid yarn for the greatest protective performance against the heat source. The 3D surface was evaluated to predict the protection level of the outer layer of the safety suits, adjusting the air gap and angle of the heat source. A system equation for predicting the protection time (t-protection) was constructed using the model. Finally, the protection time is influenced by the change of the angle of exposures along with air gaps and the increase of para-aramid content %, which significantly impacts the protection performance of the honeycomb weave structure.

Keywords

Outermost layer, Heat flux, Box-Behnken, Protection time.

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Protection Against Small and Large Splashed of Molten Metal

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Aramid and glass-based fabrics are widely used in protective clothing due to their excellent thermal resistance. This study focuses on the performance of para-aramid and glass based aluminized fabrics in protecting against small and large splashes of molten metal, a common hazard in industries such as foundries, welding, and metallurgy. A variety of samples were developed for this study and the thermal and physical properties of fabrics were analysed. Aramid allow them to resist high temperatures and prevent fabric ignition or melting upon contact with molten metal. However, sticking of molten metal were observed in case of para-aramid liner against molten aluminium test. As shown in figure 1.

Figure 1: Sticking of molten aluminium on para-aramid fabric

Whereas, aluminized fabrics showed slipping of molten aluminium. In this test the proper method of aluminization is important to have better results because it was observed that some fabrics failed in flammability test after aluminization.

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CIRCULAR OPERATIONS AND SUPPLY CHAIN MANAGEMENT

Toward Circularity in Textile Waste Management: Challenges, Innovations, and Strategic Actions

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Background

The global textile and fashion industry is currently facing heightened scrutiny for its environmental impacts, particularly its contributions to carbon emissions, resource consumption, waste generation, and pollutions. Under the influences of "fast fashion," this industry primarily driven by a linear mode, which characterised by rapid consumption, disposal, and unsustainable, resulting in significant textile waste, the majority of which ends up in landfills or incinerated. Only 13% of discarded textiles are recycled, and a mere 1% are converted into new apparel. This paper advocates for a systemic transition toward a circular economy model in textile waste management, aiming to reduce waste generation and extend the lifecycle of textile products. Such a shift could significantly reduce environmental impact by fostering sustainable practices across production, consumption, and disposal phases within the industry.

Literature Review and Current Barriers

Research indicates that the current textile waste management practices are inadequate, with landfilling and incineration representing the predominant disposal methods. These practices contribute significantly to environmental degradation, resulting in increased greenhouse gas emissions, soil contamination, and water pollution. The major barrier to improving textile recycling rates is the lack of efficient sorting and separation technologies, particularly for fabrics made from blend fibres, which are challenging to disassemble and recycle. Despite these challenges, some businesses have pioneered innovative recycling and upcycling technologies. QMILK utilises milk proteins to produce sustainable fibres, while Patagonia's closed-loop system recycles used clothing into new apparel. Although these initiatives present promising frameworks, they remain insufficient to drive a full-scale transition toward circular fashion.

Position and Proposed Solutions

Addressing the issues within textile waste management requires action across the entire value chain, from design to disposal. This paper advocates for the implementation of Extended Producer Responsibility (EPR) policies to realise sustainable practices, encouraging businesses to invest in advanced sorting and separation technologies for textiles. Additionally, policy frameworks that promote closed-loop recycling and sustainable product design are essential for establishing a circular economy in the fashion sector. Consumer and citizen engagement is also crucial to support a circular fashion economy. Public awareness initiatives can drive demand for sustainably products and responsible disposal practices, encouraging consumers to support brands committed to eco-conscious production. By addressing specific challenges, such as microfibre emissions and the use of environmental impact assessments (e.g., Life Cycle Assessment) in recycling processes, stakeholders can collaboratively advance a more effective and sustainable textile waste management system.

Conclusion

In summary, transforming the textile industry from a linear to a circular model requires coordinated action from businesses, policymakers, and consumers. It is necessary to develop scalable recycling technologies, promote sustainable design practices, and create policies that reduce waste generation. This paper calls on all stakeholders to support initiatives that will reduce the environmental footprint of the textile industry, thereby paving the way for a sustainable future in fashion.

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Sustainability Assessment of Novel Textile Waste Processing Strategies

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The environmental impact of the textile industry to the environment is significant across a series of different categories (e.g. global warming, water depletion, land use, air and water pollution). The textile industry is responsible for approximately 10% of the global greenhouse gas emissions [1] and is the industrial sector with the second highest water consumption globally [2]. The textile industry is also a significant source of waste streams, with less than 50% of post-consumer textile waste being collected for reuse or recycling, and only a mere 1% of that stream, according to the EU, is recycled into new clothes [3]. Regarding recycling methods, mechanical recycling is the most widely used technology, where the waste is physically processed to recover fibres or fabrics and convert them into useful products (such as wipes, padding and filling). This route is followed by approximately 20% of the post-consumer textile waste [4]. Another popular method, which sometimes follows mechanical recycling, is chemical recycling, where the waste is reduced to its base components and is then spun again to new fibres. Although all types of recycling contribute to resource savings and reduction of the overall environmental impact, mechanical and chemical recycling have several disadvantages, such as high energy intensity, use of several chemicals. At the same time, the new circular products are more expensive than the corresponding garments made of virgin textile fibre.

In this research paper, we aim to examine a novel way of treating textile waste, via enzymatic hydrolysis, assess its environmental performance and estimate its life cycle cost, in order to draw some initial conclusions about the environmental and financial sustainability of this novel technique. For the environmental impact assessment, the Life Cycle Assessment will used, following the ISO14040:2006 standard [5]. The selected functional unit is 1 g of mixed post-consumer textile waste, while the system boundaries include the pre-treatment and the hydrolysis of the waste stream. The Environmental Footprint 3.0 has been chosen as the preferred impact assessment method as it covers all the significant impact categories, while it also offers the opportunity to express the overall impact in a single score indicator (measure in eco-points - Pt).

Table 1 presents the Life Cycle Inventory of the studied system, as provided by the experiments that were conducted in a lab scale environment at the Technical Textiles Research Centre. The Life Cycle Assessment has been performed using the SimaPro software (Academic License v9.2) and the characterisation factors were retrieved from the ecoinvent database v3.7. The analysis has revealed that the main environmental hotspot of our proposed approach is the use of electricity, both for hydrolysis and pre-treatment, followed by the use of urea, as illustrated in Figure 1. In terms of financial impact, the proposed approach will incur an additional £0.64 per g of treated textile, with the cost of chemicals used being the major cost component (Figure 2). Although this value seems relatively high, it should be considered that the results are based on lab scale data, and when scaling up, economies of scale will positively influence the overall cost.

Table 1. Life Cycle Inventory of the proposed enzymatic hydrolysis textile waste treatment method.

Resource	Flow
Textile waste	1 g
Sodium Hydroxide	1.4 g
Water	60 mL
Urea	2.4 g
Electricity (for pre-treatment)	0.00375 kWh
Citric Acid	0.0096 g
Cellulase	0.04 g
Electricity (for hydrolysis)	0.00375 kWh

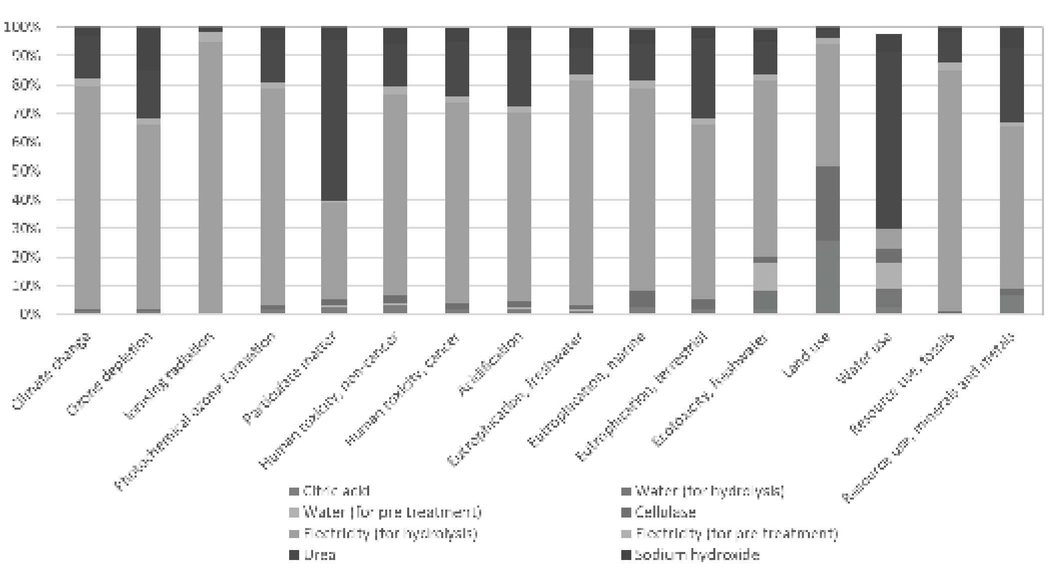

Figure 1: Environmental Impact Assessment of the proposed enzymatic hydrolysis textile waste treatment method

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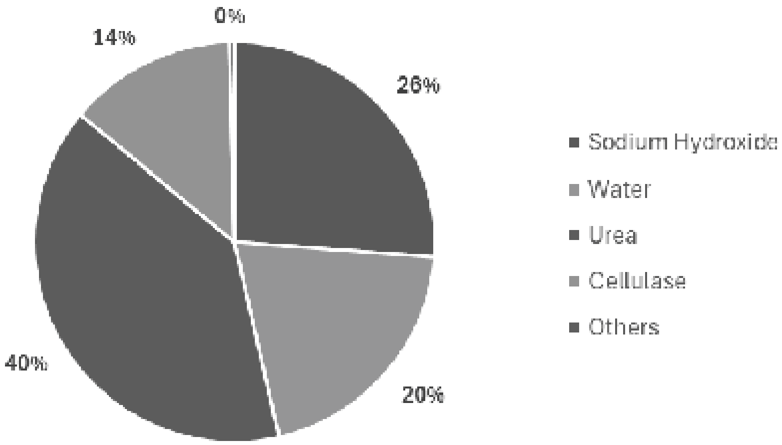

Figure 2: Cost analysis of the proposed enzymatic hydrolysis textile waste treatment method

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Integrating Ambidextrous Innovation Capabilities and Channel Coordination Mechanisms for Achieving Resilience and Viability in Sustainable and Circular Textile Supply Chain

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Introduction

The textile industry, which uses a lot of water, dyes, and chemicals, is considered to be the second most polluting after the crude oil industry [1]. The textile value chains adopt sustainability due to increased consumer awareness and regulatory compliance. Sustainability practices in the textile supply chain help to achieve environmental protection goals, lower carbon emissions, improve resource efficiency, and achieve ethical labor practices (Rossi et al., 2020). A circular supply chain goes further by recovering value from waste by collaborating with other organizations within the same industrial sector (open loop, same sector), or with different industrial sectors (open loop, cross-sector) (Bocken et al., 2016; Pieroni et al., 2019; Saidani et al., 2019). The problem of lack of sustainability and circularity in the textile industry is still a major issue. The Indian textile industry is disintegrated and highly unorganized, and it consists of problems such as a lack of coordination, disruption of the supply chain, environmental issues, social issues, a lower profit margin, and a lack of financial strength for innovations. During COVID-19 pandemic, the mandatory lockdowns caused supply chain disruptions, shutting thousands of textile manufacturing units (Khurana, 2022). The lack of resilience and viability in the Indian textile industry is another issue that needs to be addressed to prepare better for uncertainties in the future. Supply chain resilience is the ability of the supply chain to bounce back to the old normal, maintain stability, mitigate risks from economic disruptions, and achieve long-term sustainability (Gruchmann et al., 2024; Feng et al., 2024; Ivanov, 2024; Li et al., 2024). Supply chain viability is the ability of the supply chain to bounce forward and adapt to new changes, as well as consider strategic perspectives to achieve long-term success, growth, and sustainability in a radically changed environment (Echefaj et al., 2024; Ruel et al., 2024). The exploitative innovation builds on the existing knowledge to improve technology, processes, and products. The exploratory innovation relies on radical change and builds on new knowledge to develop new products and services for the new market segment. The ambidextrous innovation considers both the aspects of exploitation (continuous) and exploratory (radical) innovations.

Most recently, Pal et al. (2024) conducted research on the Indian textile recycling ecosystem, but the issues of lack of resilience and viability are still unaddressed. There are gaps in the literature on resilience and viability in sustainable and circular textile supply chains considering firms' ambidextrous innovation capabilities and channel coordination. The business problem that has been addressed in this study is how resilience and viability can be integrated into a sustainable, circular textile supply chain.

Research Questions

In this study, the following research questions are addressed:

RQ1: How can resilience and viability be achieved in sustainable and circular textile value chains?

RQ2: How can the channel coordination mechanism play a role in achieving resilience and viability in sustainable and circular textile value chains?

RQ3: How can the ambidextrous innovation capabilities of firms play a role in achieving resilience and viability in sustainable and circular textile value chains?

RQ4: How can the vital factors responsible for achieving resilience and viability in sustainable and circular textile value chains be prioritized?

RQ5: What is the cause-effect relationship among the vital factors responsible for achieving resilience and viability in sustainable and circular textile value chains?

Research Method

This study uses a mixed-method approach, including case studies and a multi-criteria decision-making model. The Indian textile firms are considered as the unit of analysis. Using the case studies, the vital antecedents are identified. Subsequently, the analytical hierarchy process (AHP) and decision-making trial and evaluation laboratory (DEMATEL) based multi-criteria decision-making models were used to rank and set the cause-effect relationship among critical factors responsible for achieving resilience and viability in sustainable and circular textile value chains. Finally, the sensitivity analysis is done to check the robustness of the model.

Findings and Conclusion

The research proposes a resilient, viable, sustainable, and circular conceptual model, considering the ambidextrous innovation capabilities of firms and channel coordination mechanisms. The proposed conceptual model, which is derived from the findings of the extensive case studies, is the novelty of the research. The ambidextrous innovation capabilities help the firms in the textile value chain to achieve resilience and viability. Exploitative innovation plays a major role in making the supply chain efficient and resilient, while exploratory innovation plays a major role in achieving viability in the supply chain. The study suggests that channel coordination among the firms in the value chain is helpful in the situation of disruptions. The vital factors are prioritized, and the cause-effect relationship among the vital factors is identified using the AHP-DEMATEL method. The sensitivity analysis is conducted by changing the weight of industry experts who participated in the study, validating the findings' robustness.

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Post-consumer Textile Waste Recycling Ecosystem: A Bibliometric Analysis, Framework and Strategy

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Introduction

The previous few decades have seen remarkable growth and transformation in the textile industry due to advancements in technology, globalisation, and shifting consumer needs [1]. However, the industry's growth has also raised environmental concerns because of its significant resource consumption and the production of enormous amounts of textile waste [2]. The textile industry is projected to dispose of around one million tons of waste annually [3]. Most of the garbage container consists of 3% waste by weight derived from fabrics which indicates presence of sufficient amount of garbage available that can be and is being recycled. The textile industry primarily emphasises two main types of recycling: pre-consumer and post-consumer recycling. Pre-consumer waste refers to the waste generated during the manufacturing process, such as stitching, cutting, or weaving. The latter refers to trash generated by clothing and household textile goods. Post-consumer waste refers to household items or garments that will not be used further and has been chosen to dispose of [4]. India produces roughly 7.7 million tonnes of textile waste annually, or around 8.5% of the global total [5]. Out of the total waste/ produced, 66% is disposed of in landfills, 19% is burned with energy recovery, and a mere 15% is recycled. Reusing post-consumer textile waste in an organised way can produce new resources, jobs and can also lower carbon dioxide emissions [6]. Though it is a complicated process with many challenges, like recycling process can be labour-intensive and end products may not have an even appearance, it can benefit the economy and the environment.

Research Aim and Question

Global textile consumption has increased tremendously due to increased population, better living standards, industrialization, and the accessibility of low-cost clothes. Due to this increase, there has been an alarming global spread of abandoned textiles in landfills and clandestine textile disposal. This paper aims to enhance the previous studies by incorporating new findings and presenting a more thorough literature overview of post-consumer waste recycling in the textile and apparel industry. The main aim of this study is to comprehensively investigate the research on post-consumer waste recycling in the textile sector, using the bibliometric technique to address the current research prospects and challenges in the Indian context. This work aims to investigate the following specific research questions:

RQ1: What are the publication trends and research patterns on sustainable manufacturing and post-consumer waste recycling in the textile industry? Which academic journals are considered notable in the field of research on sustainable production and post-consumer waste recycling in the textile industry? What is the country partnership network of the textile industry for research on sustainable production and post-consumer waste recycling? RQ2: What is the co-citation network of authors in the field of sustainable textile production and post-consumer waste recycling? What are the influential publications in sustainable production and post-consumer waste recycling research in the textile sector? What are the main research domains of sustainable production and post-consumer waste recycling research in the textile industry? and RQ3: What are the prospects of development of post-consumer textile recycling in India? What should be the strategy for sustainable post-consumer textile waste management?

Research Methods

Bibliometric analysis is a highly efficient approach for assessing patterns and changes in scholarly publications. Current studies lack a comprehensive representation of the global contributions to the field of post-consumer waste recycling, and they clearly indicate the necessity for a bibliometric study on post-consumer waste recycling within the textile industry. The bibliometric method was carried out using SciVerse Scopus, VosViewer was used to apply a citation network, and Tableau was used to visualise the geographical distribution of research on post-consumer textile recycling globally.

Findings

The bibliometric analysis of post-consumer textile recycling makes five-fold contributions to the academic literature. First, it provides insight on key researchers, top-performing countries, and top institutes performing research in the area of post-consumer textile recycling. Second, it examines the geographical distribution of research on post-consumer textile recycling globally using Tableau software. Thirdly, it discusses the essential keywords related to post-consumer textile recycling. Fourthly, it synthesises the bibliometric analysis research into a conceptual framework for post-consumer textile recycling by applying topic modelling. Finally, it discusses the prospects of the development of post-consumer textile recycling in India. No two post-consumer clothing products are the same, and they come in a variety of sizes and forms. Furthermore, every textile or apparel has a unique history of chemical and fiber blends. The main technical and practical barrier to recycling is the difficulty in separating fibers and blends in such a wide range of products. It is challenging to separate post-consumer textiles or apparel according to their fiber content. Sustainable production is an effective approach to mitigate the negative impacts of the manufacturing industry on the natural environment. In the conventional textile and apparel supply chain, manufacturers are primarily based in developing Asian nations, and consumers predominate in developed nations like the United States and Europe. Therefore, because of the associated costs, transportation challenges, and regulations of participating countries, it is nearly impossible to operate a reverse supply chain as the exact backwards of the forward chain.

Conclusion

This study offers significant insights into the current research on post-consumer recycling in the textile sector and its progression over the last three decades. With the application of bibliometric analysis, the study provides a complete and in-depth comprehension of post-consumer textile recycling practices. The results also shed light on more general industry-related problems faced during collection, sorting, processing and manufacturing. Furthermore, this review contributes to the existing body of literature on sustainable production and post-consumer waste recycling by providing insight into the academic community's fascination with this subject. Furthermore, this study makes a methodological advancement by integrating bibliometric analysis with a text analysis framework.

Ultimately, it discusses the development prospects of post-consumer textile recycle in developing country like India.

Keywords

Textile waste, Post-Consumer Waste Recycle, Garment waste, Waste prevention

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Exploring the Key Drivers and Barriers of Digital Twins in the Fashion Industry

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The integration of digital twins in the fashion industry has attracted significant attention due to its potential to transform product design, manufacturing processes, and supply chain management. Digital twins are digital replicas of physical products and systems that facilitate a seamless connection between the virtual and physical worlds [1]. Digital twins serve as a tool that fosters sustainable development because this technology enables operational optimization [2]. This technology enables fashion brands to optimize their operations through real-time data analysis and simulation. This research paper explores the drivers and barriers associated with the adoption of digital twins in the fashion industry that emphasize on the transformative impact of this technology. This study systematically consolidates and organizes the existing literature on the facilitating factors and challenges associated with digital twin implementation in this sector. Based on the existing literature, a parametric scale has been developed to assess the drivers and barriers related to the adoption of digital twins within the fashion industry. This study includes a comparative analysis of five prominent fashion brands, which reveals several critical factors that encourage the adoption of digital twins. Through this comprehensive approach, the study aims to provide valuable insights into how digital twins can reshape practices within the fashion industry. The findings highlighted the key drivers such as their role in promoting sustainability, enhancing design and personalization, and transforming supply chain operations. Additionally, the paper examines the barriers that impede the effective implementation of digital twins. These challenges include complexities related to product life cycle management, cost considerations, difficulties in data management and the need for organizational change and skill enhancement within the workforce. By analysing these drivers and barriers, this research aims to provide valuable insights for fashion industry stakeholders, technology developers, and policymakers, guiding strategic decision-making and facilitating the effective integration of digital twins to realize their full potential in the fashion industry.

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AI Integration in Fashion Trend Forecasting & Garment Design Development

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The integration of artificial intelligence (AI) within the fashion industry is catalyzing significant innovation, particularly in the domains of trend forecasting and garment design development. This research critically examines the effectiveness of AI-driven tools in enhancing predictive accuracy, operational efficiency, and creative processes such as ideation, design exploration, mood board creation, prototyping, customization, and trend application within the fashion sector. Traditional methods in these areas often suffer from subjectivity and inefficiency, leading to missed market opportunities and elongated design cycles. These challenges are exacerbated by the accelerated pace of fashion cycles and the increasingly dynamic nature of consumer preferences. This study aims to investigate how AI can revolutionize these processes, providing a data-driven approach that meets the demands of a rapidly evolving and personalized market. This study employed a qualitative approach to gain insights from industry professionals. Interviews with designers, merchandisers, and AI specialists provided deeper insights into the practical challenges and benefits of AI integration. The findings indicate that AI significantly enhances the precision of trend forecasting, enabling fashion brands to anticipate market shifts with unparalleled accuracy. AI integration in design processes has led to more efficient workflows, reducing reliance on physical prototypes, and enabling faster time-to-market. Moreover, AI-driven customization empowers brands to better meet specific consumer needs. However, the research also identifies potential risks, including the over-reliance on AI, which may constrain creative freedom, as well as ethical concerns related to data biases and algorithmic transparency. These challenges highlight the need for a balanced approach, ensuring that AI supports rather than supplants human creativity. While AI tools provide substantial benefits, their successful implementation requires careful consideration of ethical implications and the preservation of creative processes. As the fashion industry increasingly embraces AI, these ethical implications must be carefully considered. Ongoing research and development are essential to ensure that AI serves as a tool to enhance human capabilities, rather than replace them. This study contributes to the growing body of literature on AI in the fashion industry, drawing on comprehensive market data, and industry insights to provide an examination of this transformative technology.

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TRADITIONAL TEXTILES, CRAFT AND DESIGN

Comparative Impact of Traditional Canal Washing and Tank Washing Systems on Kalamkari Printed Fabrics of AP

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Traditional crafts like Kalamkari from Machilipatnam, Andhra Pradesh, embody eco-friendly practices through the use of vegetable dyes and hand block printing. This craft traditionally involved washing fabrics in river canals, a crucial step to prevent back staining of prints. However, recent regulations by district officials have banned canal washing due to the environmental impact of metallic mordants and synthetic colorants used by various small-scale producers. This ban stems from concerns about water scarcity, excessive water consumption, and majorly the direct pollution of local water bodies, as traditional washing methods do not incorporate wastewater treatment facilities. Despite the global demand for handcrafted Kalamkari increasing production, many artisans still follow traditional canal washing methods. This practice overlooks the negative environmental consequences due to the lack of effluent treatment or recycling plants to handle pollutants. The study focuses on addressing key environmental and ergonomic challenges associated with traditional washing methods. It explores an alternative tank washing system followed by Azrak block printing cluster in Kutch, as a potential model for the Kalamkari cluster in Andhra Pradesh for comparison against the yardage washed at canals. It evaluates the tank washing system that conserves water, minimizes environmental impact, and integrates wastewater treatment at the cluster level, all while preserving fabric quality. Power loom cotton fabrics, desized, bleached and treated with myrobalam traditionally at Pedana, are printed using mordants regularly used at the cluster such as fermented iron acetate, alum, and a combination of alum and alizarin. They are boiled/ dyed further at the cluster to determine the impact of different washing methods on the outcome, based on assessing various parameters such as weight, strength, and colour attributes including K/S values (HUNTERLAB), CIE lab values, and colourfastness. Additionally, it suggests design improvements for the tank based on the principle of counter-flow washing as shown in Figure 1f.

The colour parameters of canal vs tank washed samples are assessed before and after boiling in vegetable dyes. Tank system of washing showed the next highest colour strength (66.46) of black colour after the highest colour strength value (78.89) of sample washed in canals. E value of alum and alizarin combination of mordant, boiled in alizarin (4.68), which falls in the range of standard perception 2-10, the least H value indicating less difference in hue (-4.24), C values of Alum and Pomegranate (-1.02) and the sample boiled in alizarin (-1.11) are less, indicating slight dullness in chroma or saturation when washed in tank system, satisfying the need to replace the system of canal washing with washing in tank system in the Kalamkari production process. Structural changes of fiber studied by using SEM (Scanning Electron Microscope) revealed superior surface topography of

Figure 1. a. Printing with mordants; b and c. Washing at river canal d and e. Washing in tanks; f. 3D model of the proposed tank system

samples washed in tank system. The colour difference showed no significant effect on the colourfastness of fabrics washed in canal and tank systems. Thus the results are encouraging, ensuring the possibility of replacing alizarin/chemical processes with eco-friendly washing system.

While numerous studies have focused on the selection of natural resources and methods for dyeing and printing, as well as strategies for performance evaluation, there has been limited research on the sustainability of washing methods used by small-scale production units in craft clusters and their impacts. The study lends further scope for assessing market acceptance, investigating the economic feasibility of implementing tank washing system considering the factors such as initial investment costs, operating expenses and the impact on product pricing. The study throws light on the challenges and limitations associated with the tank washing system such as technical issues and also resistance of craft practitioners to change within the cluster.

Conclusion

The craft tradition had been an integral part of family businesses which led to usage of authentic techniques of the past while orienting towards market changes at present. Washing in tanks can be a perfect substitution for the fabrics printed using alizarin in combination with alum as a mordant in producing block printed Kalamkari, as it was found to be eco-friendly, practical and feasible for implementation even by small-scale units in India. Textile printing is one of the most important and versatile methods among the methods used to design and colour textile fabrics [1]. During dyeing and printing using natural dyes with mordants, there is possibility that some amounts of the dye and the mordant may be unexhausted and discharged into the environment, resulting in serious environmental and health hazards [2, 3]. The literature review provides an in-depth analysis of the transition from traditional canal washing to tank washing in Bagru's block printing industry as a case study [4]. Kalamkari industries flourished near rivers, tanks and wells which contained certain chemicals which are believed to result rich and deep colours using natural dyes [5]. However, disagreements on the risks of the usage of synthetic pigments and increasing environmental awareness result in an enhanced interest in natural resources, environmentally friendly practices based on new strategies formed the basis for the study [6]. The method of reuse of water in the counter-current washing is opposed to the traditional washing method of supplying clean water at every stage of the washing [7] that brings water and energy savings.

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The Confluence of Fashion and Contemporary Indian Subcontinent Art

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Fashion design in its more general interpretation is understood as an application of design and aesthetics to create clothing and related products. At times the term is defined including the process as well, that is material sourcing, concept creation, pattern making and garment construction and manufacturing. Whereas mainstream art is a more amorphous term, difficult to define, yet largely understood as creative expression, emotional expression or creative critical interpretation through visual representation. Art is still more plural in terms of concepts and materials and is free to be more abstract than design will ever have the freedom to be. The field of Art and fashion design have been interrelated, overlapping, in creative exchange and have been inspiring the respective visual languages since the creation of Neolithic female figurines. The visual language of the art has always been used to read and historically document the evolution of fashion aesthetics. In the late 19th and 20th C. however this exchange became more real time, when art and design became a source of inspiration and experimentation for each other and their approaches became more trans-disciplinary and interdisciplinary. Italian Futurist venturing into costumes and fashion garments not only aesthetically but also conceptually by creating short lived garments to promote industrialization is one such example. Later artists such as Sonia Delaunay, Sophia Taeuber also effortlessly moved in through both fashion and the art world creating future possibilities for the artists and fashion world to coincide and deviate at numerous occasions during Art Deco Bauhaus and Surrealism [1]. The research theme aims to look at this intriguing relationship between art and fashion in the context of the Indian subcontinent. The selected area of research, the Indian subcontinent reflects and acknowledges the social, economical and political impact of the common colonizer and the region playing an important role in the fashion industry especially as a cheap manufacturing hub. Three artists from this geo-political region have been selected, whose art practice have either directly reflected or borrowed from the field of Fashion design. Namely, artist Vivan Sundaram from India, Tyeba Begum Lipi from Bangladesh and Anoli Perera from Sri Lanka, they all have registered their presence in the national as well as International art world. Multidisciplinary Artist Vivan Sundaram created a series of artworks called Gagawaka in 2011. The series was a collection of sculptural garment or wearable sculptures (ref art forum) using everyday material and items retrieved from the trash. The series takes its inspiration as well as reflects on the Haute Couture fashion, especially led by designers such as Alexander McQueen. Although here the usage of everyday material and objects from the trash give it an anti aesthetic approach as compared to the aesthetical focus of fashion. Here the artworks or the garments cannot be separated from the social cultural construct everyday material like bras, used X ray films or retrieved piece of leather brings along [2].

Whereas, the 2007 artwork titled, 'Elastic' of Anoli Perera from Srilanka strips and destructs the readymade feminine garment, to recreate it in the form of an installation. The red flowy feminine gown creates an argument to highlight the gender, body politics and cultural eroticization of the female body in light of consumer culture. Her use of Fashion essential, bra, in the form physical material critiques exploitation of gender stereotypes by consumer culture [3]. The third case study carries forward a similar argument however steeped in its own local cultural and economic situation. Bangladeshi artist Tayeba Begum Lipi also recreates the visual form of garment and apparels however replacing the original soft material with razor sharp and metallic stainless steel blades. Her reasoning for engaging with physicality of the specific material gives a cultural twist to her conceptual concerns. Also, separating her artworks/ art practice from the place of its origin Bangladesh, that also happens to be the most sought after manufacturing resource place in Asia is not easy. The social cultural impact of this economic development cannot be ignored [4]. The idea is to study and reflect their selected artworks that are directly related to the theme in an attempt to understand the different approaches that they have used to visually interpret the same. The three selected artists display a strong cultural and social consciousness in their approach to art and have been instrumental in creating a socially conscious voice in the form of artistic platforms in the respective countries. Hence one can assume that their interpretation of fashion is beyond the usage of fashion design or garment as a mere surface for aesthetical decoration. However, one of the research objective tends to study whether their art practice on the subject generating a dialogue between an object of mass production and an object created for ideological, creative and emotional concerns. Most of these contemporary artworks and artists have been exhibited in Delhi at different time periods in the last two decade offering opportunities for primary observation. Additional Information on the artworks is to be collected through detailed survey of the exhibition literature and articles and papers published about the same. A detailed study of the selected artworks will further reveal distinct perspectives used to interpret the idea of Fashion such as in context to material, cultural and gender connotations. This is an attempt to understand how fashion has been used as a theme in art and not just a surface to be painted upon, as compared to art providing a theme for fashion. The artists are deliberately reflecting on global fashion initiating a discourse on theme from this side of world, which is a rare happening in the mainstream art. The key participation of the subcontinent in the Fashion Industry as a hub for cheap manufacturing and cheap labour , makes it all the more relevant to study the interpretation of the same from the native artists who are also representatives of the subcontinent in the global mainstream art market.

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Revival of Age-old Traditional Indian Mending Techniques for Preservation and Conservation of Textiles

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Introduction

The rich cultural heritage of India is deeply embedded in its traditional textile arts, many of which include intricate techniques of repair and mending. Practices such as *kantha* embroidery from Bengal, Rafu from Kashmir and *sujani* quilting from Bihar not only extend the life of textiles but also imbue them with artistic and cultural value. Historically, these mending practices were more than functional; they were acts of storytelling, where each stitch and patch carried narratives of family, community, and creativity (Fletcher, 2010). Despite their cultural significance, the advent of industrialization and the rise of disposable fashion have marginalized such age-old techniques. Today, as modern lifestyles and fast fashion dominate, the ethos of repair and reuse has given way to a culture of wastefulness.

Amid growing environmental concerns, there is a pressing need to revive these traditional mending techniques as a means of textile preservation and sustainable fashion innovation. Research indicates that repairing garments instead of discarding them can significantly reduce textile waste and lower the carbon footprint of clothing production (Ellen MacArthur Foundation, 2017). By blending indigenous repair practices with contemporary design sensibilities, India has the opportunity to reclaim its rich heritage while addressing global challenges in textile conservation. This research paper delves into the potential of reviving Indian mending traditions, highlighting their ecological, cultural, and aesthetic value, and exploring how they can be reimagined for a circular fashion economy.

Mending practices in India have evolved over centuries, deeply intertwined with social, cultural, and economic structures (Dhamija, 1970). For example, Kantha embroidery, originating in Bengal, epitomizes the reuse of old saris to create new, functional items such as quilts and throws, with stitches often narrating folklore and life stories (Das, 1992). Similarly, Patchwork techniques from Gujarat and Rajasthan emerged from a need to repurpose fabric scraps, creating colorful and intricate designs that were as aesthetic as they were practical (Mehta, 2008). Rafu, primarily used for repairing delicate fabrics like muslin, illustrates the mastery of Indian artisans in achieving near-invisible repairs, ensuring the longevity of valuable textiles (Ahmed, 2005).

These practices not only served practical purposes but also became embedded in the rituals, traditions, and visual culture of various communities, strengthening a sense of identity and belonging. As objects of daily use transitioned into heirlooms, mended textiles also played a role in documenting personal and communal histories (Ramaswamy, 2004).

Methodology

The methodology of this research on reviving traditional Indian mending techniques for the preservation and conservation of textiles follows a mixed-methods approach. By combining qualitative and quantitative research methods, this study aims to comprehensively examine the historical, cultural, and practical dimensions of mending practices while exploring their contemporary relevance.

1. **Research Design**
   The study employs a multi-layered framework:
   - **Descriptive Research**: To document traditional Indian mending techniques and their cultural significance.
   - **Exploratory Research**: To analyze how these practices can be adapted to modern contexts within the circular economy and sustainable fashion.
2. **Data Collection Methods**
   A. Primary Data
   1. Interviews
   - Semi-structured interviews were conducted with artisans, textile conservators, and fashion designers. The purpose was to gather insights into the traditional mending methods, materials used, and their role in garment repair.
   - Sample Size: 5 participants from textile-rich regions, including West Bengal, Gujrat, Rajasthan, Kashmir and japan were interviewed.

   2. Field Observations
   - Site visits to artisan workshops were carried out to observe mending techniques in practice.
   - Notes were taken to document tools, processes, and the cultural contexts of these practices.

   3. Focus Groups
   - Focus group discussions with fashion students and consumers were held to understand perceptions about traditional mending techniques and their acceptability in modern fashion.

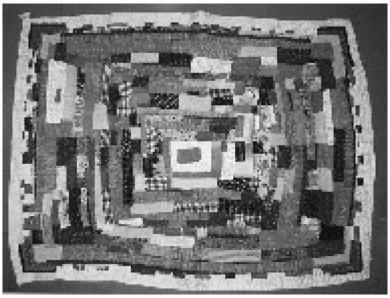
   B. Secondary Data
   1. Literature Review
   - Academic journals, books, and reports were analyzed to establish historical and theoretical foundations for Indian textile mending practices. References include works by Fletcher (2010), Chapman (2015), and reports by the Ellen MacArthur Foundation (2017).

   2. Archival Research
   - Historical documents, photographs, and museum exhibits showcasing traditional Indian mending techniques were reviewed. Archives of textile museums in India, such as the National Museum of Textiles, served as significant resources.

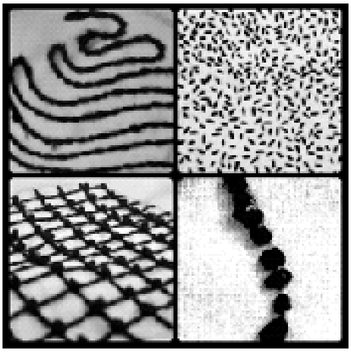
   3. Case Studies
   - Examples of contemporary adaptations of mending practices in sustainable fashion brands, such as visible mending campaigns, were studied to identify trends and challenges.

Kantha

Appliqu



Siddi quilt



variety of contemporary stiches

4. **Analytical Techniques**
   1. **Qualitative Analysis**-Transcripts from interviews and focus groups were coded using thematic analysis to identify recurring themes, such as cultural significance, sustainability, and modern adaptability.

2. **Quantitative Analysis**-Surveys were administered to consumers to understand attitudes toward repairing garments. Responses were analyzed using descriptive statistics to identify key patterns and correlations.
3. **Comparative Analysis**-Comparison between traditional mending practices and their integration into global circular fashion movements was conducted to explore innovation potentials.
4. **SWOT Analysis**-Strengths, weaknesses, opportunities, and threats of reviving traditional mending practices in modern contexts were evaluated.

5. **Ethical Considerations**
   - Informed consent was obtained from all participants.
   - Anonymity and confidentiality were maintained to protect artisan knowledge and participant identities.
   - Respect for cultural heritage was prioritized, ensuring fair representation of traditional practices and acknowledgment of the artisans' contributions.
6. **Limitations**
   - Geographic constraints limited the study to online interactions of specific regions known for prominent textile traditions.
   - Language barriers required the use of local interpreters, which may have influenced interpretations

This methodological framework ensures a comprehensive understanding of the traditional mending practices of India and provides actionable insights for their revival in sustainable fashion and textile conservation.

Key Findings

1. **Cultural Significance and Historical Value**
   - Traditional Indian mending techniques like *kantha*, *sujni, Rafu andpatchwork* are deeply embedded in regional cultures and history. They reflect local traditions, storytelling, and a sense of identity, making them more than just functional practices.
   - These methods represent sustainable practices that predate contemporary environmental concerns, showcasing a long-standing culture of resource conservation.
2. **Sustainability and Circular Economy**
   - Reviving traditional mending aligns with the principles of the circular economy by reducing textile waste, extending the lifespan of garments, and conserving resources.
   - Mended garments can transform waste into value, catering to the growing demand for eco-conscious fashion.
3. **Economic and Social Benefits**
   - Incorporating mending techniques into mainstream fashion can empower local artisans, create employment opportunities, and strengthen rural economies.
   - Skill development workshops focused on traditional mending can inspire younger generations to value and preserve these crafts.
4. **Contemporary Adaptation and Acceptance**
   - Visible mending, inspired by traditional techniques, is gaining acceptance as a form of creative and sustainable fashion. Younger consumers value these techniques for their uniqueness, aesthetics, and eco-friendliness.

- Partnerships with sustainable fashion brands and designers have shown potential in modernizing these techniques without losing their authenticity.

5. **Challenges in Revival**
   - The labor-intensive nature of traditional mending and the gradual decline in skilled artisans pose significant barriers to scaling up these techniques.
   - Modern consumer awareness of and appreciation for traditional mending techniques remain limited, requiring significant efforts in education and advocacy.
6. **Role of Technology and Education**
   - Digital tools and platforms can bridge the gap between traditional artisans and modern consumers by offering online repair tutorials, virtual exhibitions, and access to heritage practices.
   - Educational integration of mending practices in design schools and sustainability curricula is essential for their long-term survival and relevance.
7. **Consumer Perceptions**
   - Focus group discussions revealed a growing consumer interest in repairing and reusing garments, driven by environmental consciousness and a desire for individuality in fashion.
   - However, a significant portion of the population associates mended garments with outdated practices, underscoring the need for rebranding and storytelling around repaired textiles.
8. **Opportunities in Sustainable Fashion**
   - Traditional mending techniques can complement sustainable fashion initiatives, such as upcycling, bespoke tailoring, and slow fashion.
   - Collaborative repair workshops, artisan-led training programs, and repair services integrated into brand ecosystems present untapped opportunities for scaling mending practices.
9. **Barriers to Wider Adoption**
   - Fast fashion's influence and the availability of low-cost garments discourage consumers from investing in repairs.
   - Economic constraints, especially in low-income groups, prevent access to artisan services or high-quality repair solutions.
10. **Ethical and Cultural Considerations**
    - The ethical revival of these techniques must ensure fair compensation and credit to artisans. Practices should be rooted in collaboration rather than exploitation to preserve cultural heritage responsibly.

These findings emphasize the need for a multi-stakeholder approach involving consumers, artisans, educational institutions, brands, and policymakers to facilitate the revival of traditional Indian mending techniques.

Recommendations Based on Findings

1. **Integration with Sustainable Fashion Initiatives**
   - Launch eco-friendly collections featuring garments repaired with visible mending, blending traditional artistry with modern aesthetics.

- Collaborate with sustainable fashion brands to incorporate traditional Indian mending techniques like *kantha*, *sujni*, and *phulkari* into product designs and repair services.

2. **Capacity Building for Artisans**
   - Organize skill-development programs to train artisans in combining traditional mending techniques with contemporary fashion demands.
   - Provide financial and logistical support to artisan communities to create a sustainable supply chain for repaired textiles.
3. **Consumer Awareness Campaigns**
   - Develop awareness campaigns highlighting the environmental and cultural benefits of garment repair using traditional methods.
   - Use storytelling and digital media to educate consumers about the heritage and uniqueness of these techniques, making mending a desirable choice.
4. **Educational Integration**
   - Incorporate traditional mending techniques into school curriculums, fashion design courses, and community workshops.
   - Create digital modules and DIY kits that allow learners to practice traditional mending techniques at their convenience.
5. **Promotion of Visible Mending**
   - Popularize visible mending as a trend, showcasing repaired garments as symbols of sustainability and individuality.
   - Engage influencers, celebrities, and designers to wear and endorse repaired garments featuring traditional techniques.
6. **Policy and Institutional Support**
   - Establish repair hubs and textile conservation centers that promote cultural preservation and sustainability.
7. **Digital Enablement and Marketing**
   - Leverage technology to connect artisans with modern consumers through e-commerce platforms, showcasing traditional mending as a service or feature in garment restoration.
   - Develop mobile apps and online tutorials offering guidance on traditional mending techniques, making them accessible to global audiences.
8. **Collaboration with Designers**
   - Partner with contemporary fashion designers to innovate and modernize traditional mending techniques, ensuring their relevance in the global market.
   - Encourage the use of traditional repairs in haute couture and sustainable fashion lines to elevate the perceived value of these techniques.
9. **Community-Based Repair Initiatives**
   - Establish repair cafés and community-led events where consumers can learn, share, and practice traditional mending techniques.
   - Foster a sense of collective responsibility by involving local communities in repairing and conserving textiles.
10. **Ethical Practices and Artisan Welfare**
    - Ensure fair compensation, intellectual property rights, and credit for artisans whose skills are integral to these techniques.

- Set up cooperative models where artisans can gain direct benefits from their work and contribute to decision-making processes.

11. Monitoring and Evaluation

- Regularly monitor the impact of revival initiatives on artisans' livelihoods, consumer behavior, and environmental sustainability.
- Adapt strategies based on feedback and data to address challenges and optimize efforts.

12. Incentivize Repair Services

- Encourage fashion brands to provide repair services or offer repair discounts as part of their sustainability programs.
- Provide incentives such as discounts, loyalty points, or vouchers to consumers who choose mending over disposal.

By implementing these recommendations, stakeholders can work collectively to preserve India's rich textile heritage while promoting sustainable practices that align with the circular economy.

Conclusion

Traditional Indian mending practices are more than methods of repair; they are profound acts of cultural expression, sustainability, and respect for life's impermanence. Rooted in belief systems, storytelling, and emotional connections, they offer timeless lessons for modern sustainability challenges, promoting a mindful and ethical approach to fashion and textile conservation. The revival of age-old garment repair techniques gains significant momentum through quality analysis and visual documentation. These combined methods articulate how mending techniques honor cultural heritage while offering tangible solutions for environmental challenges. Together, they build a compelling case for embedding repair practices within contemporary fashion and sustainability initiatives. Through community engagement, educational initiatives, and policy interventions, these practices can be reimagined as essential tools for preserving textiles, conserving resources, and promoting environmental consciousness in the textile and fashion landscape.

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Significance of Traditional Costume, Clothing, and its Motif in the *Rabha* Society

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Clothes are our second skin. We wear them from the time we are born until we die. Clothes play a very important part in our lives and our existence. It gives us our identity and adds to our personality. Traditional clothing and design hold significant importance in all the various cultures around the world. They are not just garments to wear; they carry history, identity, cultural heritage, and artistic expression. Traditional clothing represents a cultural identity and heritage that distinguishes one community or group from another. It helps them connect to their roots, ancestors, and shared history. There is not much literature found about traditional clothing, its design, motifs, its meaning, and its significance in society. This paper aims to study the *Rabha* tribe, a prominent tribe from Northeast India, Assam, In the socio-cultural construct we live in, visual characteristics like color, motif, and design of traditional clothing plays a very important role. This paper aims to study *Rabha's* traditional clothing, its design, and its significance in Rabha society.

For the study, primary and secondary research methods were used. For secondary research, research papers and books on the Rabha tribe are refereed. For primary research field trips were made to places like Goalpara where the Rabha population inhabitant. Eminent personalities like national awardee Weaver, Rabha museum curator were interviewed. Different museums, libraries, Conventions, exhibitions, etc. were also attended to collect relevant data. Traditional designs often carry symbolic meanings that convey important messages within cultures. Colors, patterns, and motifs can represent elements like status, marital status, social roles, spiritual beliefs, good luck, protection, religious beliefs, and more. These symbols create a shared language among members of the *Rabha* community and are often passed down through generations. The importance of design, motifs, and their significance are highlighted in this paper to preserve the material culture of the tribe.

This study can be further taken to other tribes as well to understand the visual characteristics of traditional folk textile motifs, color, and clothing. This will help us understand the importance of textile and clothing design in a social context and the human psyche concerning the society they belong. As tribal societies revolve around nature, traditional clothes are always made in natural ways, be it dying, spinning, weaving, or even the way it has been worn. Their way of life concerning costume and clothing can further be studied with a sustainability framework.

Keywords

Traditional textile, Motif, Culture, Design significance, social design.

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Evolution of Bagru Craft in the Age of Commercialization: Unraveling the Threads of Authenticity

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Craftsmanship, rooted in Indian traditions and community practices, has long been admired for its intricacy, richness, and connection to cultural identity. However, in the age of commercialization, traditional crafts are going through transformations, making it hard to keep the true essence and traditional values of the craft intact. The evolution of Bagru craft in today's commercialized world presents a complex interplay between preserving tradition and responding to market trends. The rising global interest in Bagru textiles has pushed artisans to navigate the challenges of expanding production while adjusting their methods to suit consumer preferences. This transition often requires incorporating materials and techniques that may impact the traditional practices and essence of the craft. Economic constraints compel artisans to juggle between cost-effectiveness and maintaining age-old methods resulting in potential compromises, on quality. This qualitative study delves into the development of Bagru craft in the context of commercialization and examines how authenticity is preserved and altered over time. By conducting in-depth interviews, with both Bagru artisans and customers the research aims to uncover the nuances of how age-old practices adjust to market demands and consumer preferences. The questionnaire was well constructed and consisted of simple questions. The responses to the questionnaire were collected from Craft Artisans of Bagru to understand the evolution of Bagru craft, semi-structured interviews were taken with several artisans who have been deeply involved in this traditional art form for generations and have seen this craft evolving throughout. Artisans shared their experiences regarding the challenges and opportunities of commercialization while customers' viewpoints offer insight into their understanding of Bagru Crafts' authenticity and how commercialization impacts their buying choices. With increased access to domestic and international markets, Bagru artisans have faced pressures to change their craft processes to meet the requirements for mass production. Some artisans have transitioned their production from traditional hand block printing to screen printing. This transition has led to shifts in design trends and motifs, as per the evolving preferences of domestic and international markets. Traditionally, Bagru textiles featured intricate motifs inspired by nature, folklore, and historical themes, meticulously handcrafted by skilled artisans. To meet the demands of a wider market, artisans began experimenting with synthetic dyes to expand their color offerings and to ensure desired color fastness. This allowed for brighter, more varied hues that could attract a broader audience, although it also raised concerns about the environmental impact and authenticity of the craft. The commercialization of Bagru craft has led to changes in consumer perceptions of authenticity, influencing the way consumers perceive and value handmade textiles in the context of commercial markets. The results of this research will help enhance our understanding of the obstacles and possibilities faced by Bagru crafts in society and provide valuable perspectives while influencing consumer actions to uphold and celebrate genuine craft customs.

Figure 1: Bagru Artisan washing printed fabric

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Preservation of Gendra Craft as a Tool of Resilience for Homeless People through Convertible Garment

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The idea for designing all season garments for homeless people to comfort them in the harsh weather conditions. Research highlights the potential of preservation of Sujni art, traditional art of Bihar which are made from used layered clothes and sewn in running stitch into a convertible garment. This approach touches social challenges of vulnerable people on streets by providing them a feeling of warmth by providing those garments and the technique of sujni as a medium talk about sustainability as the product which are made from layers of used clothes, becoming a symbol of resilience, adaptability and care in the face of adversity. This research explores the innovative creation of Gendra, a multifunctional garment inspired by the traditional craft of Bihar, characterized by its distinctive Sujni artwork, also popularly/locally known as Gendra. Under this research a reversible clothing is designed for homeless people. Drawing motivation from Bihar's wealthy material conventions, especially Sujni weaving, this multifunctional piece is designed to supply consolation and assurance over all seasons. The piece of clothing is made from lightweight, protection texture, advertising warmth amid winter as a cover and effectively changing into a coat appropriate for summer wear A built-in plastic covering guarantees rain resistance, making the piece of clothing down to earth for the monsoon season. One of the key highlights of this plan is movability and comfort, with different pockets planned to store fundamental things, tending to the one of a kind needs of those without changeless protect. The reversible nature of the article of clothing includes to its flexibility, permitting it to be worn in different arrangements depending on the climate. By blending conventional craftsmanship with advanced development, this extend illustrates the potential of design plan to make socially impactful solutions. The result may be a stately, flexible, and strong item that provides security, consolation, and a sense of nobility to those in require.

Keywords

Resilience, Social Challenge, Sustainable, Social Innovation, Adaptability, Cultural Preservation

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Influence of Temple Architecture on Ikats of Odisha

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Indian textiles are among the finest textile traditions in the world. They are the symbols of India's cultural heritage. Similarly, rich iconographies of ancient Indian temples give meaningful strong insights into the culture of the past. This study investigates the cultural significance of textile motifs and designs inspired by temple architecture. It aims to explore the profound link between traditional architecture and weaving craft. The motifs inscribed on both temples and textiles can be linked to cultural, religious and socioeconomic factors prevailing in society. Many motifs in textiles currently in use can be projected back to earlier periods. These architectural marvels manifest mythology in myriad expressions and showcase symbols that give them a deeper meaning beyond sensory beauty. This study aims to understand the intricate relationship and influence of the ancient Indian temple architecture of Odisha on the famous ikat textiles of the region. To accomplish this research a qualitative research methodology is adopted. The interpretive-historical approach involves the analysis of primary and secondary sources through field study observations, figurative analysis and contextual narrations to uncover the underlying themes, patterns, meanings, interpretations, and cultural or social discourses embedded. Additionally, it focuses on the use and transformation of different types of motifs and designs from the built heritage to the beautiful ikat textiles of the region.
This research enriches the existing knowledge and provides unique insights into this fascinating intersection of architecture and textile design. It is rewarding to see the Indian ikat textiles in this light and to draw out the often astonishingly close relations that have existed between temple architecture & textiles over the years.

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FIBRES & COLOURS FROM NATURAL RESOURCES

Development of Banana Fibre Based Ternary Blended Textile & Clothing and its Eco-friendly Processing

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Banana is one of the world's oldest popularly cultivated fruit crops. Extraction of textile grade fibre from the banana pseudostem, commonly remained as agro-waste, is nowadays gaining academic and commercial interest for value-added product development, especially in the cottage level. The fibre can be used for making fabric, high quality paper and attractive handicrafts. Fibre is little coarser and stiffer as compared to jute fibre, but having positive attribute of ultraviolet (UV) protection and better thermal stability, making them a preferred choice textile production at low cost, while providing a sustainable solution for management this agro-waste and a avenue of income generation among the farming community. In order to achieve this, surface modification of fibre is primarily required to make them softer and finer to amenable them for blending with jute in different proportions to develop an acceptable textile grade yarn. In order to develop a clothing material and fine home textile products, still finer yarn is required. Therefore, in the blended yarn, a third component i.e., fine viscose fibre was introduced. Blending of the fibres helps to utilise the unique properties of all the individual fibres and to produce yarn with superior characteristics suitable for running in weaving machine. Jute and banana fibres were treated with eco-friendly biocatalysts followed by bleaching with peracetic acid (PAA). The control as well as chemical treated banana fibres were blended with jute and regenerated cellulosic (viscose) fibres in 35:35:30 ratios to produce ternary blended yarn of counts 4, 6, and 8 lb/spyndle. Ternary blended yarn was then subjected to dyeing using natural dyes extracted from Manjistha, Annatto, Babool and Ratanjot to produce coloured yarn with attractive look. The yarns can be utilised for making handicraft items, show pieces, fancy bags, ornaments, etc. at rural level. Bleached as well as dyed yarns were used to produce woven fabrics in handloom to develop with different designs, which can be judiciously utilised for making table runner/cover, bed cover, jackets, etc. UPF values of the naturally dyed fabrics were very good after pre-mordanting with bio-mordant and inorganic mordant combinations.

Keyworda

Banana; Jute; Ternary blends; Textile; Natural dye; UV protective

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Sustainable and Value Added Manmade Cellulosic Fibres (MMCF) for Textile & Fashion Industry

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In a world where Sustainability is no longer a choice but a necessity and a heightened sense of environmental awareness is redefining industries, Grasim Industries Limited's Cellulosic Business stands at the forefront of a textile revolution where, style meets sustainability, with materials that journey responsibly from forests to fashion, reflecting our commitment to environmental stewardship. Through our pioneering techniques, we are reshaping the fashion landscape by transforming raw materials into sustainable, high-quality textiles. In this paper, we will discuss how we are redefining fashion norms, proving that your style choices can be a force for good in protecting the planet and product stewardship requirements of global fashion industry aligning with emerging regulations in US and EU markets. Fashion industry is looking for solutions that can address the problems it is facing, to name a few - fast fashion driven excessive consumption, 2^{nd} largest water consumer, high GHG footprint, chemicals usage, de-forestation, pollution due to emissions to environment etc. Also, fashion industry generates nearly 92 million tons of waste every year and only less than 1% is recycled, rest being landfilled / incinerated, most of which is not biodegradable.

Sustainably produced value added manmade cellulosic fibres (MMCFs) can address many of these issues as they are based on natural renewable raw material sourced sustainably, manufactured using closed-loop process and biodegradable at the end-of-life. It can also be used to upscale cotton waste into fresh fibers. Grasim's business strategy is focussed on setting new benchmark in all the critical areas to make this ecosystem conducive for business - sustainable forestry, low environment impact products (closed-loop process), climate actions and circularity, thereby providing the fashion industry with an option of more sustainable choices for their products in textile sectors as well as nonwoven industry. We realized that these cannot be achieved without integrating the sustainability criteria in our day-to-day operations and include these requirements in our business processes. Our sustainability strategy has five pillars - *Responsible Sourcing, Responsible Manufacturing, Sustainable Products & Circular Economy, Valuable Partnerships and Social Responsibility*.

We are ranked leaders globally in Canopy's Hot Button Report based on our forest conservation practices, transparency and next generation fibres development. Grasim is implementing closed-loop production at all its fiber sites as prescribed in EU BAT guidelines. Next, we have launched a range of eco-enhance and circular products to fulfil the needs of sustainable raw materials. Some of the recent products are:

- Livaeco viscose & modal fibres for textile applications which comes from FSC® certified forests and is produced in EU BAT compliant facilities. Livaeco has 50% less GHG emission and consumes 60% less water than conventional viscose. Livaeco comes with supply chain transparency and traceability through a unique molecular tracer and blockchain based platform.

- Purocel Eco is eco-enhanced viscose fibre for nonwoven applications. Purocel Eco comes from FSC® certified and has 60% lower GHG emission and water consumption compared to conventional viscose. They have a unique molecular tracer that can be identified in the end products like wipes and helps the end consumers trace the origin of the product through blockchain based platform.

- Liva Reviva is a viscose fibre which contains up to 30% pre-consumer cotton fabric waste and is RCS (Recycled Claim Standard) certified. Liva Reviva comes with significant environmental benefits like low GHG consumption, low water consumption and complete supply chain transparency and traceability features like Livaeco.

- Birla SaFR is an inherently flame-retardant cellulosic fibre. This fibre is 100% plant based, made from wood pulp, sourced from sustainably managed forests and that adhere to highest global norms on environmental responsibility. Birla SaFR has a Limited Oxygen Index (LOI) of > 28 as per ISO 15025 testing standard for inherent flame retardant fibre.

- Birla Viscose™ Intellicolor VSF is a first of its kind patented anionic viscose. It is a breakthrough in the process of dyeing using cationic or basic dyes, reducing the dye input and enabling up to 95% dye bath exhaustion. The process helps achieve brighter shades with high tinctorial value and colour depth compared to reactive dyes with the same concentration of dyes. The process also stands out for its lower impact on environment.

- Birla EcoSodium: Recognizing the need for sustainable alternatives, Grasim explored the eco-friendly aspects of recovered Sodium Sulphate from its viscose fibre manufacturing process. The primary objective was to comprehensively assess the sustainability credentials focusing on circular flows in energy, water, emissions, and raw materials traceability.

In conclusion, by integrating cutting-edge technology with sustainable practices, Grasim is setting new standards for fashion that prioritizes both style and environmental responsibility. Our extensive range of MMCF offers consumers a more sustainable choice without compromising on quality or comfort. As the global demand for environmentally friendly alternatives grows, Grasim remains dedicated to innovating and enhancing the future of fashion, ensuring that every garment contributes positively to the planet.

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A Review on Non-destructive Silk Cocoon Testing Methods for Measuring Quality Parameters

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The sericulture industry in India, home to the world's largest cocoon markets, faces significant challenges in accurately assessing cocoon quality. Current testing methods, which are labor-intensive and destructive, result in the loss of valuable and costly silk material, discouraging farmers and traders from participating in quality assessments. Essential parameters such as cocoon classification by gender, identification of defective cocoons, shell ratio, single cocoon filament length, number of cocoons per kilogram, and reeling reliability are currently determined through destructive means. This reliance on subjective assessments leads to biases, errors, and market inefficiencies, ultimately affecting pricing fairness and quality control. With the global demand for silk continuing to rise, there is an urgent need for non-destructive, efficient, and reliable cocoon testing methodologies. Recent studies have demonstrated the significant potential of AI and machine learning techniques for non-destructive testing across various applications. For example, Mendoza et al. (2012) utilized a combination of sensors to measure the firmness and soluble solid content of apples, highlighting the potential of integrating multiple sensing modalities for comprehensive quality assessment. Similarly, Chen et al. (2012) analyzed the compressive properties of silkworm cocoons using a Dynamic Mechanical Thermal Analyzer (DMTA), which provided insights shell structure morphology and thickness of the cocoons. The DMTA is used to characterise the shell thickness and density of various types of silk cocoons which can be utilised as a reference for a non-destructive measurement. Cai et al. (2014) employed X-ray imaging to classify mulberry silkworm pupae, achieving a classification accuracy of over 93% using features such as elliptical axes and shape descriptors. Koppad et al. present a non-destructive method for assessing silkworm cocoons using X-ray imaging combined with a Generalized Regression Neural Network (GRNN). The study focuses on estimating the raw silk content, classifying cocoon gender, and grading cocoon quality without the need for manual inspection or destructive testing. The X-ray technique measures key physical parameters such as shell thickness, area, and perimeter, which are then processed through image segmentation and feature extraction. The GRNN model, trained with these features, predicts the silk content and overall quality with an average accuracy of 94.56%, providing a reliable and automated alternative to traditional methods. This paper will provide a comprehensive review of the existing literature on non-destructive testing techniques, exploring innovative approaches that can transform cocoon quality assessment. By moving away from traditional destructive methods, the industry can improve accuracy, reduce economic losses, and enhance the overall efficiency of silk production.

Keywords

Silk, Silk Cocoon testing, non-destructive textile testing, economical testing, reelability

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Silk in Technical Textiles & Non-textile Applications: Bridging Tradition with Technological Innovation

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Silk, a natural protein fiber with a rich historical legacy, has long been prized for its unique combination of strength, elasticity, and biocompatibility. Traditionally utilized in apparel and luxury textiles, silk's remarkable properties have also positioned it as a promising material for technical textiles and non-textile applications. This natural fiber, with its unique properties, can be tailored to meet specific demands in various fields. This paper explores the evolving role of silk in the advanced sectors, its utility beyond fashion and reviews the properties of silk that make it suitable for technical textile applications, discusses its current uses, and explores emerging innovations in this field. Key areas of focus include the development of silk-based biomaterials, biomedicine, smart textiles, bio-sensors, environmental sustainability, and so on [1-2]. In medical textiles, silk's biocompatibility and biodegradability make it ideal for sutures, wound dressings, tissue engineering scaffolds, and drug delivery systems. In environmental applications, silk has shown potential in filtration systems and biodegradable packaging offering sustainable alternatives in response to the global need for eco-friendly materials. Silk fibers are being explored for integrating electronic components, such as sensors, conductive threads, and microelectronics, into textiles. Because silk is lightweight, flexible, and biocompatible, it provides a comfortable and practical substrate for wearable devices, such as health-monitoring garments or smart clothing. Researchers have successfully embedded silk with conductive nanoparticles or carbon-based materials, enabling textiles to conduct electricity and function as sensors. These garments can monitor physiological parameters like heart rate, temperature, or muscle activity, making them ideal for healthcare applications. Silk can also be studied for making ballistic fabrics and other protective clothing due to its inherent strength-to-weight ratio [3]. Silk fibers, when treated with appropriate chemicals, can be used in flame-retardant technical textiles. Silk fibers, with their natural strength and durability, can be used in the production of agricultural nets or plant support structures.

Silk's natural moisture-wicking and temperature-regulating properties can be enhanced through technological advancements to create textiles that adjust to environmental conditions. By incorporating piezoelectric materials or conductive polymers into silk, researchers have developed fabrics capable of responding to mechanical stress (e.g., pressure or stretch). As the world increasingly turns toward environmentally friendly solutions, silk-based smart textiles offer a promising alternative to traditional synthetic fabrics and electronics, reducing e-waste. The use of silk in this context supports the development of eco-friendly, disposable, or recyclable smart garments and wearables. The other possible silk technical textile areas are provided in Figure 1. These include silk use in nonwovens, protective clothing, parachute fabrics, green composites, automotive textiles, filtration, 3D woven and knitted fabrics, etc. [4]. Ongoing research and technological advancements have also led to novel uses of silk in non-textile applications. The two primary proteins of silk i.e.,

Sericin and Fibroin, possess unique properties that make them ideal for various value-added applications. Silk is also believed to have proven skin-rejuvenating, anti-irritation, anti-inflammatory properties making it suitable for cosmetic applications. Fibroin can be processed into various forms, shapes and sizes [6]. Other useful byproduct of silk are pupae, chitosan, waste cocoons, cut-cocoons, etc.

In addition to this, the sericulture industry, while renowned for its production of luxurious silk, generates substantial waste in the form of cocoon waste and residues from the reeling and weaving process. Unfortunately, much of this waste is underutilized in India, and so exported to other countries instead of being harnessed domestically for manufacturing of value-added products. Therefore, it is a great opportunity to tap this silk waste and utilize it to develop high-value products of technical applications. Therefore, these innovations underscore silk's vast potential in technical textiles and beyond, showcasing its role as a sustainable, high-performance material for various applications.

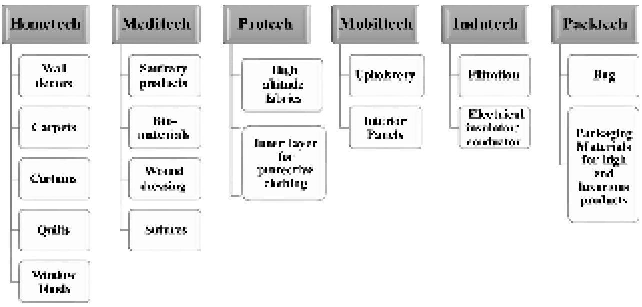

Figure 1: Applications of silk in technical textiles

Therefore, by bridging the gap between traditional silk production and technological innovation, this review underscores the transformative potential of silk in a wide range of applications, paving the way for a more sustainable and functional future.

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From Waste to Fibre: Electrospinning Cellulosic Materials from Post-consumer Waste for Sustainable materials

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Recycling textile materials, particularly cellulose-based materials, remains an underexplored area in sustainable practices. With the growing emphasis on environmental conservation and waste reduction, it is imperative to find effective methods to recycle cellulose waste products into valuable materials [1]. Despite the availability of cellulose as a significant component of textile waste, its recycling into functional materials is not commonplace. Traditional cellulose is difficult to process due to its high crystallinity and inherent properties, which hinder its ability to be spun into fibres [2]. This study focuses on recycling waste cellulose into nanofibers through the electrospinning process by contributing to the sustainability of the textile industry.

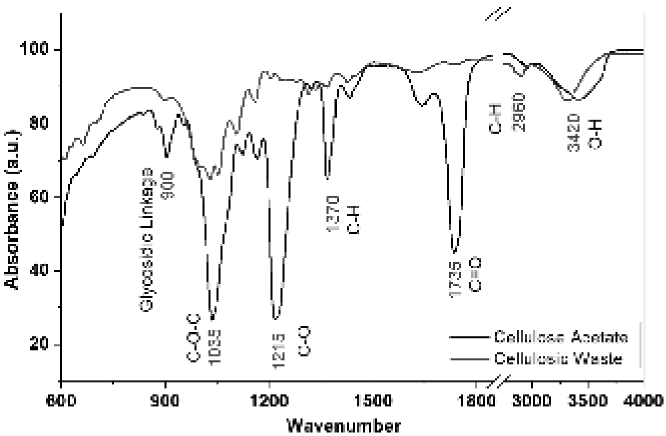

Figure 1: ATR-FTIR spectra of the waste material and the recycled material

To facilitate the electrospinning of cellulose, waste cellulose materials were first converted into cellulose acetate, a more suitable form for fibre formation. This conversion was achieved using a combination of acetic acid, acid anhydride, and sulfuric acid [3]. During the acetylation process, the reaction was terminated by adding water. This step is crucial for neutralising the reaction and precipitating the cellulose acetate from the solution. Fourier Transform Infrared Spectroscopy (FTIR) was employed to confirm the successful transformation of cellulose to cellulose acetate, with characteristic peaks indicating the formation of the acetylated structure. The strong bands at 3420 cm^{-1} and 1035 cm^{-1} are attributed to -OH stretching and C-O-C vibrations in the anhydroglucose units. In contrast, the spectrum of acetylated cellulose (Figure 1) exhibits three significant vibrations associated with the acetyl groups at 1735 cm^{-1} (νC=O), 1370 cm^{-1} (ν-CH_3), and 1215 cm^{-1} (νC-O) (Figure 1) [4]. The degree of substitution (DS) for cellulose acetate was determined from the FTIR results, indicating a DS of 1.71. Additionally, X-ray Diffraction (XRD) analysis was conducted to assess the crystallinity of the resultant cellulose acetate, providing further validation of the conversion process (Figure 2). The XRD results indicated a decrease in crystallinity, supporting the hypothesis that cellulose acetate is more amenable to spinning.

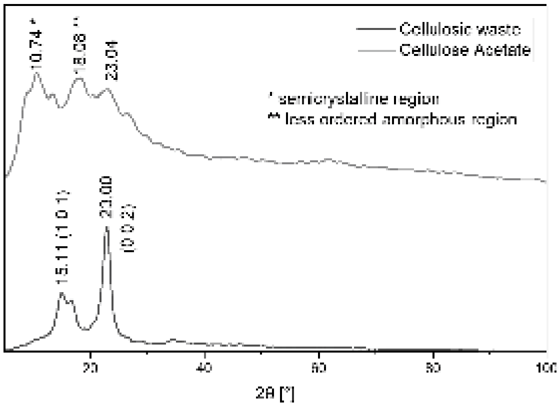

Figure 2: XRD spectra of the waste material and the recycled material

The electrospinning conditions were set as follows: a concentration of 17% w/v cellulose acetate, a voltage of 12 kV, a distance of 8 cm between the needle and collector, and a flow rate of 1 mL/h [5]. Scanning Electron Microscopy (SEM) was utilised to analyse the morphology of the produced fibres, confirming the successful formation of nanofibers (Figure 3).

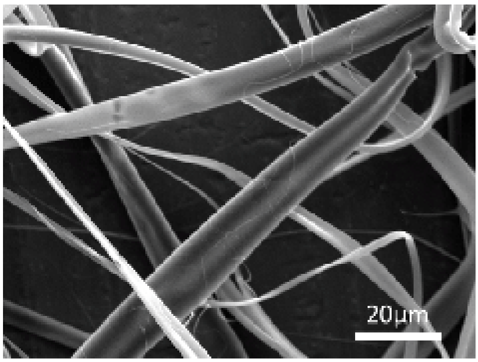

Figure 3: SEM of the electro-spun fibre\ae

The ATR-FTIR analysis and XRD results demonstrated distinct peaks corresponding to cellulose acetate, confirming the successful conversion from cellulose. SEM images revealed the effectiveness of the electrospinning process using the prepared cellulose acetate solution. Therefore, this research successfully demonstrates the recycling of cellulose waste into nanofibers through an innovative electrospinning technique. The findings highlight the potential of utilising textile waste products, particularly cellulose, to create valuable materials, thus contributing to sustainable practices in the textile industry. By transforming waste cellulose into functional nanofibers, this study paves the way for further exploration of recycling methods and the development of eco-friendly materials. Future research will focus on optimising the electrospinning parameters and exploring the applications of the produced nanofibers in various fields, including textiles, composites, and biomedical applications.

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Falconeria Insignis: A Novel Plant Source for Sustainable Finish on Museum Textile Antiquities

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Museum textiles are very fragile in nature because they are age old. These antiquities are exposed to many environmental factors such as temperature, relative humidity, dirt, dust and many more. Therefore, the researcher carried out this study to conserve our past heritage so that this will serve as an inspiration for the future generations. According to the survey of 30 selected museums of India, in the present study, conservators used to keep neem leaves, black pepper and clove in the showcases. But all such materials leave stain on textiles as well as these are edible sources therefore the researcher dig out the new novel source that can overcome all the previously occurring problems. *Falconeria insignis* is a monoecious deciduous tree that grows to a height of 15 metres. A thorough assessment of the literature on the plant under consideration revealed that there are no widely published studies on the phytochemical analysis of "*Falconeria insignis*" anywhere in the globe. As a result, the current study was designed to look into the potential chemical components by first planning the plant leaves extract of *Falconeria insignis*. The phytochemical analysis i.e., Qualitative and quantitative screening of phytochemicals was carried out. The plant extract was also tested for its antimicrobial activity. Antimicrobial activity of plant extracts increased with the increase in concentration of extract because in more concentration a greater number of phytochemicals were present therefore the plant extract exhibits higher zone of inhibition as the concentration of plant extract increases.

Keywords

Falconeria insignis, Phytochemical Analysis, Total Phenolic Content, Total Flavonoid content, Total Tannin Content, Antimicrobial Activity

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Eco-Friendly Dyeing of Eri Silk Using Plant-Based Dyes and Mordants

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Natural dyeing on silk represents a revival of ancient practices that aligns with modern sustainability efforts in the textile industry. India is the only country producing all four major silk types, with eri silk, known as "peace silk," accounting for 19% of India's total silk production. This study explores the natural dyeing of eri silk using plant-based dyes from mulberry fruit (*Morus alba*) and wild guava (*Careya arborea*) bark, combined with biological mordants derived from myrobalan (*Terminalia chebula*) and pomegranate rind (*Punica granatum*). Dye extractions were optimized using UV-visible spectroscopy, with maximum colour yield observed at pH 3 for mulberry fruit and pH 7 for wild Guava (*Careya arborea*) bark. The dyeing was conducted using the exhaust method under controlled temperature conditions, and colour measurements were carried out using colour spectroscopy. The dyed fabrics were evaluated for colour fastness according to ISO standards, demonstrating the potential for vibrant, eco-friendly textile dyeing with minimal environmental impact.

Introduction

Natural dyeing on silk is a sustainable and culturally significant practice that offers numerous benefits to both the environment and the textile industry. Natural dyes, derived from plant sources like mulberry fruit and wild guava bark, offer a sustainable alternative. In addition, plant dyes often possess functional properties like antibacterial [1, 2], insect-repellent, antioxidant, and UV-resistant characteristics etc. [3, 4]. As such, plant dye has become the main focus for new dye development [5] With increasing awareness of environmental issues and the harmful effects of synthetic dyes, there has been a renewed interest in using natural dyes, especially on luxurious fabrics like silk. However, conventional dyeing methods often rely on synthetic dyes that can harm the environment [6, 7, 8]. India is the only country in the world that produces all four major types of silk: mulberry, tasar, eri, and muga. Among these, eri silk stands out as the only completely domesticated non-mulberry variety [9]. Eri silk, also known as the "peace silk"[10] due to its non-violent production process. Eri silk contributes to about 19% of total raw silk production in India [11]. Eri silk is valued for its soft texture and thermal properties. Traditionally produced in the northeastern regions of India, eri silk is increasingly sought after for its eco-friendly and sustainable qualities [12].

This study explores the natural dyeing of eri silk using plant-based dyes in combination with biological mordants, highlighting their potential to produce vibrant and durable colours with minimal environmental impact.

Materials and Methods

Materials

Eri Silk Fabric: The Eri silk fabric used in this study was procured from East Ends Silk, Malda, West

Bengal. The fabric was woven using 30Ne eri ring-spun yarn in both the warp and weft directions, with warp density of 80 ends per inch and weft density of 60 picks per inch. The fabric has a GSM (grams per square meter) of 80 and an off-white colour.

Natural Dyes: The natural mulberry fruit (*Morus alba*) used for dyeing was collected from the mulberry plants in Karnataka region. The wild guava bark was collected from the north eastern region of India. These plant materials are known for their rich colour profiles: mulberry fruit yields shades of grey and pink, while wild guava bark produces earthy browns and yellows.

Biological Mordants: The eri silk fabric was pre-treated, post-treated, and simultaneously treated with biological mordants derived from plant sources, specifically myrobalan (*Terminalia chebula*) and pomegranate rind (*Punica granatum*). These mordants were chosen for their ability to fix natural dyes to the fabric without the use of harsh chemicals.

Methods

Extraction of colour: Mulberry fruit & dried wild guava bark was pulverized for 2 minutes to obtain a fine paste and powder respectively. For the extraction, 10 grams of pulverised material was mixed in 100 ml of water and the pH conditions were varied using citric acid. Extraction of the colour was done by heating at 80-90°C for 30 minutes. After heating, the colour extract was allowed to stand for 15 minutes for settling, followed by filtration. The resulting filtrate was either used directly for dyeing or diluted to the specified concentration, if necessary, to achieve the desired dyeing conditions.

UV-visible spectroscopy: UV-visible spectroscopy was used to optimize the extraction conditions, given that different acidic conditions were employed. The extracted dyes were diluted 500 times, and the λmax for both dyes was determined using a UV-5800i, Shimadzu spectrophotometer. The colour yield of the mulberry fruit was found maximum at pH 3, while the colour yield of wild guava (*Careya arborea*) bark was highest at pH 7.

Compound Identification: The identification of dye compounds was performed using Gas Chromatography-Mass Spectroscopy (GC-MS).

Pretreatment of Eri silk fabric: Prior to dyeing, eri silk fabric was treated in a solution containing 2gpl non-ionic detergent and 0.5gpl soda ash at 80°C for 30 min followed by hot wash at 60°C for 10 min to remove impurities introduced during the spinning and weaving processes.

Dyeing and Mordanting Process: The biological mordant was prepared by heating 2.5 grams of myrobalan (*Terminalia chebula*) and pomegranate rind (*Punica granatum*) in 100 ml of water at 80°C for 30 minutes, followed by filtration. Pre-mordanting, post-mordanting, and simultaneous mordanting processes were also experimented. The cleaned eri silk fabric was dyed using the exhaust method, with the colour extracted from the plant materials at a material-to-liquor ratio (M:L) of 1:30, using an IR dyeing machine to ensure controlled temperature conditions. The dyeing and mordanting cycles used in the experiment are illustrated in Figure 1 and Figure 2, respectively.

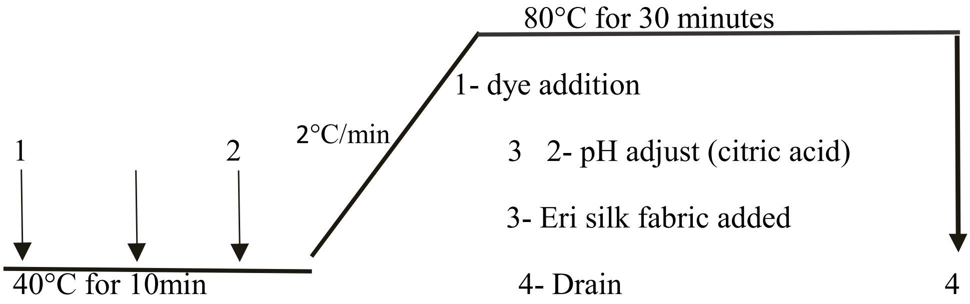


Figure 1: Dyeing Cycle

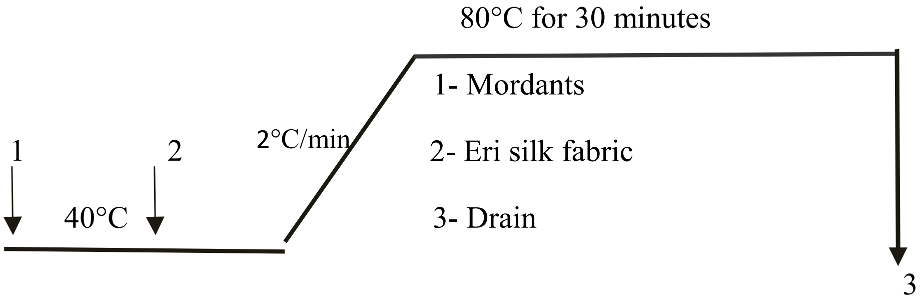


Figure 2: Mordanting Cycle

Colour Measurement: The colour values of the dyed eri silk samples were measured using Datacolour spectroscopy (CIE Lab), where L*, a*, b* values are representing the lightness and colour coordinates of the samples as showed in figure 3. Additionally, the overall depth of colour on the dyed samples was quantified using the K/S values using Kubelka-Munk equation. This measurement was employed to facilitate a comparative study of the effects of different dyeing conditions on colour intensity and uniformity.

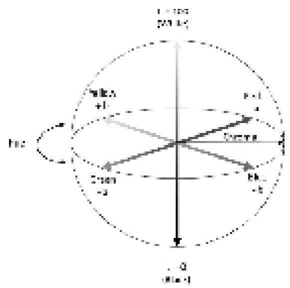


Figure 3: CIELAB Colour Space Diagram

Colour Fastness Evaluation: The colour fastness of the dyed samples was assessed according to standard ISO methods. The ratings were determined using a grey scale, providing a quantitative measure of the fabric's resistance to fading under various conditions.

Results and Discussions

Colour Measurement: The colour measurements of eri silk dyed with wild guava bark and mulberry fruit were conducted using a Datacolor Spectrophotometer. The measurements were taken with and without the use of biological mordants. The device was set under the conditions of D65 illumination and a 10° viewing angle. The fabric samples were folded into four layers, and five different points were measured randomly. The average value of these measurements was used for analysis. The following colour characteristics of the dyed fabrics were determined:

Colour depth (K/S value): The K/S value reflects the depth of colour, with higher values indicating a richer, more intense colour, and lower values representing a lighter, less saturated colour.

CIE Lab - L, a*, b* values:* These values were used to quantify the colour in terms of lightness (L*), red-green (a*), and yellow-blue (b*) dimensions.

Table 1: Colour Characteristics of Eri silk dyed with Mulberry fruit under varying pH

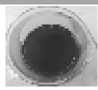
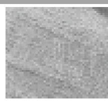
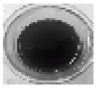
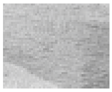
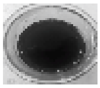
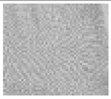
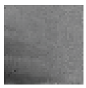
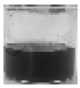
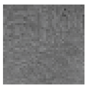
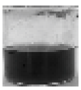
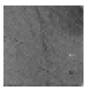
pH	L*	a*	b*	K/S	Dye Solution	Dyed sample
3	71.48	4.23	8.48	2.59		
5	75.19	1.39	7.29	2.05		
7	77.43	1.39	7.34	1.70		

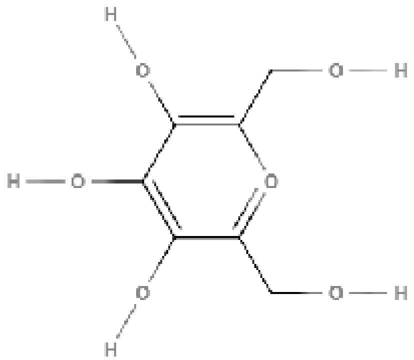
Table 2: Colour Characteristics of Eri silk dyed with Wild Guava under varying pH

pH	L*	a*	b*	K/S	Dye Solution	Dyed sample
3	*71.74*	*10.28*	*11.23*	*2.95*		
5	*69.88*	*10.02*	*13.57*	*3.20*		
7	*65.41*	*11.97*	*14.27*	*3.55*		

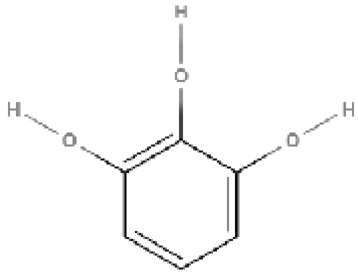
Here, the effect of pH on dyeing behaviour was observed, revealing that changes in the dye bath pH not only affect the colour depth but also alter the hue. The colour depth, as measured by the K/S value, ranged from 1.70 to 2.59 for mulberry fruit dyeing and from 2.95 to 3.55 for wild guava bark dyeing. Despite using the same concentration for each dye bath, variations in dye exhaustion and fixation were noted with different pH levels. These variations may be attributed to changes in the ionic strength of silk at different pH values.

GC-MS Analysis

GC-MS is an analytical technique to identify the various compounds present the extracts. GC-MS analysis of the methanolic extract of mulberry fruit and wild guava bark was done and the identification of the components was done on the comparison of their mass spectra with the compounds present in the library of the National Institute of Standards and Technology (NIST). The structures of the main compounds detected in the extracts are shown in Figure 3 (a) & (b). Methyl-b-D-glucopyranoside present in Morus alba fruit is organic soluble compound with aldehyde group and is commonly found in leaves and rose petals. Pyrogallol also called as C.I. Oxidation Base 32 present in Carya arborea bark is a water-soluble brownish compound which is used in hair dyeing and dyeing of suturing materials. Both the compounds present in the extracts are responsible for colouring properties.



(a)



(b)

Figure 3: (a) Methyl-b-D-glucopyranoside (mulberry fruit) (b) Pyrogallol (wild guava bark)

Conclusion

The study confirms that Eri silk can be successfully dyed using natural dyes derived from mulberry fruit and *Carya arborea* bark, with the aid of biological mordants. The resulting fabrics are not only aesthetically pleasing but also environmentally sustainable, aligning with the growing demand for eco-friendly textiles. Colourfastness tests, including washing, light exposure, and rubbing, indicated that the naturally dyed Eri silk performed well, with colours remaining stable over multiple washes. The use of biological mordants was found to enhance the wash fastness and light fastness of the dyed fabric, making it a viable alternative to synthetic dyeing processes.

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CLOTHING DESIGN FOR SPECIAL NEEDS - II

Circular Transformation in the Workwear Industry: Challenges, Pressures, and Opportunities

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Advances in workwear materials have significantly enhanced the durability and functionality of workwear clothing, increasing their effectiveness and ensuring workplace safety. The consistent quality and volume of materials used in the workwear industry suggest a strong potential for circular practices. However, strict functional requirements for workwear pose challenges to fully adopting circular practices. With rising regulatory and market pressures, the industry urgently needs systemic solutions to enhance circularity and meet demands for innovative, circular products. This pilot study examined the circular value chains of five Scandinavian workwear companies, assessing their current status, external pressures, and readiness to adapt. Using a framework of 15 circularity aspects across product, process, supply chain, and relationship levels, the study explored each aspect's significance based on three criteria: status quo, external pressure, and readiness to respond. Data collection involved survey responses from all five companies followed by in-depth interviews with three of them to gain deeper insights. Findings show that product-level circularity is the most advanced, particularly in product durability and longevity. However, significant challenges remain in product design for recyclability, reverse logistics, and the use of data traceability tools. Companies reported high external pressures to enhance circularity, especially in the areas of chemical selection and use-phase circularity practices. In contrast, pressures for partnership and collaboration were relatively low. The readiness to respond varied: companies showed high readiness to improve product durability and reduce chemical impact, but readiness was low for integrating design for recyclability and reverse logistics. In conclusion, the workwear industry demonstrates a willingness to improve circular practices, particularly in product longevity and chemical management. However, significant gaps remain in the areas of recyclability, collaboration, and end-of-life waste management. Future research should explore strategies to overcome these challenges, emphasizing innovation, reverse logistics, and strengthening partnerships. These steps are crucial for the industry to meet both regulatory expectations and market demand for circular workwear solutions.

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Empowering the Designer Through Strategy

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As the year 2030 rapidly approaches and the targets and goals of the United Nations Sustainability Development Goals (SDG) loom large on that horizon with Goal 12 Sustainable Consumption focussing on amongst other things Chemical and Waste, the designer is faced with a lack of power or authority to intervene. With this report we hope to look deeper into the function of clothing beyond the usual durability and serviceability with a more articulate response to circularity and sustainability through materials selection and specification. A particular blocker in the pathway to circularity is synthetic fabrics, with blended natural and synthetic filament a key concern. With the “C” [Chief] Suite taken up traditionally with Business and Technology executives, only in very few instances has the Chief Design Officer had a seat at the strategy table. The designer sits within a department usually as subordinate to a STEM manager in an 'inhouse' design situation, the designer can be vocal at their peril, with lose of employment a serious circumstance, even when citing legislation and worlds best practices. With the advent of the concept of “purpose” in the triple bottom line operational framework, large corporations to small to medium enterprises grapple with profit while existing with planet, employing people to fulfill a function, purpose has emerged as the fourth “p” to frame the environment (planet) as the most significant element of manufacture causing a rethink on purpose. While the designer has shown the have input at all levels of the innovation ladder, management subjugates them to the level of stylist, only occasionally engaging them in process and minimally allowing them sanction in the strategic sanctuary of the C suite. Textiles are in the frame for a major increase in microplastic pollution in the world environment, with microplastic filament exposed in the Himalaya's retreating glaciers, and found within the cells of heart muscle and brain [1]. How can the designer influence corporate direction in sustainable textile manufacture?

This article will look at existing literature in environmental sustainability and organisational management to provide a firm context for designers to establish impactful processes in building sustainable practices within the textile and clothing sector in developing nations. With a particular focus on India and its extensive footprint in this industry, the paper hopes to provide direction in framing design for sustainability principles linked to the United Nations Sustainable Development Goals. With rapacious consumption in the textile and clothing sector, movements are being advanced to intervene such as “sufficiency” [2] around human behaviour to lead change, which can be framed around the Sustainable Development Goals (SDG)12 Target 12.8 to 'Promote universal understanding of sustainable lifestyles' [3]. More commonly developing nations such as China discuss “slow design” in an attempt to raise quality over quantity [4] but this report through the Institute of International Sustainable Development Limited (ISD) 'Sustinari' largely levels responsibility at the designer, while not recognising the tenuous situation that an 'in house' designer faces when relating world's best practice to management, who effectively have the final say on selection of materials and budgets tied to contracts, especially in the 'fast fashion' world of fast moving consumer goods environments internationally to meet SDG12 [5] target 12.6 to 'encourage companies to adopt sustainable practices and sustainable reporting by the year 2030.

As design has broadly attained a firmer footing within the corporation's innovation ladder, a rung above the 'design as styling' level and inputs into 'design as process', it is the final level that needs a focus to assist in building a green and sustainable textile and clothing industry, [6] building on Anders Kretzschmar's 2003 work and research through the Danish Design Centre. What this paper hopes to achieve is a preliminary framing of guidelines to assist designers in strategy, at any level of practice as individual makers, inhouse or contract to foster best practice amongst the textile and clothing manufacturing industries, to guide the 'C'Suite towards better modes of operation to causally effect a shift in the use of synthetic blended filaments.

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Design and Development of Fashion Accessories by Colour and Weave Effect Using Naturally Dyed Yarns on Handloom Fabrics

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This research explores the use of naturally dyed yarns on handloom fabrics to create classic black-and-white houndstooth and diamond weaves, focusing on sustainability. Black and white, known for their timeless appeal and high contrast, were chosen for their ability to enhance intricate weave patterns. The fabric preparation involved desizing and scouring yarns (counts 2x5 and 6) using natural cleansing agents. The yarns were dyed using a combination of Triphala (kadukka, nellika, dhandikka) and iron rust water. This process produced a yellow color from Triphala, which gets oxidized to black with the help of the iron rust acting as a mordant. The resulting fabrics were woven into houndstooth patterns. The tear strength and tensile strength of the fabrics were tested, with a mean tear strength of 4.68 and a tensile strength CV% of 4.554%, indicating consistent performance under stress. Additionally, color fastness to rubbing, both wet and dry, was assessed. Wet rubbing results showed a staining rate of 4, and the color change was minimal, indicating high durability and color retention. These results demonstrate the potential of natural dyes combined with traditional weaving techniques to produce aesthetically pleasing and durable handloom fabrics. This study highlights the benefits of using sustainable materials and processes, contributing to eco-friendly textile production.

Keywords

Natural dyes, houndstooth weave, handloom, sustainability

Materials and Methods

Black and white is a classic color combination that transcends trends and has a timeless, elegant appeal. It has been a popular choice in fashion, design, and art for decades. Black and white are versatile colours that can easily be paired with other colours if needed. They serve as a neutral base, allowing for flexibility in design and coordination with other elements. The high contrast between black and white draws attention and creates a visually striking effect. This can be especially effective with patterns like houndstooth and diamond weave, where the contrast enhances the clarity of the design. Houndstooth and diamond weaves are classic patterns that, when combined with black and white, create a visually appealing texture. The combination emphasizes the structure of the weaves, showcasing their intricate details.

Iron Mordanting (Fe^{2+} to Fe^{3+})

Iron rust water typically contains ferrous ions (Fe^{2+}). When the fabric is immersed in the iron rust water and heated during mordanting, the following reaction occurs:

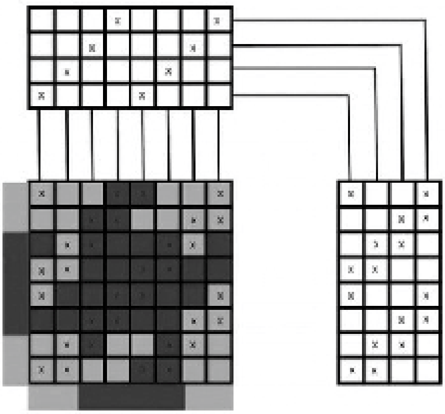

Figure 1: Analysing Houndstooth weave

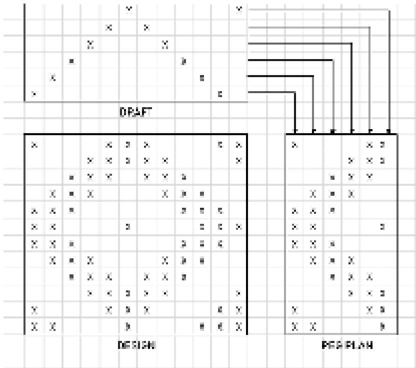

Figure 2: Analysing Diamonds and Diaper weave

1) $6\,Fe^{2+} + O_2 + 12\,H_2O \rightarrow 4\,Fe\,(OH)_3$

This reaction results in the oxidation of ferrous ions (Fe^{2+}) to ferric ions (Fe^{3+}), forming iron hydroxide [$Fe\,(OH)_3$] compounds on the fabric's surface.

Desizing and Scouring

Yarn of count 2x5 and 6 have been sourced. It will be 2 kgs of 2x5's count yarn and 2 kgs of 6's count yarn. The first step involves washing the yarn in soap water to remove impurities and residues. The next step is to prepare a mixture of soap nut water (4 Liters) and ash water (2 Liters) in 250 Liters of water. This mixture serves as a cleansing agent. To boil the yarn in the soap nut and ash water mixture for about an hour. This process helps to remove sizing agents, oils, and other impurities from the yarn. After boiling, dry the yarn and separate the strands. This prepares the yarn for the dyeing process by ensuring it's clean and free from any substances that could interfere with the dye.

Dyeing using Triphala and iron rust

The first step involves, preparing the Triphala mix, which consists of kadukka (for dyeing), nellika (for fixing the dye), and dhandikka (for herbal factors), in a ratio of 6:3:1 respectively. The rust water mixture was prepared by combining 10 kg of iron rust with 50 Liters of water, and then adding 20 Liters of sugarcane juice. Allow this mixture to ferment for 2 days. This mixture serves as a mordant, which helps to fix the dye to the yarn. In a vessel containing 250 Liters of water, add 4 kg of the Triphala mix. This serves as the dyeing solution. Take out 20 Liters of this solution and allow it to cool. This cooled solution will be used later in the process. Run the dried yarn through the 230 Liters of the dyeing solution. This will impart a yellow color to the yarn. After dyeing, run the yarn through the rust water mixture. The rust water acts as a mordant and helps to fix the dye to the yarn, enhancing its color fastness and durability. This will get oxidized and yield a black colour. The fabric was produced with the houndstooth pattern.

Figure 3: Naturally dyed yarn using iron rust and triphala

Results and Discussion

Table 1: Tear strength

	x	x-x̄	(x-x̄)^2
	5	0.32	0.1024n
	4.5	0.18	0.0342n
	5.2	0.59	0.3481n
	3.9	0.78	0.6084n
	4.8	0.12	0.0144n
x̄	4.68		0.2768

The mean tear strength is calculated as $\bar{x}$ =4.68, indicating the average tear strength across the five samples, providing a baseline for comparing individual measurements. The standard deviation of 0.47025 indicates the spread of tear strength values around the mean. A lower standard deviation would signify more consistent tear strength among the samples. The CV% of 10.04% suggests that the variation in tear strength is relatively low compared to the mean, indicating that the material demonstrates a uniform tear strength across the samples. This consistency is crucial for applications where predictable performance under stress is necessary, such as in home-textile applications. The mean tear strength of 4.68 and standard deviation of 0.47 suggest that the fabric can withstand a reasonable amount of stress before tearing, with minimal differences between individual samples.

Table 2: Tensile Strength

Elongation	**x**	**$x-\bar{x}$**	**$(x-\bar{x})^2$**
9.10	18.7	0.74	0.5476
8.90	17.5	0.46	0.2116
9.90	16.9	1.06	1.1236
8.50	18.8	0.84	0.7056
9.30	17.9	0.87	0.7569
Average	17.96	Total	3.3453

The CV% of 4.554% reflects a fabric that exhibits uniform tensile strength. This is an important characteristic for fabrics used in applications requiring consistent performance under mechanical stress. Low variability in tensile strength implies that the fabric can endure similar levels of stress before breaking across different samples. The elongation values are relatively close, indicating that the fabric has a moderate stretchability and can recover without significant deformation. This is ideal for applications requiring flexibility, such as clothing or certain types of home textiles like towels or bedding, where movement and pressure are frequent. The combination of tensile strength and elongation results suggests that the fabric is both strong and moderately flexible, making it suitable for use in products that experience regular wear and tear.

Table 3: Colour fastness to rubbing (wet & dry)

Sample No	Staining rate (wet)	Change in colour (wet)	Staining rate (dry)	Change in colour (dry)
1	4	4	3-4	3-4
2	4	4	3-4	3-4
3	4	4	3-4	3-4
4	4	4	3-4	3-4
5	4	4	3-4	3-4

Wet rubbing simulates real-world conditions like washing, perspiration, and moisture exposure, which could lead to increased color transfer and fading. A staining rate of 4 suggests minimal color transfer when the fabric is rubbed in wet conditions. This is a very positive result, as wet conditions typically exacerbate color transfer. The high rating implies that the naturally dyed fabric is highly resistant to color bleeding or staining, even when exposed to moisture. The change in color rating of 4 indicates excellent color retention in the fabric after wet rubbing. The fabric's original appearance is mostly preserved, with only minor fading, which is common but acceptable. This rating signifies that the dye is stable and remains well-bound to the fabric fibres, even when moisture is present. Both the dry and wet rubbing tests yield strong results, with similar ratings for staining and color change. This consistency across conditions suggests that the natural dye used in these fabrics is highly effective and provides good durability. Wet rubbing typically results in more significant color loss or transfer compared to dry rubbing, but in this case, the results are consistent.

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Design and Development of Affordable Bikers Denim with High-performance and Natural Fibres

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It's amazing how quickly motorcycles have become a popular form of transportation in rural areas. Nowadays, motorbikes make up the bulk of the vehicles on low-volume rural roads in several nations across the world, especially in third-world countries like India, Africa, Latin America, etc. The expanded use of motorbikes has also resulted in increased number of injuries to riders and traffic accidental deaths. In 2022, the number of deaths on two-wheelers increased by about 8% to around 75,000, making up 44% of all road fatalities in India. Therefore, the safety of the rider becomes an important concern. The safety of the rider cannot be provided by using simple clothing such as denim made of 100 % cotton. It was, therefore, thought of developing/designing a protective cloth (denim) that could help riders from serious injuries and build up consumer confidence. Hence, to achieve this objective, this research was undertaken to develop a protective cloth (denim) by using high-performance fiber like UHMWPE & HPPE and comparing its performance in terms of crease recovery, tearing strength, and abrasion resistance with that made from 100 % natural fiber (cotton).

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Improvising the Indian Traffic Police Reflective Safety Jackets: Enhancing Safety and Comfort

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A Traffic Police jacket is specialized protective clothing designed for safety and visibility. Various proposed and trial prototype design as shown in the below (Figure 1) use polyester fabric as the base layer which makes product lightweight and durable, Reflective tapes, Florescent colours like orange, a mesh, but they have generally fallen short in terms of heat resistance, durability, and comfort. The Traffic police in India works in 2 shifts per day which had a duration of 8-10 hours. The shift timings are morning shift (6 am - 2 pm) and evening shift (2 pm - 10 pm) also varies during, bad weather conditions, accidents and peak time traffic managing hours. Study shows that the traffic police are prone to health hazards due to prolonged exposure to sunlight and ultraviolet (UV) radiation. Prolonged UV exposure leads to multiple health risks, such as skin cancer, cataracts, sunburn, and premature aging [2]. Recent data shows that approximately 60-70% of traffic police in major cities of India face UV-related health problems, with 20-30% suffering from severe conditions such as photodermatitis and other RTI's [5]. This paper addresses the drawbacks of currently used designs of reflective jacket tailored specifically for Indian traffic police.

The current methodology states the phase change materials (PCMS) when added to the textiles, they absorb heat energy by changing the state from a solid to a liquid and dissipates heat energy as they return to solid state [1]. This paper proposes the idea of jackets which features enhanced comfort during long hours of wear, and with the use of PCM the jacket can keep the user cool during the high temperature and warm during cold hours. By collaborating scientists and designers many experiments and explorations are done in a new way to replace the traditional methods of garment construction with the use of sewing machines, and needle and thread [3]. By inculcating the stitch-less garment technology the performance of the garment will be enhanced as the seams will be stronger, reduce fraying and tearing and additionally the product will be lighter in weight, Overall impact of using this technology leads to reduction in wastage and utilized fewer resources as compared to conventional methos.

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Redefining Fashion: Aesthetic Solutions for Adaptive Clothing Needs for Lower Body Disabilities

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Adaptive clothing is an extension to the functionalities of clothing, which is often created or adjusted with existing clothing options and hence tends to lack aesthetic appeal.

The study addresses the critical gap between the functionalities and aesthetic appeal in the adaptive clothing options. Considering individuals with lower body disabilities in India, such focus is often ignored. While the global adaptive clothing market has shown significant growth, it remains insufficient in catering to the needs of this demographic, particularly in the Indian context. The research explores the challenges faced by individuals with disabilities and their caregivers, shedding light on the lack of accessible, functional, and aesthetically pleasing clothing options.

Research Problem and Aim

The primary aim of this research is to identify and propose solutions to the challenges faced by individuals with lower body disabilities in India regarding adaptive clothing. The study seeks to bridge the gap between functionality and aesthetics, ensuring that adaptive clothing for this demographic is not only practical but also enhances the wearer's confidence and well-being.

Materials and Methods

The study utilizes both primary and secondary data, which are collected through surveys, interviews with individuals with disabilities, research articles, government reports, and relevant online sources. The research focuses on design modifications that improve accessibility, comfort, and aesthetic appeal in adaptive clothing. A case study was examined for the lower body disability, and the design solutions with added aesthetics were specially innovated.

Results and Discussion

The results highlight several key areas for improvement in adaptive clothing design: ease of wear, comfort, and the integration of unique design elements. The study found that current adaptive clothing options often fall short in meeting both functional and aesthetic needs, which in turn affects the independence and dignity of individuals with disabilities.

Proposed Design Solutions

The study proposes an innovative design solution by creating an apt Design Collection of suitable outfits for cases with lower body disabilities, considering functional usage of breathable fabrics, suitable trims, and apt design solutions with exceptionally added features of functions and aesthetics in the surface explorations. The outfits feature creative surfaces inspired by artwork created by individuals with disabilities, combining functionality with a celebration of personal expression.

Conclusion

The research advocates for a paradigm shift in the adaptive clothing market, emphasizing the need for industry collaborations and innovative design thinking by prioritizing both utility and aesthetics. The proposed designs aim to empower individuals with disabilities, improving their quality of life and fostering a more inclusivity, equitable society and expressing their individuality with confidence.

Acknowledgments

We would like to express our deepest gratitude to the institute where the collection was showcased as a part of the annual Design Showcase at MKSSS's School of Fashion Technology, Pune. We sincerely appreciate the efforts and hard work of our team members and our fellow designers—Sanjana Karwa, Sejal Indani, Vedanti Kavatkar, Ssaneeya Karyekkar, Anee Jain, Anushkaa Joshi, and Prerna Mirge—for their unwavering support and dedication in building this collection. Their commitment and hard work have been crucial in bringing the vision to life. A special thanks to Dr. Adarsh Chavan Sir for using his extraordinary skills to transform ideas into stunning prints and paintings. His artistic insight has truly elevated the collection. We would also like to acknowledge and express our heartfelt gratitude to Mr. Satyajit Joglekar for coordinating our meeting with Meghana Munot Ma'am, a Wheelchair Basketball Coach, who in turn facilitated our meeting with Mr. Laxman Dalvi Sir and Ms. Aasma Ma'am. Both are wheelchair basketball players and served as our case study subjects. Their insights and experiences have significantly enriched our understanding and inspired the collection.

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Sportswear Related Barriers: Adaptive Sportswear for Wheelchair Tennis Players of India

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Sportswear is a huge market, and as per the forecast of revenue for the global sportswear market that Statista, 2023-2030 put forward, it is expected to rise from 213 billion U.S. dollars in 2023 to 294 billion U.S. dollars in 2030. Globally, many brands are catering to tennis apparel. The popular ones are Adidas, Nike, Puma, Lacoste, Uniqlo, Under Armour, Lululemon, New Balance, Asics, Wilson, Fila, Castore, Lotto, Boast, etc. However, brands catering to wheelchair tennis are still limited. Some designers and brands have recently collaborated with para-athletes participating in the Paralympics. In 2022, the global Adaptive Clothing market share was 13683.53 million and is expected to grow at a CAGR of 5.63%. Hence, there will be a growing demand for adaptive sportswear in the coming future. Very limited studies have been carried out with respect to adaptive sportswear in India and there is a real need to focus on this category in the market. People have experienced clothing-related barriers in the past and adaptive clothing can remove the problems [4] [5]. The pilot study was carried out with wheelchair tennis players in 2019 to understand the user requirements. The main aim of the study is to carry out ethnographic research to understand wheelchair tennis player's needs and design adaptive sportswear. Also to study sports-related barriers for wheelchair tennis users with User Centred Design (UCD) approach.

Methodology

An ethnographic study with the FEA model of Lamb and Kallal, 1992 [1] was conducted on ten wheelchair tennis players at Karnataka State Lawn Tennis Association (KSLTA), Bengaluru, India who volunteered for the study. The sample size for the study consisted of six men and four women players who played regularly at KSLTA in the age group of 22 to 45 years. The impairment of the players restricted the mobility of their lower limbs due to poliomyelitis [2], accidents etc. The survey has been done with the help of questionnaires, focus group interviews, and direct, indirect, and participant/non-participant observation to understand the difficulties wheelchair tennis players face in daily life. The data were collected with the help of verbal and non-verbal observations and systematic observations. As a researcher, the ethnographic timeline with Etic and Emic perspectives was adopted. Experiments were also conducted with InfraRed Thermography [3] to study thermoregulation during sports activities.

Research Findings

Adaptive sportswear was developed with various sportswear materials as per industry standards. The researcher explored and found out the sportswear-related barriers regarding adaptive sportswear.

- It was seen that diverse material panels can be incorporated into the garment for ventilation and breathability. However, it was found that the effect of an athlete's body during physical activities can change the sportswear's performance. The kind of sports being played along with the movement of specific body parts including external equipment can also play a significant role in designing the sportswear.

- During the study, 70% of wheelchair tennis players had problems with their lower garments due to the inclusion of orthotic braces/callipers used by players. Zippers at the bottom hem of track pants were incorporated for easy donning and doffing.
- Hybrid garments with stitch less technology, in addition to traditional stitches, were developed to make them lightweight and give the edges/joints a flat and smooth finish, and better thermoregulation
- Men and women players have individual colour preferences. 60% of wheelchair tennis players said they like vibrant colours that can attract the audience's attention while playing a match. And women players, comprised of 30%, showed more interest in the fashion aspects of tennis clothing. Players also preferred concealed modifications on the sportswear.

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SUSTAINABLE AND CIRCULAR FASHION

Innovative Approach towards Circular Fashion by Transforming Waste into Sustainable Solutions

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The growing challenge of waste management is a global issue impacting every region of the world. The world generates an estimated 2.24 billion tonnes of solid waste annually, which is about 0.79 kilograms per person per day, the environmental and resource-related implications are becoming increasingly severe. India generates over 62 million tonnes of waste annually, including 5.6 million tonnes of plastic waste, 7.9 million tonnes of hazardous waste, 1.5 million tonnes of e-waste, and 0.17 million tonnes of biomedical waste. A significant portion of this waste comes from organic materials, including millions of tons of fruit waste discarded each year, particularly in countries like India. This fruit waste contributes substantially to environmental degradation and resource depletion. While various waste utilization strategies have been explored across multiple sectors, an innovative opportunity has emerged within the fashion industry to repurpose fruit waste into valuable products, offering a sustainable and creative solution. This study reviews current waste utilization practices across industries, with a particular focus on the fashion sector, and identifies a unique opportunity to convert fruit waste—into sustainable fashion accessories, such as buttons and brooches. By transforming these natural byproducts into eco-friendly alternatives to conventional plastic materials, the approach addresses the growing demand for sustainable and environmentally conscious fashion choices. The research adopts a mixed-method approach, combining qualitative stakeholders feedback with experimental material testing. The process involves collecting fruit waste, processing it into usable materials through methods like drying, grinding, and binding with natural additives, and then developing prototypes of fashion accessories. Stakeholder engagement is integrated throughout, with feedback gathered through interviews with industry experts and surveys of potential consumers to evaluate market acceptance and feasibility. The findings demonstrate that fruit waste can be effectively converted into durable and aesthetically appealing fashion accessories. Prototypes made from waste were tested for mechanical properties, sustainability, and visual appeal, showing substantial potential as alternatives to traditional plastic materials. Feedback from stakeholders indicated a strong market interest in sustainable fashion products, underscoring the feasibility of scaling up this approach. The results suggest that such innovative use of fruit waste not only reduces environmental impact but also adds economic value and supports circular economy principles by turning waste into valuable resources.

Overall, the study underscores the potential of repurposing fruit waste in sustainable fashion, providing a practical solution to waste management challenges while contributing to environmental sustainability. By advocating for the integration of waste into the fashion value chain, this research aligns with several Sustainable Development Goals (SDGs), such as responsible consumption and production, climate action, and sustainable communities. It also paves the way for future research into other innovative applications of waste materials in fashion and other industries, promoting a broader adoption of circular economy practices.

Keywords

Eco-friendly solutions, Waste management, Recycling, Innovative techniques, Sustainable Future

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Individual Upcycling As Recreational Activity

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Upcycling represents a transformative process where waste materials are repurposed, giving them a new lease on life with equal or greater value. This innovative practice breathes new life into textile waste, offering a solution to a significant challenge confronting the global apparel and textile sector. By reimagining the potential of discarded materials, upcycling contributes to a more sustainable industry model, reducing the environmental impact and promoting a circular economy. Through this approach, the lifecycle of textiles is extended, diverting them from landfills and reducing the need for new resources. It's a creative and responsible way to address the excess of consumption and production, aligning with the growing demand for environmentally conscious practices in fashion and beyond. The concept of "upcycling" was first articulated by Reiner Pilz of Pilz GmbH in 1994. He described it as a process that enhances the value of old or used items, in stark contrast to the more commonly known process of recycling, which often diminishes the value of the original materials. [1].

Unwanted products into new materials or products perceived to be of greater quality, such as artistic value or environmental value is known as upcycling. It involves a combination of environmental consciousness, creativity, innovation, and diligence, culminating in distinctive, sustainable, and handcrafted items. The goal of upcycling is to produce goods that are not only sustainable and affordable but also innovative and imaginative. In contrast to down-cycling, which might repurpose old garments into cleaning cloths or used for inferior purposes in contrast to its prior use, upcycling would reinvent these garments into an enhanced product, like a uniquely handwoven rug, adding value and extending the material's lifecycle. There are a few examples in the Indian textile and apparel industry like Péro, Doodlage, Abraham and Thakore and many more which are taking initiative in this direction.

Upcycling in the fashion industry hinges largely on consumer behaviour and their consumption choices rather than on industrial practices. For upcycling to truly take hold within the realm of fashion, it's crucial to educate consumers about the negative consequences of current consumption trends on the environment. Additionally, raising awareness about the advantages of textile upcycling can steer consumers towards more sustainable practices. This shift in consumer awareness and behaviour is essential for upcycling to make a significant impact in the fashion sector. In today's fast-paced environment, the competitive nature of society can be overwhelmingly tense and stressful. Individuals are finding it increasingly necessary to cultivate strategies for managing the pressures that stem from professional duties, household responsibilities, and other commitments. Engaging in leisure activities is widely recognized as an effective method for alleviating stress. Such pursuits offer a diversion from the daily grind, fostering personal well-being and promoting equilibrium and self-respect, which are essential in mitigating feelings of anxiety and depression. Here, crafting new objects that are pleasing to the eye, functional, or both, serves as a soothing leisure pursuit. It's a form of recreation that yields

the gratifying feeling of time well-spent, transforming discarded materials into something concrete. This process is a physical manifestation of one's creativity and effort.

The study presented in this paper focused on conducting a detailed case analysis of personal upcycling practices. It meticulously tracked the workload, time investment, and the influence of integrating upcycling into daily routines on mental well-being. To assess the psychological impact, the research utilized a range of stress assessment instruments, including the Perceived Stress Scale, across a specified period. This approach aimed to provide insights into how adopting upcycling as a habitual activity affected individual stress levels and mental health. The study had focused on college-going students as the effects of stress on them could be long or short-term, acute or chronic. The root causes of such stress are multifaceted, often stemming from heightened duties, inefficient time management, altered dietary and sleep routines, coupled with insufficient self-care pauses. This constant state of worry and anxiety is a common thread that runs through the student body, impacting their daily lives and academic performance.

In the conducted case study, a group of five college students participated. They were encouraged to engage their creativity by utilizing textile waste to co-design products that aligned with their interests. For a period of one month, they dedicated two days per week, two hours each day, to this project. The stress levels of the students were measured using perceived stress scales at both the beginning and the end of the month. The results were then analysed and compared to determine the impact of the recreational activities on their mental wellbeing. The students' involvement promoted a sustainable consumer approach. It advocated for the adoption of the 4Rs of sustainability - Refuse, Repair, Repurpose, and Reinvent - among the masses, which further contributed to the development of a conscious circular fashion approach.

The research yielded ample data, enabling the evaluation of the hypothesis across a broad sample size. Upcycling transcended mere consumer awareness of its advantages; it required integration into the fabric of daily life, allowing individuals to actively engage with and take pleasure in the practice. The insights garnered from this study laid a substantial foundation for ongoing inquiry.

Keywords

4Rs- refuse, repair, repurpose, reinvent, circular fashion co-design, individual upcycling, recreational activity, stress management,

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Value-driven Design Developments to Encourage Responsible Consumption of Fashion Clothing

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Introduction

This paper covers the classroom project under the theme of "value-based design developments & new-age clothing" conducted at the National Institute of Design, India. Value-based clothing aims to create a meaningful dialogue that addresses the current need by making, wearing, selling, and promoting clothing that is durable, lasting, and timeless; made with love and respect for the environment; celebrates craftsmanship and the maker; promotes equality; values local resources, culture, and traditional practices; follows fair trade practices; made purposefully slow and to last longer; reduces wastage, and most importantly, makes you consume less.

The tutor defined the following key areas and categories

1. Service Design: This category includes expanding the clothing life, collection, and distribution of old garments to relevant social/commercial groups, material extraction/value addition, etc.
2. Apparel Product Development: This category focuses on using leftover/surplus or industrial/post-industrial waste materials as the main material source.
3. Awareness Drive, Event Creation, or Experience Design: This category includes awareness drives for expanding the clothing life, collection, and distribution of old garments, creating and expanding the donor base, market expansion, and better connecting with the client and donor, etc.
4. Training: This category focuses on identifying and building on the tailoring/making-related skill set. It involves working with the local communities and their skill pool, skill level, and newer applications of the same skill set.

This paper also covers the process and methodology followed by the 2nd year students of the Masters in Apparel Design program for their design studio "Value-based Clothing." The students studied the existing "Apparel Design and Production" system to map the gaps or design opportunities to work with "post-production or post-consumer" clothing waste Their personal interest and in-depth research led to their design briefs.

Outcomes

The paper highlights two of the 13 projects that came out of the design studio "Value-based Clothing"

1. Maai - Mended with Love (Service Design)

Maai is a platform that offers the service of mending and personalization, focusing on expanding the clothing life and improving the emotional durability of the mended/customized garments. Maai builds a network of local artisans and serves as a link between the artisan-wearer and the social/commercial groups. The project aims to create value by mending old garments with love and care, lending them a new lease of life, thus reducing wastage.

2. Wearwise (Service Design)

Wearwise is a hybrid space that blends cultural practices and knowledge, with technology to offer support and service for young students and professionals staying away from home. The project aims to create awareness about the material and emotional value of clothing, encourage responsible consumption, by informing the consumer about the right product care, and a digital app that helps them map their clothing usage and preferences, digitize their wardrobes, and thus help them organize and increase the life of their clothing items. The app also introduces them to organizations and platforms for donating or appropriately disposing of unused clothing for reusing/repurposing.

Conclusion

The National Institute of Design was a catalyst, and the collective efforts paved the way for more responsible, equitable fashion businesses that offer non-homogeneous and lasting products. Both projects were diligently approached, addressed the local needs, and created alternative ways of looking at responsible ways of designing, making, selling, and wearing/consuming in the Indian context. The wearer's engagement with their clothing improved, and so did the emotional durability.

Keywords

Value-based, Responsible, Longevity, Emotional durability, Second hand

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Process-Standardization and Evaluation of Efficacy in case of Up-Cycling of Old-Shirt: A Systematic Approach Towards Circular Fashion

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Introduction

The term 'Circular Fashion' represents an approach within the fashion and textile industry that aims to create a closed loop system, with an objective of reducing waste and maximizing the lifespan of clothing. It aligns with the basics of the circular economy, which includes not only the production and lifecycle of a garment, but also its recycling or upcycling after the expiry of its present end-use [1]. In this context, so far as the post-consumer waste is concerned, the approach is to upcycle the abandoned apparel product to transform it into another product with a fresh start of lifecycle. So that the rapid depletion of energy and water can be restricted, along with reduction in carbon-footprint [2][3].

Literature Review

A huge amount of water and natural resources are consumed in producing fabrics. It is evident that 2700 liters of water are consumed for making one t-shirt, which is enough for a person to drink for 900 days [4][5]. Manufacturing of shirt involves different processes which require 10 kilowatt-hour of energy. Also, a large amount of carbon emission is noted in the process of garment manufacturing [6]. In this context, so far as the sustainability of planet earth is concerned, the main principle of circular fashion is to design and adopt the mechanism of creating new and market-acceptable products by upcycling the old garments [7][8][9]. Moreover, it is essential to formulate a standardized process of product-development using old fabrics.

Research Method

The 100% cotton plain-woven old shirt is collected form volunteer-household following proper social and medical protocols. Collected old shirt is properly disinfected followed by washing as per standard method [10]. After ironing, the back portion of the washed and disinfected shirt is cut to extract a rectangular piece of fabric of the dimension 60 cm x 30 cm (approx.) (Figure-1). The areal density (GSM) and longitudinal stiffness (flexural rigidity) are determined as per ASTM test methods. Three embroidery designs with known parameters as available in authentic source [11] have been selected. CAD simulation is done using CorelDraw Graphic Suite 2022 software for virtual visualization of the embroidered fabric in case of each of the three embroidery motifs, using the scanned image of the cut-fabric from the old shirt. Also, the predicted GSM and flexural rigidity of the simulated embroidered fabrics are determined using the established prediction equations in this context [11] [12]. Accordingly, the suitable embroidery motif is identified based upon predicted mechanical and physical properties. Next, five different garment silhouettes are designed for infant (3 to 6 months age-group), based upon the dimension of the cut-fabric. All the five different garments are virtually developed using all the four simulated embroidered fabrics, using CorelDraw Graphic Suite 2022 software. Hence total 20 options of garments are simulated. Out of which one garment option (silhouette) is selected for actual stitching. The operation breakdown and Standard Allowed Minute (SAM) for the selected garment are estimated using PMTS and GSD software. Next, the actual embroidery is carried out on the cut-piece, using the selected motif as mentioned above. The actual flexural rigidity and GSM of the embroidered fabric piece are determined and compared with the corresponding predicted values. Also, the actual SAM and thread consumptions are noted. Finally, the estimated carbon footprint and the water and energy consumption for embroidery and stitching of those garments using fabric pieces of old shirt are estimated. This is compared with the standard energy and water consumption and carbon-footprint in case of those garments produced from new and virgin fabrics.

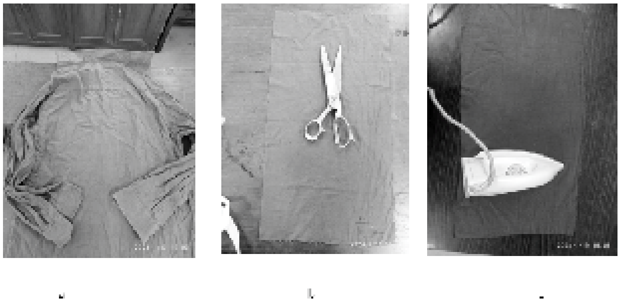

Figure 1: Extraction of fabric cut-piece from old-shirt

Results & Discussion

The Simulated embroidered-fabric along with corresponding product-visualization of garments are represented by Figure 2 to Figure 5 using different embroidery motifs.

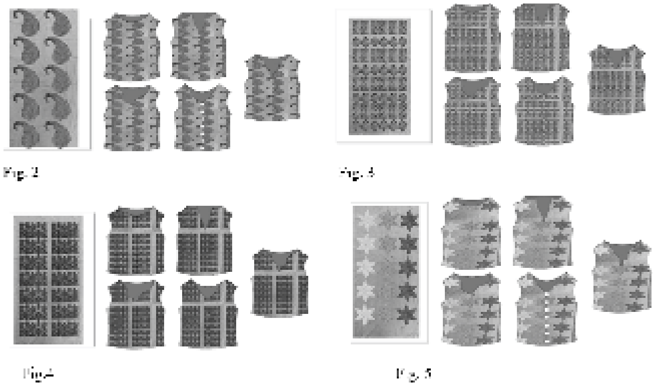

Figure 2 to 5: The simulated fabrics along with simulated garments using different embroidery motifs on the scanned image of the fabric cut from old shirt

Furthermore, the image of the actual embroidered fabric and stitched garments are as represented by Figure 6 and 7 respectively.

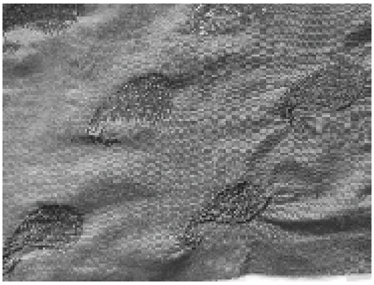

Figure 6: Embroidered old-fabric piece using selected embroidery motif

Figure 7: Stitched garment using the embroidered old fabric-piece

It is found that the predicted flexural rigidity and GSM of the embroidered fabric-piece are in very close proximity to the corresponding actual values. Table-1. It is found that the estimated energy consumption and carbon-footprint are much lower in case of such planned garments by upcycling of old- shirt, compared to regular infant wears produced from fresh and virgin fabrics.

Table 1: Comparison between actual and predicted Values

Parameter (unit)	Value in case of the old-fabric piece before embroidery	Predicted-Value (as per empirical equation) in case of the embroidered old-fabric	Actual Value
GSM	142.38	153.12	164.10
Longitudinal Flexural Rigidity (Dyne.cm)	103.46	108.24	111.31
Stitching time (minute)	0.404	0.403	

Table 2: Comparison between carbon foot-print and consumption of natural resources

Category (unit)	Value in case of linear and traditional manufacturing using fresh fabric	Value in case of proposed Circular manufacturing by up-cycling of old fabric
Carbon foot-print (Kg)	69.49	11.043
Consumption of water (Liter)	3,450	1,500
Consumption of energy (Electrical +Thermal)	4,500 Kcal + 70 Watt	0 Kcal + 70 Watt

Conclusion

It is noted, based upon the comparison with respect to energy-consumption and carbon-emission data, the production of such infant-wears by upcycling of old shirt is significantly environment-friendly and sustainable, without compromising the aesthetics and consumer-acceptance. Also, it is demonstrated that all the initial stages of product development, sampling, motif selection, color selection, pre-estimation of physical and functional parameters of final product etc. can be done using design software and established empirical equations. Hence such simulation process also saves lots of material and reduces carbon-footprint. It helps the designers to explore unlimited options for upcycling of old and abandoned garments, i.e. post-consumer waste, which is essential for the global sustainability.

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Closing the Loop - Sustainable Fashion from Fabric Waste of Bagru Printing

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India's rich cultural diversity and extensive handicraft traditions shelter many unexplored treasures, where Bagru, a small town in Rajasthan, standing out for its traditional textile block printing technique. The handmade Bagru prints are renowned both within India and internationally. However, the craft faces environmental challenges, particularly concerning the disposal of cotton fabric, known as Achara, used as the top layer on printing tables. This study examines Bagru printing from a sustainability perspective, focusing on the significant waste generated by discarding Achara fabric, which annually sends tons of fabric to landfills. The research aims to explore sustainable practices in the traditional craft of natural block printing by reducing fabric waste and minimizing landfill contributions. The objective is to identify innovative waste management strategies, including upcycling, recycling, and resource-efficient production methods, to promote a more sustainable approach in the fashion industry.

The literature review underscores the textile industry's substantial environmental impact, particularly through resource consumption and waste generation. Previous studies have emphasized the need for sustainable practices in textile production, focusing on resource efficiency and waste reduction. However, the environmental implications of traditional crafts like Bagru block printing, especially in terms of fabric waste, have been less studied. Existing research highlights various strategies for waste management in the textile industry, including upcycling, which creatively reuses waste materials to produce higher-value products. This concept has gained traction in the fashion industry as a sustainable practice, offering insights into how Achara fabric could be repurposed into fashion products, thereby reducing the ecological footprint of the Bagru printing industry.

During the field investigation in Bagru, the researchers observed that the Achara fabric, discarded after 2-3 months due to color saturation, contributes significantly to fabric waste. With approximately 20,000 meters of Achara fabric (Figure 1) discarded annually from about 1,000 printing tables in the town, of which 80% ends up in landfills, this is of fabric waste inspired the project to upcycle the fabric into fashion garments. The research methodology involved combining the fashion design process with traditional textile printing, creating a collection of high-end fashion garments from waste Achara fabric. The collection celebrates the non-uniformity and imperfections of the prints, blending tradition with contemporary fashion, and offering customers unique, exclusive garments (Figure 2) that cannot be duplicated. This initiative not only promotes circular fashion, reduces the ecological footprint of the Bagru printing industry but also improves the socio-economic status of the people living in the town by providing additional source of income, skill enhancement and community empowerment.

The results of the study demonstrated the successful creation of a fashion collection that resonated with the principles of sustainability and circular fashion. The Achara garments, with their unique

Figure 1: Printing tables a, b, c, and, and d presenting achara fabric as the top layer

Figure 2: Achara fashion collection with contemporary silhouettes

prints and cultural significance, offer a distinct fashion experience to global audiences while promoting waste reduction and recycling within the Bagru printing industry. The discussion highlights the importance of a multifaceted strategy in promoting sustainable fashion, combining knowledge sharing, teamwork, ethical behaviour, and efficient marketing. The Achara collection serves as a bridge between the past and the present, showcasing the versatility of Bagru's artistry in a new format and contributing to a more sustainable future for the craft industry.

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First and foremost, we would like to extend our heartfelt thanks to the artisans of Bagru village, Rajasthan, who have preserved and passed down this traditional craft of hand block printing through generations and especially Mr. Anup Chippa, in whose place we stayed and learned the valuable craft. This project was done under a classroom exercise so we would extend our sincere thanks to our university authorities for giving us this chance to work on Bagru printing. We are deeply indebted to the craftsmen and craftswomen who generously shared their invaluable knowledge, techniques, and personal experiences during the documentation process.

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A Wardrobe Study on Clothing Consumption and Disposal Patterns Among Men in Kannur, Kerala: Towards a Circular Fashion Approach

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Introduction

Global textile consumption exceeds 30 million tons annually, leading to significant social and environmental impacts throughout the supply chain. Addressing sustainability concerns is critical for the fashion industry [1]. Concerns about sustainability are vital to the fashion industry. [2]. According to India's National Household Survey (2015), the demand for textiles in households reached $73.70 billion in 2014. Textile consumption increased from 31,636 million meters in 2012 to 36,086 million meters in 2014. Globally, the per capita textile consumption in 2014 was 28.70 meters. In addition, men's apparel consumption has expanded dramatically as a result of the rising popularity of online shopping sites in the 2020s and their alluring sales, lower costs, and accessibility to digital technologies. Regular clothing buyers discard their purchases more frequently without considering the most environmentally friendly ways to do so, which raises the risk of environmental pollution. [3]. According to international estimates, 95% of the 92 million tons of textile waste generated annually is recyclable. However, only 25% of this waste is actually recycled. The absence of repurchase services or free repair policies, as seen during the pilot trial in India in 2023, may be the cause of this. Styles and fashion are developed, marketed, and then abandoned. [4]. India's menswear business has expanded significantly; by 2021, it is expected to be worth over $19 billion. (source: Statista). Apart from redesigning products and introducing environmentally sustainable manufacturing practices, it is critical to focus on patterns of consumption. Customers frequently don't realize how their consumption patterns affect the environment. There is limited research on the consumption and disposal of apparel, particularly among Indian men. Therefore, in the perspective of circular fashion, it is imperative to conduct a thorough study that focuses on the contemporary clothes consumption and disposal habits of Indian males. Analysing men's habits of clothes consumption and disposal in Kannur is the goal.

Research Methodology

The research methodology employed in this study is ethnographic research, which involves an in-depth observation of the clothing consumption patterns and clothing disposal behaviours of 104 participants aged between 15 and 64 years, who volunteered for the wardrobe study from different parts of the city of Kannur.

Eminent researchers like [6] and [7] have reported that that human aspects play an important role in the change process toward more sustainable practices. To gain more knowledge researchers need to study individuals, consumption, and consumer behaviour through a socio-psychologically enriched understanding. The ethnographic research involved a wardrobe study and semi-structured interviews at the homes of the participants [8]. This phase aimed to observe and analyse their wardrobe composition, decision-making, acquisition, storage, usage of clothing, and disposal patterns based on the consumer household logistic system of [5].

Research Findings

The study consisted of ethnographic research based on wardrobe analysis of the participants to study clothing consumption and disposal practices.

Clothing Consumption Pattern

The study observed that formal wear and casual wear dominate about 80% of men's wardrobes in Kannur, Kerala. Formal shirts and trousers make up 45%, with participants owning an average of 12.9 shirts and 7 trousers. Casual wear includes an average of 12 T-shirts and 11 pairs of jeans/shorts, with T-shirts being the most frequently disposed of item. Key items frequently purchased are formal shirts, trousers, jeans, and T-shirts, as seen during the wardrobe study. The data highlights the need for sustainable fashion focusing on these categories, particularly T-shirts. Despite DIY ideas for upcycling T-shirts, India lacks organized companies or design houses dedicated to this. Most old T-shirts are recycled into items like floor mats or cleaning wipes. The study emphasizes the need for systematic channels for T-shirt redesign, collection, and disposal to promote circular fashion in India.

Clothing Disposal Practices

Respondents used various methods to dispose of unwanted clothing, with most passing them on to others or donating. Only 2.4% sold their clothing online or at second-hand stores, and few threw items away. This highlights the need for greater awareness around sustainable practices in clothing consumption and disposal. Brands should focus on creating disposal channels, offering repair, refurbishment, and resale options to encourage circular fashion in India.

Conclusions

This study examines clothing consumption and disposal patterns among men in Kannur, India, through ethnographic research. The findings reveal that limited awareness of sustainability issues, with T-shirts being the most purchased and disposed of item. There is no systematic post-consumer disposal channel for key wardrobe items like T-shirts, jeans, shirts, and trousers. Lack of repair, refurbishment, and resale options from brands hinders sustainable practices. To foster circular fashion, research on recycling materials like cotton and polyester blends is needed, along with a reverse supply chain to collect post-consumer T-shirts and incentivize returns, promoting circular fashion in India.

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The Functional Aspects of Indigo-dyed Fabrics and Product Development Using Various Techniques

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Indigo is one of the earliest dyestuffs recorded in history and still retains its supremacy. The global economic and trade history of indigo is closely associated with the history of colonial Bengal's indigo cultivation. The magical aspect lies in the changing chemistry of the indigo-bearing plants in each stage of their application of the textile substrate. The colour does not readily exist in the plants; they are present in the form of its precursors, which release the indigo colourant after fermentation. Natural indigo dyeing has always been considered a sustainable practice, as the insoluble indigo colourant is reduced in an alkaline medium before dyeing with the help of naturally found agents. This reduction process makes the indigo water-soluble. Indigo repels insects and mosquitoes and treats skin infection, constipation, liver disease, heart palpitations, and gout. Indigo is derived from the plants *Indigofera tinctoria* (true indigo) in India and the Middle East, *Polygonum tinctorium* (Japanese indigo, knotweed) in the Far East, *Indigofera Suffruticosa* (anil) in South and Central America, and *Isatis tinctoria* (woad) in Europe. Before Adolf von Bayer synthesised indigo in 1880 [1], India monopolised natural indigo because of its high yield and rich lustrous quality. Indigo has a very low affinity for cellulosic substrates in reduced and solubilised forms and is applied by the reduction and solubilisation process. A reduction potential of ~ -700 to -750 mV is required for reduction purposes [2]. Before the availability of chemical-reducing agents, the naturally occurring indigo was reduced by fermentation of organic matter. But to serve the growing industrial demand, synthetic reducing agents, sodium hydrosulphite, etc., have been introduced, which cause severe environmental concerns when released in industrial wastewater due to their carcinogenic health effects [3]. Today's eco-conscious consumers are interested in the eco-friendly processes of natural dyeing, particularly during the reduction stages. Numerous natural reducing agents, including date palm, ripe banana, banana peel, etc., are now used in indigo dyeing [4]. The present study prepared indigo vats with various natural reducing agents: jackfruit, banana, madder, jaggery, etc. The reduction potential of organic vat under alkaline conditions was measured through a cyclic voltmeter. The cellulose and protein fabrics were dyed in those vats and were tested for antimicrobial and antifungal properties. Indigo-dyed matka silk fabric was quantitatively tested for antibacterial activity following the AATCC 100-2019 standards, which showed a 99.77% reduction for *S. aureus* and a 99.76% reduction for *K. pneumoniae* bacterial strain. It was also tested for antifungal activity, following the AATCC 30: Part 3-2017 standards, which shows no growth of *Aspergillus niger* on the dyed fabric surface.

Based on the results, a product range has been developed using indigo, reduced with madder, overripe banana, etc., using different surface embellishment techniques. These assessments prove indigo to be an ideal dye source for creating functional textiles.

Keywords

Eco-friendly, Functional, Indigo, Reducing agents, Sodium hydrosulphite.

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HEALTHCARE AND MEDICAL TEXTILES

3D Printed Next Generation Bone Scaffolds

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The advent of biodegradable implant materials and the rise of minimally invasive surgical techniques have significantly advanced healthcare over the past few decades. The development of these scaffolds necessitates the integration of diverse, multifaceted properties, each operating autonomously. The engineering and large-scale production of such scaffolds, designed from traditional polymer networks without the reliance on intricate chemical synthesis and modification, presents a formidable challenge. Under this circumstances, hierarchical porous functionalized 3D scaffolds made of biodegradable polymers are critical for damaged tissue restoration because they mimic and regulate biological response at the same time. Commercially, these are often made by employing porogenic materials within polymeric matrix, but they lack interconnectivity, have limited control over design architecture, and become tissue specific. In this work, we replicated a 3D woven fabric structure by printing poly(ε-caprolactone) (PCL) ink, utilizing a combination of high internal phase emulsion (HIPE) templating and 3D printing. Emulsion droplets served as sacrificial templates for micropores and macropores, forming a microporous architecture within the 3D-printed macroporous fabric after solvent evaporation. These bioinspired mats exhibited bone-like morphology and mimicked the mechanical strength of cartilage. The pore structure and mechanical properties were customizable by adjusting emulsion composition and printing parameters. In vitro cytocompatibility with osteoblasts, in vivo studies, biodegradation, drug release, and biomineralization demonstrated the potential of these scaffolds for bone tissue engineering.

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Pickering Emulsion-templating for Green Synthesis of Poly (e-caprolactone) Scaffolds

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Although bone tissues exhibit exceptional regenerative capabilities which allow them to repair a variety of bone abnormalities, these physiological processes may become ineffective if the defects reach a critical level, necessitating medical interventions. Autografts and allografts are widely acknowledged as the most effective methods; however, they suffer significant limitations such as limited availability, complications at the donor site, the risk of disease transmission, and transplant rejection by immune system. Bone tissue engineering is a viable alternative that enables the regeneration of bone tissues by utilizing a three-dimensional porous scaffold that not only promotes cell adhesion and proliferation but also mimics the structural and mechanical characteristics of the native tissue. To address these challenges, scaffolds were created utilizing high internal phase emulsion (HIPE) templating resulting in the formation of highly porous structures of crosslinked poly (e-caprolactone) (PCL). While the conventionally stabilized HIPEs require extremely large quantities of surfactants, which end up as environmental waste, Pickering HIPEs are stabilized using nanoparticles which further lead to enhanced structural properties of the scaffolds. Hydrophobically modified silica nanoparticles led to the formation stable Pickering HIPEs, which on polymerization resulted in nanocomposite scaffolds with excellent cyclic compressional stability. Additionally, inclusion of silica nanoparticles led to enhanced surface roughness on the scaffolds which is desirable for cell adhesion. These scaffolds were further functionalized using clove oil which prohibited the growth of both gram-positive and gram-negative bacteria, elucidating the effectiveness of the scaffolds to fight implant-site infections. The clove oil functionalized nanocomposite scaffolds exhibited exceptional cytocompatibility toward MG-63 cells, enabling them to adhere and proliferate while maintaining their cellular morphology.

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Development of Sustainable Antifungal Nonwoven Fabric Using *Hibiscus Sabdariffa* Bast Fibre

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The textile industry in India, one of the largest in the world, is increasingly exploring sustainable and eco-friendly alternatives to traditional raw materials. One such alternative is the use of agricultural waste fibers, which not only reduces environmental impact but also adds value to by-products that would otherwise be discarded. Leveraging agricultural waste fibers for textiles aligns with India's focus on sustainability, innovation, and circular economy principles. The extraction of micro sized fibers from agricultural plant sources indubitably represents most of the development in cellulose-based materials during the several years. Among the bast fibers *Hibiscus Sabdariffa* (Roselle) is one of the most perceptible fiber crops with superior cellulosic substance. Bacterial retting is the widely using method to extract the fiber from the harvested plant stem due to the betterment quality than in chemical retting. The extracted fiber from the Roselle stem was materialized and investigated after its surface modification by delignification through Kraft pulping process with alkaline medium. To make the cellulose fibre more pliable, soft, and capable of absorbing liquids, the inorganic components were eliminated. Environment friendly total chlorin free bleaching like oxygen bleaching is selected as alternative for hazardous chemical bleaching. The high-quality pulp yield made possible by this microfibril extraction technique is chosen for the nonwoven industry's improved fabrication process. Nonwovens are distinctive, essential, high-tech-created, innovative fabrics formed from fibres that are used in a variety of products and applications across the globe. Nonwovens made inroads into the expanding arena of health care and hygiene applications owe to their comparatively adaptable in integrating various mechanical properties and disposability which reduces cross-infection and enables high planes of hygiene to be sustained. 'Hydroentanglement' also known as spunlacing, is a versatile and widely used process in the production of nonwoven fabrics. This technique employs high-pressure water jets to entangle loose fibers, forming a cohesive fabric structure without the need for adhesives, binders, or thermal bonding.

Natural fibered fabrics are renowned for their breathability, softness, and eco-friendliness. However, these fibers can also provide a suitable environment for the growth of bacteria, fungi, and other microorganisms, particularly in warm and moist conditions. To address this, antimicrobial finishes are applied to enhance the hygiene and longevity of natural fiber fabrics. It also helps to reduce odors, prevent discoloration, and prolong the life of the fabric by preventing microbial degradation. In clothing, natural herbal antimicrobial finishes are particularly beneficial for items that are worn close to the skin or in environments where hygiene is a concern. Herbal finishes in spunlace fabrics represent an innovative approach to enhancing the functionality and sustainability of textile products. By integrating herbal extracts into the fabric, manufacturers can impart various beneficial properties, such as antimicrobial effects, skin soothing, and anti-inflammatory benefits, while maintaining the

inherent qualities of spunlace fabrics. Due to efficacy, cost, and safety, herbal medications are gaining popularity among people in urban and rural areas in emerging nations. The use of natural, healthy herbal infusions in clothing for health reasons has increased significantly in recent years. Industrial clothing contains a lot of harmful chemicals and substances that are absorbed into the body through the skin. These substances derived from plants are extracted out of their leaves, flowers, fruits, roots, etc., for functional finish resolution in order to prevent the use of dangerous chemical finishes. A little bit of traditional knowledge-based formulation or indigenous traditional medicine in clothing has played a fundamental part in the development of novel health care products. In this work finishing of fabric is done with the composite herbal extract sourced from the leaves and flowers of plants *Vitex negundo* and *Sesbania Grandiflora*.

In this study, the raw fiber and pulped *Hibiscus sabdariffa* fiber were analyzed under Fourier-Transform Infrared Spectroscopy (FTIR) finds difference in its character. Fluffing, carding and lapping of the microfibril pulp is followed with nonwoven fabric formation analyzed with Total Moisture Management (TMM) test, for its hydrophilicity pertains good result. Natural herbal finishing of fabric confirms under Scanning Electron Microscope (SEM) analysis and tested with disc diffusion method for antimicrobial (bacteria and fungi) efficacy ensemble admirable outcome for functional Hygiene products.

Keywords

Hibiscus Sabdariffa, Kraft Pulping, Delignification, Cellulose, FTIR, TMM, SEM, Antimicrobial.

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Investigation of Electrospun Nanofibers of *Cassia fistula* Induced Chitosan for Wound Healing

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Managing wounds effectively is difficult due to their intricate nature. The adverse effects of contemporary medicine and the reduced cost of herbal products have made natural herbal therapies for skin conditions and infections more and more important. These treatments present a strong substitute for treating wounds. The growing interest in herbal medicine is evidence of the therapeutic potential of medicinal plants for the healing of wounds. Wound healing is aided by the antibacterial, anti-inflammatory, and antioxidant properties of several herbal remedies. *Cassia fistula*, commonly known as the "Golden Shower Tree" is recognized by Ayurveda for its medicinal qualities, which are attributed to bioactive compounds. In recent years application of electrospinning nanofibers have aided to the wound healing process. Chitosan, a naturally occurring polymer that is highly helpful for wound healing because of its properties, is used as a polymer to electrospun the ethanolic extracts of *Cassia fistula*. The objective of this research is to develop a product that can cure wounds by employing an electrospun chitosan polymer mat that has *Cassia fistula* extracts integrated into it. This approach aims to expedite the healing process by utilizing the medicinal properties of the plant and the synergistic benefits of the natural polymer. Additionally, it might pave the way for more effective treatments for many kinds of wounds.

Keywords

Herbal, Wound Healing, *Cassia fistula*, Chitosan, Electrospinning, Nanofibers

Introduction

Wound management is one of the major global challenge in terms of fighting the infections and its impact. Wounds can be of different type and few can be treated with the primary treatment of wound dressing accelerating the healing process. Lately, there is a rise in development of herbal loaded wound dressing due to the presence of numerous phytoconstituents and pharmacological activities [1]. The golden shower tree, or *Cassia fistula*, is a known for the pharmacological activities that has been used in Ayurveda and other traditional medical systems for its therapeutic activities. The bioactive compounds have been found to possess wound-healing, anti-inflammatory, and antibacterial properties. These findings have prompted to highlight the potential applications of this material in textiles and wound dressings [2]. Electrospun nanofibers can incorporate and release therapeutic agents and are regarded as advanced dressing options because of their high porosity and permeability to both water and air. The high surface area, flexibility, and potential incorporation of bioactive natural products are just a few benefits of these nanofiber wound dressings. Furthermore, electrospun nanofibers have gained widespread significance in tissue engineering and drug delivery, and they present a promising solution for the management of wound healing [3]. Chitosan, a naturally occurring biopolymer has a nature of adaptability and fit for a range of wound types make it a promising polymer for wound-healing applications. Wound dressings based on chitosan have been developed for a variety of wounds, including diabetic ulcers and other acute wounds. Though there is a multiple natural and synthetic polymers chitosan is one of the most important polymers due to its pharmacological activities. The electrospun chitosan nanofibers possess a good biocompatibility which is much needed for the wound healing [4].

Materials and Methods

1. ***Extraction of sources:*** Fresh leaves, flowers, and seed pods of *Cassia fistula* were collected in Coimbatore, dried, and ground into powder. 20 gms of the powdered sources were extracted with ethanol, using Soxhlet extraction method.
2. ***Preparation of Chitosan solution:*** Chitosan was obtained from Himedia. 3gms of chitosan was dissolved in 100ml of distilled water containing 3% acetic acid, using a hot plate magnetic stirrer until a clear solution was obtained.
3. ***Preparation and Optimization of Spinning Solution:*** As chitosan is high in viscosity even at the lesser concentration the electrospinning of chitosan makes it difficult to spin without the addition of other polymers. To overcome this difficulty the chitosan is mixed with PVA at the desired ratio. The spinning solution is prepared by adding the *Cassia fistula* extracts to the Chitosan/PVA solutions at a desired ratio with different combinations.
4. ***Spinning of nanofiber mats:*** The prepared polymer solution is spinned with the help of electrospinning procedure by inducing 15KV, which converts the solution into nanofibers.
5. ***Analysis of the nanofiber mats:*** The obtained matt is subject to various testing like FTIR, SEM Analysis, GC-MS, Antimicrobial tests, Invitro assays and biodegradability tests.

Results and Discussion

The ethanolic extracts of the plant showed the presence of phytochemicals. The spinning solutions and the nanofibers showed a good antimicrobial effects against the selected microbes. The study of the produced samples based on the stated testing have produced effective results.

Conclusion

The study showed that the extracts of *Cassia fistula* aids in the wound healing and provides a scientific rationale for the traditional use of the plant in treating the wound and can be further investigated as a substitute for synthetic applications.

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Jerusalem Artichoke Extracts in Alginate Fibres for Wound Dressing

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Wound healing is one of the most widely studied areas of medical textiles. Recently, there have been numerous developments in this field, including the use of different plant and fruit-based extracts for imparting beneficial properties to the wound dressings and bandages that have anti-inflammatory properties. Jerusalem Artichoke (JA) extracts will be obtained from JA peels and JA leaves using the freeze-drying method with ethanol as a solvent. The objective of the research will be to check the effect of JA extracts on wound healing and then incorporating the extracts into SA fibres to fabricate multifunctional medical textiles. The JA extracts will be investigated in TNF-alpha activated human dermal fibroblasts using scratch assay and proliferation assay, subsequently the extract will be incorporated into Sodium Alginate (SA) fibres which will be obtained by the wet spinning method and by electro spinning method. This involves cross-linking of the SA solution containing JA extracts with Calcium Chloride in wet spinning method, to form the fibres. Additionally, SA films containing JA extract will be fabricated using the solvent casting method, to obtain a novel, biodegradable wound dressings. This study uses waste from JA peels and leaves to make multifunctional medical textile, making the product sustainable and environment friendly. The natural, bio-based ingredients used in the study make the wound dressings biodegradable and optimising the process to have a lesser negative environmental impact. With adequate functional properties, this is a novel biomaterial used in wound dressing.

Keywords

Jerusalem Artichoke, Sodium Alginate, Wound Dressing, Functional Fibres, Biomaterials.

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Studies on Various Absorbency Characteristics of Eco-Friendly Sanitary Napkins

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The spectrum of healthcare medical textiles includes disposable baby diapers, feminine sanitary napkins and tampons, and adult incontinence pads. These textile products aid in the control of infections and protecting against certain diseases, promoting personal hygiene by enhancing cleanliness and sanitation in both personal and hospital settings. The consumption of sanitary napkins increases at a high pace due to increased awareness of healthcare and improved economic conditions, especially in rural areas. The large-scale disposal of sanitary napkins poses a significant environmental risk due to the use of synthetic materials, which are not biodegradable and have a significant adverse impact on the environment worldwide. The current Medical textiles market is accounting about 30 billion US$, which is approximately 11% of the global consumption of technical textiles. At present, India's sanitary napkin market stands at 750 million US$ amounting only 3.2% of the total medical textiles consumed in India. The growth potential of sanitary napkins at home is estimated to 8.8% by 2030. The present study aims to design and development of eco-friendly sanitary napkins by incorporating selected natural biodegradable materials viz. cotton, silk, corn, PBAT, PLA. The performance study of these sustainable sanitary napkins has been under taken. Sanitary napkins, commonly known as sanitary pads, sanitary towels, or maxi pads, are essential to maintain reproductive cleanliness during women's menstrual periods. Currently wide range of sanitary napkins are available in the market such as huge pregnancy pads and incredibly thin panty liners. A typical sanitary napkin consists of three layers: the top sheet, the absorbent layer, and the back sheet. However, to enhance comfort, a skin-friendly fabric soft layer has been incorporated, providing a smooth touch next to the skin during use (Figure 1).

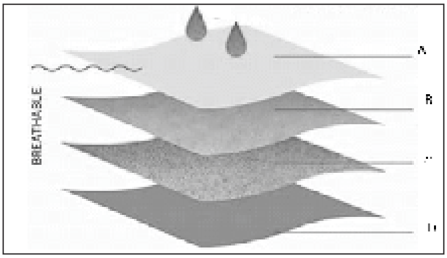

Figure 1: Functional layers of menstrual undergarments

A - Top Sheet: Moisture transport layer (Nonwoven sheet)
B - Moisture absorbent layer (Wood pulp and Corn starch)
C- Protective layer (PBAT + PLA Back sheet)
D- Skin-friendly fabric layer (Cotton fabric, Viscose fabric)

Figure 2 shows the construction details of the menstrual underwear. The thermo-physical comfort during the menstrual period is a crucial requirement. The absorbency characteristics of the materials and holding capacity of the layers play a crucial role in the performance of napkins.

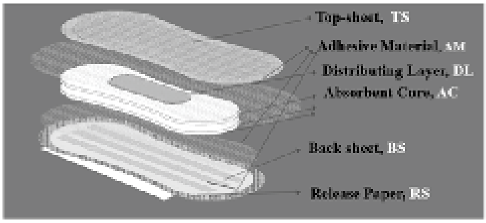

Figure 2: Layers wise construction of women's menstrual sanitary napkin

The large and extra-large sanitary napkin of maxi, ultra-thin and skinny-thin have been made using the commercial facility. The physical, mechanical and hydraulic characteristic have been studied. The performance evaluation have been carried out in laboratory such as absorption and rewet test using the synthetic blood. The fluid distribution along the length of core layer is also a crucial factor in comfort property. The distribution length also have been compared among the samples made from different biodegradable materials. The various results have been discussed and critical analysis have been made. The typical test results of a samples SNL8, a sanitary napkin (Large size) made from organic cotton have been showed in Figure 3. It exhibited the minimum absorption time in both the cycles as compare to the other samples. The outcome of the research study have been displayed graphically and important conclusion have been drawn to develop the eco-friendly sanitary napkins.

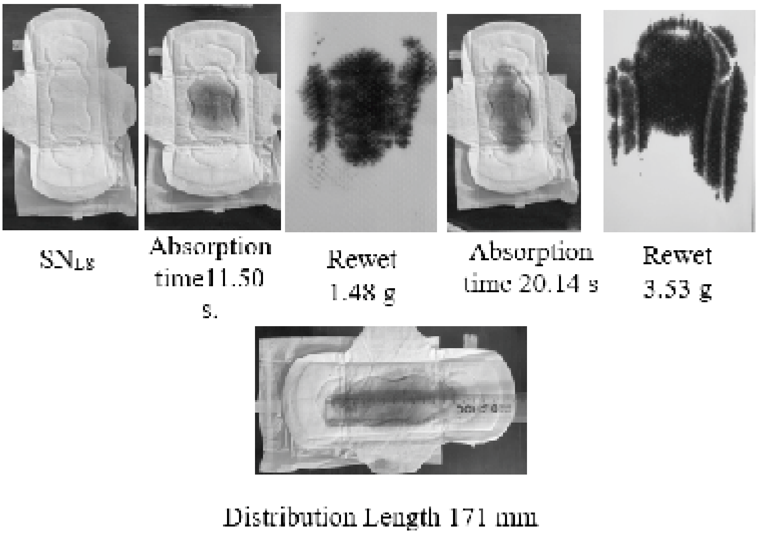

Figure 3: Absorbency, and rewet for the organic cotton Sanitary napkin (SN_{L8} 240mm)

The SN_{L8} sanitary napkin, the top sheet is made up of organic cotton has shown the least time in fluid absorbency among all samples, to the cellulosic in nature of organic cotton and is having highly amorphous and random structure of polymers i.e. open structure. In polymer matrix, there is high open space due to random arrangement of the cellulosic polymer chains. So, it can absorb the fluid faster and also can absorb high quantity of fluid. The use of these novel sanitary products can certainly protect the environment.

Keywords

Sanitary Napkin, Fluid absorbency, Comfort and Eco- friendly protection

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Study on Flyout Behavior of Polyester and Nylon Spindle Tapes in Ring Spinning Drive System

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The spindle tape is an industrial textile product which is essential in ring frame to drive the spindles at uniform speed. In this study, the fly-off behaviour of spindle tapes in the ring spinning has been investigated under special conditions such as flanged jackey pulley, reversing of tapes, etc. The various grades spindle tapes manufactured by Elgi Ultra such as GX, GX IMP, EFX, XT, G1, G2, PREIMIUM ++ have been analyzed for flyout behaviour in the model ring frame manufactured by LMW. In this study, the reasons for tape fly-off, fly off behavior of various tapes and solutions suggested to minimize the tape fly off from the tape circuit. The fly-off of behaviour of nylon and polyester tapes have been compared under different conditions. This study also reports the requirements of good quality spindle tapes and preventive measures to be taken to avoid the tape fly-off.

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COMPOSITES AND TECHNICAL TEXTILES

Contribution of Fibre Lumen on the Void Content of Jute Polyester Unidirectional (UD) Composites

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Due to ongoing awareness of environmental issue researchers are trying their best to explore natural materials to use in diversified products. Composite researchers are also following the same trend and thus various natural fibres as well as resins are utilized to manufacture composites. Jute is a well-known natural fibre to use in composites production. Huge availability as well as very good mechanical properties of jute fibre make it suitable to utilise in composite manufacture. Several end uses of composites such as structural and others, mechanical properties have great importance and mechanical properties of composites depend on various aspects and void content is one of them. As natural fibre, jute fibre has a lumen and there is a good chance to contribute void to the composites due to lumen. Thus, lumen of jute fibre is characterised in this experiment to know the influence of fibre lumen on the void content of composites. To achieve the purpose, raw jute fibre and jute fibre embedded in composites are examined under scanning electron microscope (SEM) to analyse the characteristic of fibre lumen of raw jute and jute fibre in composites. Also, SEM-EDX spectra is obtained and examined to charaterise the lumen of fibre embedded in composites as well as the matrix. SEM micrograph show different character of jute lumen for raw fibre and fibre in composites. SEM-EDX spectra reveals that lumen of jute fibre is filled with matrix and lumen doesn't influence the void content of jute polyester UD composites.

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A Study on Thickness Loss of Hand Tufted Carpets after Prolonged Heavy Static Loading

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The effect of pile height, pile density and ends per metre (EPM) or picks per metre (PPM) of primary backing on thickness loss of hand tufted wool carpets after prolonged heavy static loading has been studied. The relation between the process variables has been analyzed with response surface methodology based on the Box-Behnken design of the experiment. The experimental plan was a 3-factor 3-level Box-Behnken design. Table 1 lists the variables along with their coded and actual levels.

Table 1: Coded and actual levels of variables

Variables code	Variables	Levels		
x_1	Pile height, mm	10	13	16
x_2	Pile density, (tuft/metre^2)	31000	38750	46500
x_3	Primary backing fabric, EPM or PPM	393	472	551

Three different levels of pile height, pile density, and EPM or PPM of the primary backing fabric were used to prepare fifteen (15) samples. The primary backing fabric's EPM and PPM remained constant. Carpet samples were tested with the help of static loading machine and digital carpet thickness gauge. The ANOVA results of the regression models were checked by using F-test and its associated p-value. Interaction terms of pile height and pile density as well as pile height and primary backing fabric's EPM or PPM, and the quadratic term of primary backing fabric's EPM or PPM are statistically significant for thickness loss after static loading of all recovery periods. Thickness loss of hand tufted carpets gradually decreases with the increase in recovery period from instantaneous to 24 hours.

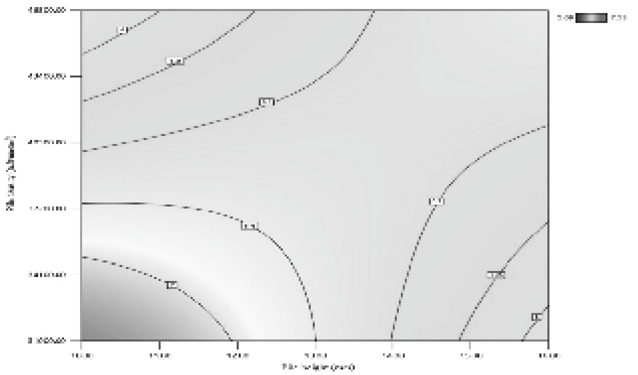

Figure 1: Effect of pile height and pile density on instantaneous thickness loss.

Figure 1 depicts the influence of two carpet construction parameters (pile height and pile density) on instantaneous thickness loss of hand tufted carpets after prolonged heavy static loading. It is observed that thickness loss decreases with the increase in pile height and pile density. The maximum thickness loss occurs at the combination of lowest values of pile height and pile density.

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Extraction of Helicteres Isora Fibre and its Potential Application in Agro Textiles

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Unconventional fibres are the fibres which are non-traditional in nature and are rarely used by the textile industry. Exploring the unconventional plant fibres and its application in suitable area is the need of hour in today's context. This research work focuses on extracting the natural unconventional fibre from Helicteres isora (Tamil name - valamburi) plant bark and its application in agro textiles. Researches on Helicteres isora fibre till now are limited to its extraction and scouring of fibres. This research work aims to extract Helicteres isora fibre using different chemicals like sodium hydroxide, sodium carbonate, non-ionic detergent, acetic acid, magnesium chloride, which are generally used for bast fibres extraction. Softening is also done which is totally a new attempt on this fibre. The extraction of fibres is done with 4 different stages. Water and chemical retting are done to remove all the unwanted substances and to strip of the fibres from stem and the retting processes are compared. Scouring is done to remove wax and oily substances and softening is done to reduce the fibre fineness and to enhance the fibre surface and handle characteristics. Then the fibres are tested for physical properties like Length, Diameter Tenacity, Elongation and Chemical composition like cellulose, hemi-cellulose, lignin, fat and wax, ash and moisture regain and then comparison was made between untreated and softened fibre properties, to assess the effectiveness of softening processes.

After fibre bulk production, the non-woven fabric manufacturing is carried out using needle punching machine with different blend ratios of isora and recycled cotton fibres (80:20, 70:30 and 60:40) with a GSM of around 1390 and with a thickness of 10mm. The non-woven fabrics are tested for its basic properties like, bulk density, tensile strength, abrasion resistance, moisture regain, air permeability for its application in agro textiles. In order to assess the performance of the blended non-woven in agricultural textile, mulch mats are made and subjectively analyzed. In the analyses, plant growth, weed control, water absorption and degradation of the mulch mat were observed on the daily basis and it is proved to be a good natural bio- material which retains moisture for a longer period.

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The methodology used for carrying this project work is given as below:

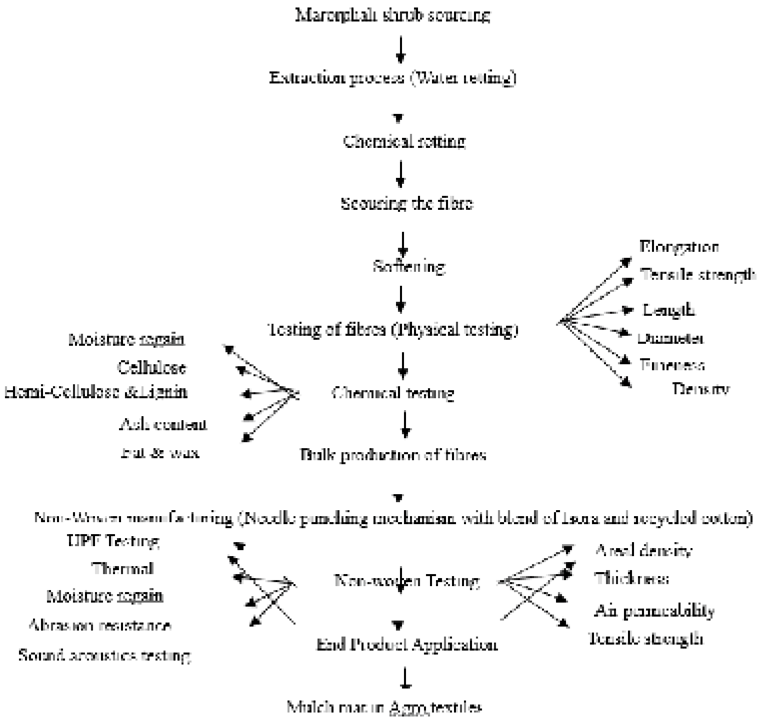

Figure 1: Flow diagram of the project

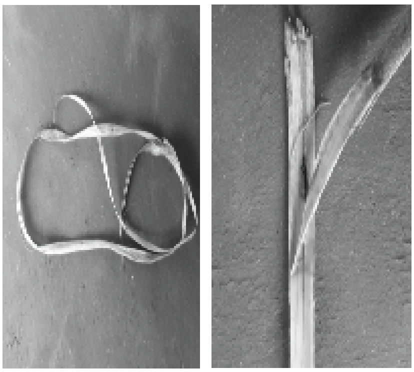

Figure 2: Striped layers of stem

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Acoustic and Aesthetic Characterisation of Polyester Warp-Knitted Fabrics for Enhanced Building Acoustics

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Polyester warp-knitted fabrics are increasingly utilised in home textiles due to their drapability, aesthetic appeal, and dimensional stability. However, their potential in sound absorption applications has not been explored. Existing studies on sound absorption primarily focus on nonwovens, woven fabrics, and microperforated panels, with minimal attention to the acoustic behaviour of warp-knitted fabrics. This study investigates the acoustic and mechanical performance of a 2-guide bar warp-knitted resistive screen backed by polyester hollow-fibre nonwovens. Samples were prepared with varied structural parameters, and their sound absorption was measured using the impedance tube method. Mechanical properties, including durability, were evaluated alongside visual characteristics such as lustre and softness, which are critical for applications demanding a luxurious appearance. Results demonstrated that the warp-knitted resistive screens significantly enhanced the noise reduction of the hybrid panel, with sound absorption performance significantly dependent on warp knitted fabric structural parameters. Findings from this study offer valuable insights for the development of optimised warp-knitted fabrics to meet both aesthetic and acoustic requirements in architectural and interior applications.

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Optimising Stuffer-to-Binder Ratio in 3D Woven UHMWPE Fabric Composites for Enhanced Mechanical Properties

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Unidirectional (UD) and bidirectional (2D) composites lack out-of-plane mechanical properties and undergo delamination in various mechanical loadings. 3D fabric composites overcome these shortcomings by the inclusion of through-thickness reinforcement. A 3D noobed fabric is composed of three sets of yarns: stuffer, binder, and filler. The stuffer and filler yarns remain almost straight within the fabric and determine the properties of composites in two principal directions. On the other hand, binder yarns are crimped, which reduces their contribution to mechanical strength, but they provide crucial structural integrity to fabrics and composites. The properties of 3D fabric composites can be tuned by optimising the proportions of these three sets of yarn. The structural parameters such as stuffer-to-binder yarn ratio (S:B), binding step, binding depth, and pick density significantly affect the properties of the 3D fabrics and composites. A higher S:B provides more straight yarns but a less stable structure due to a lower number of binding points. Similarly, a higher pick density provides more load-bearing components but affects the fabric porosity, which can deteriorate the resin penetration inside the structure. Therefore, the focus of this research is to optimise the S:B ratio and pick density in a 3D orthogonal fabric by varying them at three levels. Ultra-high Molecular Weight Polyethylene (UHMWPE) yarn (1350 denier) was used as stuffer and filler, whereas same yarn of finer linear density (400 denier) was used as binder. S:B ratio was varied from 1:1 to 4:1 and number of layers of filler was four. Epoxy resin was used as the matrix and composites were manufactured using compression moulding technique. The study reveals that a high S:B ratio leads to higher tensile strength, impact energy absorption, bending strength and in-plane shear strength. On the other hand, a higher pick density inversely affects the bending and in-plane shear properties.

Keywords

3D fabric; Composite; Compression moulding; Stuffer yarn; UHMWPE.

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Packaging Materials as Marine Fish Freshness Indicator

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Sustainable food packaging with active and intelligent features is increasingly important for reducing food waste and maintaining food quality, especially in response to the rising incidence of food-borne illnesses and environmental concerns over plastic waste. Historically, food packaging was designed to act as a physical barrier, protecting food from contaminants and delaying spoilage. However, advancements in technology have introduced more efficient materials that extend shelf life while safeguarding against contamination. Currently, around 36% of food packaging materials are derived from petroleum-based products, such as polyethylene, polypropylene, and polystyrene (1). While these are popular due to their low cost, durability, and ease of production, they contribute to a range of environmental, ecological, and health issues, including waste management challenges. Today, with a heightened focus on protecting human, animal, and environmental health, combating climate change, and reducing reliance on fossil fuel-based materials, the global market is increasingly seeking eco-friendly alternatives and intelligent packaging solutions. Polysaccharides extracted from macroalgae—such as agar, carrageenan, alginates, and ulvan—are widely utilised and studied for developing bio-based intelligent food packaging films (2). Carrageenan (CAR) is recognized as an excellent material for fabricating color indicator films due to its sulfur content, strong film-forming ability, biocompatibility, antioxidant properties, and barrier functions. However, its films exhibit weak mechanical properties. Anthocyanins, natural edible pigments found in sources like grapes, mulberries, red cabbage, and raspberries, have reported in the literature as effective color indicators and can be incorporated with polysaccharides. This study investigates the development of color indicator films using carrageenan and anthocyanins, reinforced with nanocellulose, for assessing the freshness of marine fish.

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Effect of Milling on the Fly Ash/OTES Treated Cotton Nonwoven Fabrics on Oil-water Separation Applications

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The problem of oil spills in the marine ecosystems and costal area possess one of the major threats that can cause significant environmental and economic problems, particularly affecting coastal regions, and leads to water and soil pollution. Therefore, the research on textile based advanced adsorbent materials has been increased specifically designed for oil-water separation. In this context, we modified the cotton nonwoven fabric to develop hydrophobic surface, capable of separating oil from oil-water mixture. In this study, milled and unmilled fly ash, at various concentration (0-20%), was used to create surface roughness and then coated with n-octyltriethoxysilane (OTES) to reduce surface free energy and impart hydrophobicity to the fabric surface. The effect of fly ash concentration and effect of milling was then studied on the wettability of modified cotton surface. The hydrophobicity imparted on the cotton nonwoven fabric was then utilized for the oil-water separation applications. It was observed that the oil-water separation efficiency was increased with increase in fly ash concentration. Also, oil-water separation efficiency was higher for milled fly ash treated samples, than unmilled samples. Therefore, this study demonstrates the utilization of waste fly ash for developing functional cotton fabric for oil-water separation applications.

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SMART AND E-TEXTILES

Development of An NFC Antenna Multiplexing System for the Application in Smart Textiles

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Smart Textiles are an attractive use case for Near Field Communication (NFC). As most textile products have regular physical contact with the user, they fulfil the proximity requirements of NFC. Moreover, there are some applications that benefit from having more than one NFC contact point, such as Smart Clothing for communicating with on-skin biomonitoring patches [1]. For this purpose, we propose an NFC Antenna Multiplexing approach to selectively connect any of the NFC antennas to a central NFC circuit using a Radio Frequency (RF) switch [2]. The established approach of adding a dedicated NFC circuit for each contact point [3] can lead to system integration issues and significant manufacturing effort when used on a Smart Textile. That is why our multiplexing system aims to not only reduce the number of required components but also aggregate them into a central point, thereby reducing manufacturing effort and easing system integration. In order to achieve seamless integration into the textile, conductive yarn is sewed into a coil mould to produce flexible textile-based antennas [4]. The system uses long cables of conductive yarn to allow remote placement of the antennas, as shown in Figure 1. The NFC reader and switching circuits are situated in the hub, which can be included in the main circuit board of a Smart Textile.

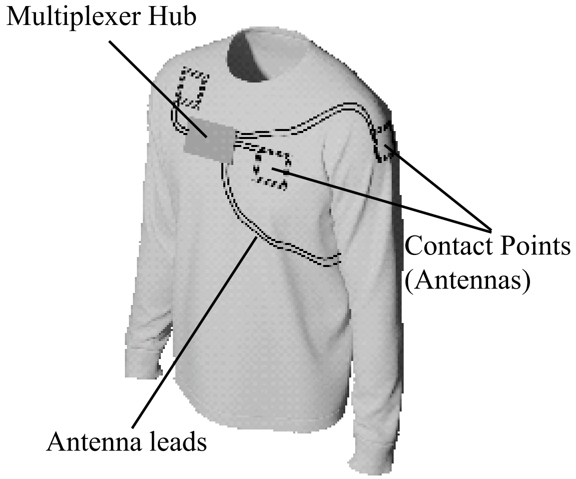

Figure 1: NFC Multiplexing system integrated into a shirt

Since the NFC system needs to be able to supply power to passive NFC devices [5], it is important to compare the signal power to other approaches. Our testing aims to quantify the impact of adding the

RF switch and the long leads between the NFC circuit and the antenna. In this scope, an overview of the system's impedance matching mechanisms is provided. Our testing shows that even with significant losses in signal power, the multiplexing system can perform successful communication with NFC devices. Although these losses are not unique to the multiplexing approach, we present some options to increase the effectiveness of the system. We are confident that, in certain use cases, NFC Antenna Multiplexing is a beneficial alternative to other NFC implementations.

Acknowledgments

We would like to thank the Federal Ministry of Education and Research for funding the research project as part of the "PhysioTaix" innovation area. (Funding reference: 16SV9249).

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Development of a Tactile Feedback System for the Guidance of Independent Rehabilitation in Smart Textiles

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Demographic change in Germany and many other industrialised countries, together with steadily increasing life expectancy, poses major challenges for medical rehabilitation. Due to age-related risk factors, an increasing number of injuries to the musculoskeletal system can be expected. In addition, a lack of exercise in the workplace is increasingly leading to health problems, particularly in the back, even among young people. [1] This results in an increasing need for rehabilitation programmes, which cannot be met due to the lack of suitable specialists. As a result, many people do not undergo an optimal rehabilitation proc ss, which leads to higher long-term costs due to secondary illnesses and lost working hours [2].

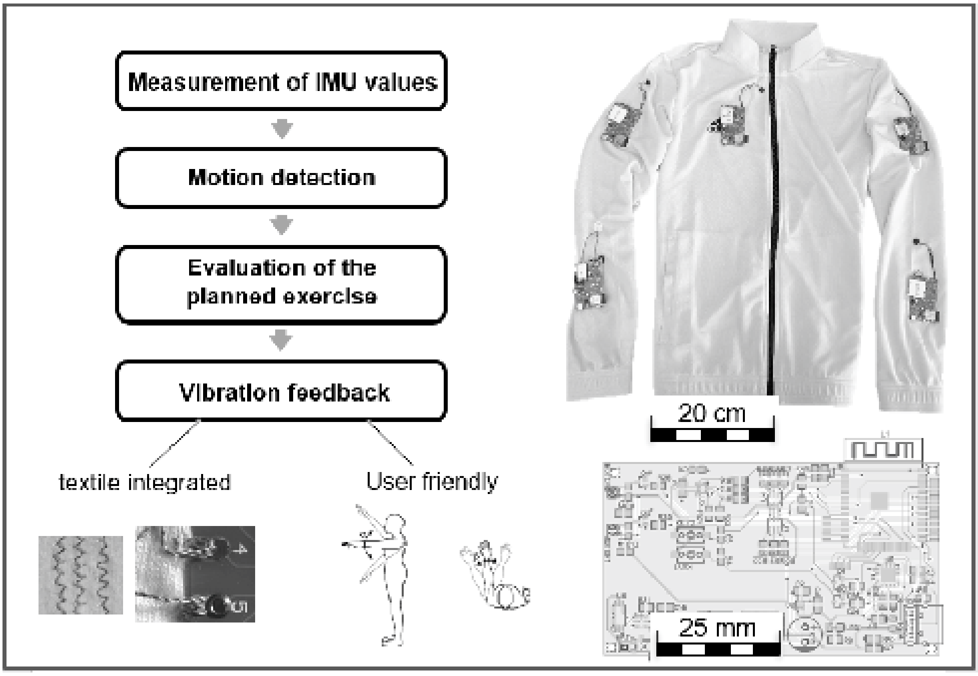

Figure 1: Illustration of smart jacket with freedom of movement and textile integration of electrical components

The aim of this work is to develop a textile-integrated system for detecting upper body movements in order to guide patients through their exercises. The additional integration of tactile feedback by means of vibration motors is intended to improve the performance of rehabilitation exercises at home. Special emphasis is placed on the comfort and user-friendliness of the system.

The first step was to analyse different conductive yarns to determine their suitability as textile conductors and how best to connect these yarns to a circuit board. This was important because the connections to the vibration motors are central to the feedback system. The next step was to record and analyse the influence of the vibration motors on the adjacent inertial measurement unit, which is important because the motors can cause unwanted interference in the motion detection sensors. Different forms of tactile feedback were then tested on several test subjects. Finally, modules were developed containing both an integrated inertial measurement unit and a microprocessor for data processing and control of the vibration motor.

Our tests show that the conductive yarns analysed have a high resistance, which is exacerbated by a washing process, suggesting that the electrical components should be modular and replaceable. However, the connections used proved to be robust enough to ensure reliable communication with the vibration motors. Measurement inaccuracies caused by the use of vibration motors in combination with inertial encoders could be minimised by maintaining a sufficient distance between the modules. Tactile feedback of motion has been shown to be convenient and effective with appropriate controls. The demonstrator developed in this project fulfils the requirements and is therefore suitable for the further development of algorithms for motion evaluation and the integration of other systems.

Acknowledgments

We would like to thank the Federal Ministry of Education and Research for funding the research project as part of the "PhysioTaix" innovation area. (Funding reference: 16SV9249)

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Modulating the Wetting Behaviour of Woven Gas Diffusion Layers in Proton Exchange Membrane Fuel Cells

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Proton Exchange Membrane Fuel Cells (PEMFCs) are the global future of sustainable mobility, and at the core of this technology is a three-dimensional (3D) carbon fibre-based structure known as gas diffusion layers (GDLs). This component is critical to PEMFCs due to their multifaceted role of facilitating gas diffusion, electron transfer, and water management while supporting the microporous layer (MPL). GDLs are available in woven and nonwoven forms, known as carbon cloth and paper, respectively. While nonwoven GDLs provide a relatively porous network, woven GDLs offer a more compact design for fuel cell assembly. Furthermore, the highly regular structure of woven GDL creates a uniform backing for optimised catalyst deposition. However, the wettability of the GDL is crucial for both types of GDLs, governing their water management capabilities in the fuel cell. Optimised water management ensures proper functioning and longevity of the fuel cells. In contrast, poor management can lead to flooding in the proton exchange membrane and disrupt the electrochemistry of the fuel cell. Targeting the desired wettability via engineering the microstructure of GDLs is a beneficial strategy to improve overall PEMFC performance. This work aims to elucidate deeper insights into the wetting behaviour of woven GDLs by developing an analytical model for predicting the apparent contact angle of woven GDLs. The 3D microstructure of the woven GDL is obtained using X-ray micro-computed tomography (microCT) analysis, which formed the basis for a multiscale analytical model to predict the apparent contact angle of woven GDLs. Based on the pioneering work of Cassie and Baxter (1944), the model initially predicts the apparent contact angle of yarn based on the intrinsic contact angle of carbon fibre and yarn structural parameters such as packing fraction, packing geometry and yarn diameter. Subsequently, the apparent contact angle of the woven GDL is predicted from the yarn contact angle and the construction parameters of the fabric. The predicted results are validated with the measured contact angle of commercial GDL samples, demonstrating a good agreement. It must be noted that commercial woven GDLs are often coated with Polytetrafluoroethylene (PTFE) or other surface finishes to modulate the wetting behaviour and improve the interaction with the MPL. However, this can create a surface with non-uniform wetting behaviour. Therefore, the proposed model has been generalised for broader applicability, including fabrics with uniform and non-uniform wettability. Consequently, the robustness of the analytical model has been verified by validating the results with a Kevlar-PTFE fabric selected from the literature (Liu et al., 2022). To summarise, this work deciphers the relationship between the 3D microstructure and wetting behaviour of different types of woven GDLs and similar structures.

Keywords

Fuel Cell, Gas Diffusion Layer, Wettability, Water Management

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Development of Textile-based Surface Electrode for Bio-signal Monitoring

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Introduction

Textile materials which sense and respond to stimuli like pressure, temperature, and electrical impulses are called smart textiles. Smart textiles can be made by spinning, weaving, knitting and electrospinning, from conductive materials like metals, conductive polymers and carbon derivatives. Smart textiles find growing applications in various fields like healthcare, defence and sports.

Aim of the Research

In healthcare sector bio-physiological signal monitoring plays a prominent role in detection and treatment of diseases. For example, ECG aids in the detection of many heart diseases and EMG is used in diagnosing neurological and neuromuscular issues and facilitating physical therapy. This calls for continuous monitoring of bio-signals where the current clinically employed Ag/AgCl gel electrodes fails, due to gel dehydration. Smart textiles on the other hand can provide seamless long-term bio-physiological signal monitoring as they can be integrated in daily wear.

Materials and Methods

In this work, a conductive carbon solution containing carbon black and graphite was prepared in different concentrations: 5%, 45% & 50% . The solution was then padded on cotton fabric and the resulting conductive fabric was developed into a textile-based surface electrode.

Results and Discussion

The prepared electrodes were observed under optical microscope. Their conductivity was analysed using IV curves and Hall measurements. The IV curves of the textile electrode exhibited ohmic nature indicating its conductivity. The sample with 50% concentration showed the lowest resistance of 7.6 kΩ. The electrode was further characterized using Raman Spectroscopy to understand the material behaviour. It was also tested for its Thickness, Tensile strength, and Air permeability to understand the mechanical properties. The signals from the 50% concentration electrodes resembled the closest to the ECG and EMG signals obtained from commercial Ag/AgCl gel electrode.

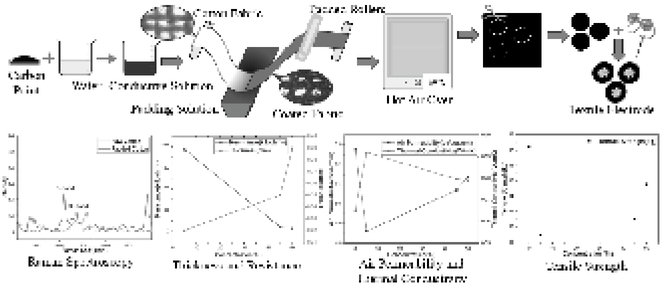

Figure 1: Electrode Fabrication and Characterisation

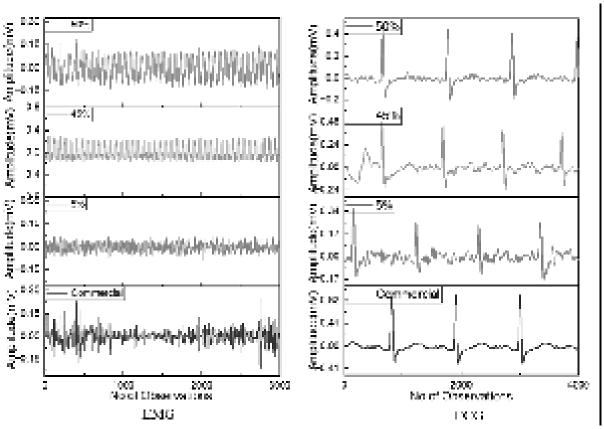

Figure 2: EMG & ECG Results

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Awareness Level of Consumers Towards Wearable E-textiles

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The rapid advancement of technology has introduced the concept of wearable e-textiles, blending traditional clothing with modern electronics to enhance user experience. Despite their growing global presence, awareness and acceptance of wearable e-textiles still remain uncertain. This study aims to assess the awareness, perception, and potential market for wearable e-textiles among diverse demographic groups. The research seeks to understand the factors influencing or restricting the adoption of wearable e-textiles and to identify the preferred types of smart clothing, footwear, and accessories among the population. Key objectives of this research comprises of assessment of the awareness of wearable e-textiles among different demographic groups, exploring the types of wearable e-textiles known or used by the respondents, evaluation of the perceived importance and utility of wearable e-textiles in daily life, identifying the factors influencing and restricting the buying decisions for wearable e-textiles, determine the preferred types of smart clothing, footwear, and accessories and analysis of the significance of sustainability in the manufacturing of wearable e-textiles.

The literature review examines global trends in the adoption of wearable e-textiles, highlighting studies on consumer awareness, technological advancements, and market growth. Existing research underscores the potential benefits of wearable e-textiles in healthcare, sports, and fashion. However, there is limited literature on consumer perception and adoption in the Indian context. This gap in research highlights the need for localized studies to understand Indian market dynamics. The primary research problem addresses the low awareness and adoption of wearable e-textiles, that could hinder the growth of this emerging market in the region. The study aims to identify the awareness level, perceptions, and potential barriers to the adoption of wearable e-textiles. A quantitative survey was conducted to gather comprehensive data. The survey was administered to a diverse sample of individuals segmented by gender, age group, occupation, and family income. The questionnaire included multiple-choice questions and Likert-scale to assess awareness, usage, and attitudes towards wearable e-textiles. Data was analysed using statistical method to identify trends and correlations, while qualitative responses were coded for thematic analysis.

The findings revealed varying levels of awareness about wearable e-textiles, with younger age groups showing greater familiarity. The types of wearable e-textiles known or used included smart clothing, smart footwear, and wearable accessories, with preferences influenced by factors such as functionality, comfort, and aesthetics. Sustainability in wearable e-textiles emerged as a significant concern, with respondents emphasizing the importance of eco-friendly materials in manufacturing. Key factors influencing buying decisions included multi-dimensional functionality, durability, and technological features, while barriers included lack of awareness, high costs, and concerns about data privacy. The study also identified healthcare and sports as the most promising areas for the adoption of wearable e-textiles.

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The results suggest a need for targeted awareness campaigns and affordable product offerings to increase the adoption of wearable e-textiles. Additionally, manufacturers should consider sustainability as a core component of their product development strategies. Further research could explore the long-term adoption patterns and the impact of emerging technologies on consumer behaviour in this region.

Acknowledgments

We extend our heartfelt gratitude to all 390 respondents who took the time to complete our survey. Your insights are invaluable, and we are especially thankful to those who went the extra mile to share the questionnaire within their networks. Everyone's support is deeply appreciated.

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Moisture Management Properties of Rib Knit Structures Intended for Next to Skin Applications

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Moisture management properties are crucial for textiles intended for next to skin applications like intimate wear, socks, gloves etc. in order to ensure rapid sweat dissipation and dry microclimate. Knitted fabrics owing to their excellent stretch ability, good handle and comfort properties are preferred choice for all such applications. The present study was undertaken to study the influence of fibre, yarn and fabric parameters on moisture management properties of polyester/cotton and viscose/cotton rib knit structures intended for next to skin applications. Polyester-cotton blended fabrics exhibited higher thermal resistance, lower thermal conductivity and better moisture vapor transfer properties compared to their viscose-cotton counterparts. Viscose-cotton fabrics on account of their lower thermal resistance, were found to be suitable for summer wear accessories intended for static/low physical activity level. However, PET/C fabrics were found to be suitable choice in cold weather conditions owing to superior thermal properties. PET/C and V/C fabrics showed an increase in thermal resistance and decrease in air permeability and water vapor permeability as the polyester and viscose filament denier was increased. Fabrics developed by feeding two yarns separately through different feeders were found to be more permeable to air and water vapor as compared to their counterparts.

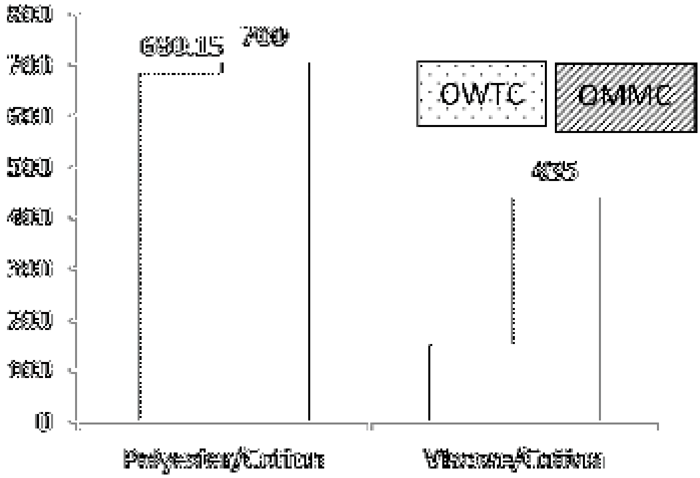

Figure 1: One way transport capacity & Overall moisture management properties of Polyester/Cotton & Viscose/Cotton fabrics

Table 1: Physical properties of test samples

Sample Code	Aerial Density (g/m^2)	Thickness (mm)	Fabric Porosity (%)	Tightness Factor (Tex cm^{-1})
PC1	301	1.58	87.0	7.25
PC2	311	1.30	91.0	5.64
PC3	168	1.19	91.0	5.08
PC4	223	1.32	90.0	7.40
PC5	167	1.52	87.9	7.90
PC6	171	1.53	90.3	7.40
PC7	265	1.64	92.0	5.60
PC8	263	1.63	92.0	5.90
VC1	332	1.40	86.8	4.80
VC2	217	1.60	83.9	6.30
VC3	343	1.82	75.0	11.26

Keywords

Sports, moisture transmission, comfort, energy harvesting, solar cell.

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NATURAL FIBRES

Water Hyacinth: A Wearable Weed

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Water hyacinth (*Eichhornia crassipes*), is a floating aquatic macrophyte formerly limited to the Amazon basin. The plant, with thick green leaves, lavender-blue flowers, and dark purple roots, has spread rapidly and poses significant threats to the environment and humanity. Water hyacinths choke streams, limiting water activities like fishing, impeding photosynthesis, lowering oxygen levels, and deteriorating water quality. Despite the Bengal Water Hyacinth Bill being passed in 1933, the weed grew, becoming the *Terror of Bengal* [1]. This fibre has cellulose (63.75%), hemicellulose (12.33%), and lignin (20.67%) as major constituents. It has moderate absorbency, medium strength, and elongation. The fibre exhibits strong thermal insulation and has several hollow holes that can retain moisture [2, 3]. Research on water hyacinth extraction and characterisation has shown that mechanical extraction leads to the highest elongation, while chemical extraction produces more even fibres and yields [2]. Water hyacinth fibres can be blended with polyester and cotton to produce yarn [4]. It can also be used in biogas production [5]. Nonwoven from water hyacinth stalks and needle-punched fabrics have also been studied and reported [6-7]. Governments and NGOs are also taking initiatives to use this *terror* to produce different craft items. However, there is plenty of scope for using this abundantly available natural resource in various fields of textiles. This helps partially clean water bodies, converts waste into valuable products, and reduces natural resource consumption. It also saves aquatic life by cleaning this weed from water bodies and reducing the consumption of other resources in textile applications. Functional clothing may represent an area in which clothing crosses conventional boundaries. In this work, an initiative has been taken to produce yarn from fibre extracted from water hyacinth and blended with other regenerated fibre to understand its potential for use as a textile raw material. The fibre from the water hyacinth stems was extracted and characterised in terms of fineness, length distribution, bundle strength, cross-section, dissolution behaviour, tenacity and elongation, then blended with other regenerated fibres viz., excel, viscose etc to make yarn. The yarn was produced through ring spinning and rotor spinning techniques. The ring spinning system was used to produce a 12 Ne yarn by blending water hyacinth with viscose and excel fibre. On the other hand, excel and water hyacinth were used to produce 8 Ne yarn in the rotor spinning system. Both the yarns were converted into woven and knitted fabrics and further used for garments. Air permeability, pilling tendency, moisture management, thermal behaviour etc. were tested and compared with the cotton and Excel fabrics having similar specifications. Analysing all the testing results it may be concluded that the water hyacinth fibre has the potential to be used in apparel. It shows better results in an open-end spinning system compared to ring spinning. Using the high moisture regain property of this fibre it can be further used to produce sportswear, summer casuals etc. A treatment with aloe vera extraction showed good antifungal and antibacterial activity against selected fungi and bacteria.

Keywords

Bacterial, Fungi, Functional, Ring spinning, Rotor spinning, Water hyacinth.

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Circular Economy in Nettle Fibre Plant for Applications in Textile and Other Industries

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Natural fibre crops produce range of natural fibres, which are primarily used for textile manufacturing, and the byproducts (stalk/stick, short fibre, spinning waste, leaves, etc) may be used to produce composites, particle boards, pulp & paper, activated carbon and value-added chemicals. In a circular economy, products, byproducts and other materials are kept in circulation through processes like reuse, refurbishment, remanufacture, recycling and composting. In this context, nettle plants are grown naturally as forest weeds in the Himalayan region without much explored economic value. The plant remains under-explored as far as extraction of fibre for textile and other industrial applications are concerned. Present study highlights a complete value-chain of nettle plant starting from fibre extraction, quality evaluation, yarns & fabrics making, colouration, fabric development, and products manufacturing. Extracted Himalayan nettle fibre was characterized in terms of physical, morphological, mechanical, thermal and chemical properties. Nettle fibre of fineness of 2.2 -2.4 tex, tenacity of 10-16 cN/tex and elongation of 3% was blended with regenerated rayon fibre in 75/25, 50/50 and 25/75 proportion to produce blended yarns along with development of 100% nettle yarn. These yarns were utilized in the weft direction to produce union fabric in handloom, keeping the cotton yarn as warp. Yarn and fabric properties were also evaluated in details. Apparel textile products, like female fashion wear (cost $ 13) and 'shawl' (cost $ 39) were produced from the as-prepared, bleached and dyed yarns. The developed apparel products are not only fashionable, but also biodegradable. During the yarn spinning, fibres get wasted as carding, drawing and spinning droppage, were utilized in paper making, which shows breaking load of 59 N, tear strength of 700 mN and initial modulus of 395 N/mm^2. In the fibre extraction process, nettle plant remnant was used in making particle board in combination with jute stick using synthetic resin. Research findings advocate that the whole nettle plant can be considered, as an untapped potential source of raw material for textile, paper and composite board manufacturing industries.

Keywords

Nettle; Circular economy; Fiber properties; Textile; By-product utilization

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Investigating Effect of Blend Ratio and Twist on Properties of Yarn Made from Himalayan Nettle (*Girardinia diversifolia)* and Polyester Fibres

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With increasing awareness on sustainability and biodegradability, the utilisation of different natural fibres is gaining considerable attention these days. The well explored conventional natural fibres like cotton, flax, ramie etc. could not meet the increasing demand of natural fibres for textile products. Thus, research communities are taking interest to explore other unconventional natural fibres to meet the demand. India has vast resources of indigenous plants having potential source of cellulosic fibres. One notable plant among them is Himalayan Nettle (*Girardinia diversifolia)* (1). It is found at the altitude of 1200-3000 m throughout the moist Himalayan region (2). The fibres extracted from the barks of Himalayan nettle have good mechanical properties and low linear density (3), making them suitable for being spun into yarn and used for textile applications.

Samanta et. al[4] developed nettle/viscose blended yarn with blend ratio 100:0, 75:25, 50:50 and 25:75 and reported linear density, tenacity and elongation of the yarn 75.8-93 tex, 0.88-1.23 gf/den and 2.06-4.20 % respectively. The yarn developed is very coarse and have strength very low. Vijayalakshmi and Manonmani[5] developed nettle/cotton and nettle/polyester yarn using different blend ratio and reported their linear density around 60 tex and tenacity (0.54 - 0.86 gf/den). The yarn developed are very coarse and the strength of the yarns are also low. These study lacks the effect of twist and their interaction with blend ratio on the property of yarn. There is need to develop fine yarn with good strength and elongation.

For this study, nettle ribbons were obtained from local NGO in Uttarakhand. The ribbons were alkali treated to extract the fibres. The extracted fibres were cleaned using trash analyser to remove remaining vegetative part. The cleaned fibres were blended with polyester fibres in different blend ratio and passed through miniature carding to obtain the lap. The lap was then passed through draw frame, roving frame and ring spinning in sequence to obtain the yarn. The various machine parameters were set to obtain yarn of fixed linear density. The twist multiplier was also varied. The yarns made were evaluated for physical and mechanical properties. The effect of blend ratio and twist multiplier on the yarn properties were investigated and the optimum blend ratio and twist multiplier yielding best quality yarn was determined. This paper will present the results of this study.

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Utilizing Pearl Millet *(Pennisetum glaucum)* Crop Waste: A Journey from Fibre Extraction to Sustainable Yarn Development

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Pearl Millet *(Pennisetum glaucum)*, a drought-tolerant cereal predominantly cultivated in arid and semi-arid regions for its grain, produces lignocellulosic stalks as a byproduct. These stalks present a viable, underutilized resource for sustainable cellulosic fibre extraction. This study aims to optimize the extraction and application of fibres derived from pearl millet stalks for textile purposes like clothing, home textiles, technical textiles, and industrial products. Employing a combination of pretreatment techniques, including soaking and mechanical crushing, the extraction process was refined to enhance fibre quality. The sheath segment yielded high-quality, bright golden-yellow long fibres, while alkali treatment (optimal at 5% NaOH for sheath fibres) improved fibre separation and structural integrity. Deviations from this concentration led to fibre degradation due to defibrillation and matrix removal.

The spinnability of the optimized fibres was assessed through blending with viscose, polyester, and cotton in a different blend-ratios. Initial carded web formation, conducted via roller carding, yielded evenly distributed blends, which were converted into sliver for subsequent yarn development. Yarn formation has been done with process variables being fine-tuned based on mechanical performance and structural limitations. This research demonstrates the technical feasibility of harnessing pearl millet stalks as a sustainable fibre source, with promising implications for eco-conscious yarn and textile manufacturing.

Keywords

Agro waste, Pearl Millet, Lignocellulosics, Sustainable textiles, Fibre Extraction, Textile Blends.

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Effect of Chemical Treatment for Extraction of Fibres from Indian Industrial Hemp (*Cannabis sativa*)

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The chemical processing of hemp fibres for their commercial application in apparel, technical textiles, and biocomposites primarily focuses on the removal of non-cellulosic components, such as pectin, hemicellulose, and lignin, to obtain individualised fibres. Industrial Hemp (*Cannabis sativa*), has recently become available in Uttarakhand state after the lifting of the ban on the cultivation of Hemp plants. The extraction of fibres from the stems requires labour-intensive processes like sun-drying, field retting and water retting, rigorous washing, and manual beating. These traditional procedures often lack precision leading to over-retting and yielding poor-quality fibres [1]. The fibre processing involves the sequential removal of lignin from the outer bark tissues, followed by pectin (primarily homogalacturonan), which binds the fibre bundles. Each fibre comprises primary and secondary cell walls, consisting of cellulose microfibrils protected by a network of hemicellulose, pectin, and glycoproteins [2]. The chemical composition of fibres and the distribution of the constituents define the properties of the fibres. According to the literature, raw hemp ribbons are generally composed of 59.25% cellulose, 3.11% lignin, 13.39% hemicellulose, and 24.25% pectin and wax [3]. The hemp fibre bundles present beneath the bark are held together by pectin in the middle lamella, acting as a glue. Within the fibre cell wall, pectin forms covalent bonds with hemicellulose or cellulose, and strong hydrogen bonds between pectin and other components in the cell wall [4]. Pectin forms calcium cross-bridges through electrostatic interactions between negatively charged non-esterified or low-methyl-esterified galacturonan blocks and positively charged calcium ions. The formation of ionic linkages between calcium and the carboxyl groups of pectin causes difficulty in the removal of pectin. Consequently, removing calcium ions can accelerate the degradation of calcium-rich pectic substances [5]. The objective of the study is to investigate the effect of chemical treatments in the removal of lignin, pectin, hemicellulose and other non-cellulosic components to extract separate fibres. In this study, alkaline extraction is carried out using various concentrations of NaOH and KOH along with a chemical chelator such as EDTA (ethylenediaminetetraacetic acid) for the removal of calcium and homogalacturonan i.e. the major component of pectin polysaccharide from hemp ribbons. The morphological, physical, and mechanical properties of the extracted hemp fibres are subsequently analysed and compared.

Acknowledgement

The author (SS) would like to acknowledge the stipend provided by UGC for carrying out the research work.

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Bleaching of Pearl Millet *(Pennisetum glaucum)* Fibres

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Pearl Millet *(Pennisetum glaucum)* is lignocellulosic in nature and is commonly farmed for food and fed in Northern India. After harvesting, excess straw is left in the field since mechanical harvesters are used. In order to save time and labor, farmers frequently burn this crop debris, which causes extreme air pollution in the Delhi NCR region, Noida, and Gurugram throughout the winter. Recently environmental considerations have led to increasing interest in naturally occurring lignocellulosic material as they are abundant and biodegradable. After extraction, fibres obtained from the straw of Pearl millet facilitate its application in value-added products like apparel textiles, home furnishings, and handicrafts by blending with other fibres like viscose, banana, and polyester. Bleaching, dyeing, and finishing are important steps for making value-added products.

In this study, bleaching treatment for pearl millet fiber was done using various oxidizing agents, such as Peracetic acid, Hydrogen peroxide, Ozone, and Sodium Hydrosulphite - reducing bleaching agent, in order to determine the minimum tensile strength loss to achieve a good whiteness index. It was found that bleaching of Pearl millet fibre with 0.5% H_2O_2, time 15 min and temperature 90℃ can produce a bleached Pearl millet fibre with retention of >95% tensile strength and whiteness index of >60, which is suitable for the subsequent dyeing process. However, looking forward to the alternative, environmentally friendly bleaching treatment that uses very little water and no chemicals. In order to obtain the tensile strength and whiteness degree comparable to hydrogen peroxide, various ozone bleaching treatments were carried out in this study. The effects of the fibre's water pickup value, duration of the ozone treatment, rinsing process after ozonation, and pH value of the fibre were analyzed.

Keywords

Lignocellulosic, abundant, biodegradable, bleaching treatment, Ozone, value-added products.

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PROTECTIVE TEXTILES

Role of Textile Finishing Chemical in Improving UPF of Fabrics/Garments

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The UPF value of fabrics/garments depend on several factors and some are GSM, count, cover factor weave, nature of fibre, picks/inch, ends/inch, elastic recovery, moisture, wetting properties and dyes. Out of these, the nature of fibre, picks/inch, ends/inch play bigger role in making fabric UV resistant. The application of dyes and finishing chemicals are also contributing factors in improving UPF value of fabrics/garments. The effect of dyes on UPF values were studied by several researchers. In this study it was revealed that after chemical finishing of fabrics/garments, some finishing chemicals affect the UPF values and improve it. The synergistic effect of dyes specially some reactive and Direct dyes and finishing chemical produce good U.V. resistance in the fabric. The effect of finishing chemical is very encouraging as compared to dyeing effect.

Keywords

Cotton fabric, UPF value, Reactive and Direct dyes, Textile finishing chemicals

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Development of Stab Resistant Armour through Synergistic Effect of Boron Carbide (B4C) Ceramic Particles and Shear Thickening Fluid Treated P-aramid Fabric

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Stab-resistant armours are essential for police and security forces. However, the mechanisms of fabric failure during stab and bullet impacts are dissimilar due to huge difference in associated energy densities. This research aims to design a stab-resistant body armour using coating of hard boron carbide (B4C) ceramic particles and shear thickening fluid (STF) on p-aramid fabric. The effects of thickener type used for coating, size of ceramic particles and particle to binder ratio on stab resistance have been investigated. The efficacy of coating was evaluated by checking adhesion between ceramic particles and fabric, bending and shear moduli. Dynamic stab resistance tests were conducted following NIJ 0115.00 (level 1) standard at 24 J energy. Results indicate that acrylic co-polymer-based thickeners are not suitable for stab resistance applications due to the stiffness and rigidity they impart to the fabric which deteriorate the stab resistance performance. In contrast, an oil-water emulsion-based thickener maintains flexibility of the fabric coated with ceramic particles. While increased ceramic particle content enhances stab resistance, poor adhesion to the fabric creates a practical challenge. A comprehensive solution was developed, by strategically combining ceramic particles coated and STF impregnated p-aramid fabrics, which utilises the synergistic benefit of both approaches. When ceramic coated and STF impregnated fabric layers are placed at the strike face and rear side respectively, the fabric panel significantly outperforms its counterparts with individual treatments.

Keywords

Boron carbide; Ceramic; NIJ 0115.00; Kevlar, Shear thickening fluid; Stab resistance.

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Analysis of Impact Energy Absorption and Comfort Characteristics of 3D Knitted Fabrics Impregnated with Shear Thickening Fluid

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Some sports involve frequent collisions between the players, and between the player and the playing surface, leading to injuries such as muscular strains, dislocations, sprains, lacerations, fractures and soft tissue injuries. In some instances, these injuries are so severe that they may cause bone fracture or dislocation of joints [1]. In recent years, researchers are focusing on reducing these injuries by using protective gears and protective clothing to cover the torso, head, hands and legs. Protective padding is commonly used in many sporting activities to prevent impact related injuries [1, 2]. Shoulder pads made of closed cell foams are commercially available, but they are often discarded by the players due to their stiffness and discomfort. The closed cell foams have the capacity to absorb energy on impact and have proven to protect human body from injuries but they pose several challenges in terms of durability, dimensional stability and thermal comfort [3]. Spacer fabrics are three dimensional fabrics consisting of two separate fabric layers connected vertically with pile yarns. Due to their unique structure, spacer fabrics present excellent compressibility and high permeability as compared to conventional textiles. These fabrics recover easily with the body movement and provide a high level of comfort. 3D spacer knitted fabrics have shown promise for applications that require impact protection, relief of pressure and friction due to the resilience imparted by the connecting filaments and also help to maintain the integrity of the clothing assembly during an impact [2, 4].

In recent years, shear thickening fluids (STF) have gained the attention of researchers to use it as impact resistant material because of its excellent energy absorbing capability [5]. STF is a non-Newtonian fluid containing nanoparticles and a solvent. The particles used can be of various materials such as silicon oxide (SiO_2), calcium silicate and polymers (polystyrene, polymethyl methacrylate). The solvent used can be aqueous such as water with or without salt or polymer stabilized particles, organic such as polyethylene glycol, ethanol or silicon based such as silicon oils. The particles are suspended in solvent and should produce a fluid that has shear thickening property. A shear thickening fluid has Non- Newtonian flow behaviour which is often observed in concentrated colloidal dispersions which exhibit sudden increase in viscosity above a critical shear rate, which transforms a liquid dispersion into a material with solid like properties [6-9].

In this research, an attempt has been made to explore the potential of using STF infused flexible 3D spacer knitted structures to replace the currently used commercial foam for impact protection. 3D spacer knitted fabrics of different constructions were developed in flat bed knitting machine using nylon multifilament yarns of different denier as the surface yarn and nylon monofilaments of different diameter as spacer or pile yarn as shown in Table 1. Shear thickening fluid was prepared by dispersing fumed silica nanoparticles of different particle sizes in PEG-200 and PEG-400 as solvent. Polyethylene glycol (PEG) was selected due to the highest solubility of silica particles in it. The fluids were prepared at three levels of concentrations i.e. 20%, 25% and 30%. Fumed silica was first dried in oven at 100° for 2 hours to remove any moisture content. Silica was then added into PEG in small quantities (1g at a time) at regular intervals. Mixing was done using magnetic stirrer at about 1200 rpm for 12 hours. It was then subjected to ultrasonic vibration for 2 hours using a horn tip sonicator having a probe of 12 mm diameter.

Table 1: Construction of 3D spacer knitted fabric

Samplec code	*Outer layer yarn denier*	*Spacer yarn diameter (mm)*
S1	420	0.08
S2	420	0.12
S3	420	0.16
S4	350	0.08
S5	350	0.12
S6	350	0.16
S7	280	0.08
S8	280	0.12
S9	280	0.16

The rheological properties of all the fluids were measured in ARES-G2 rheometer with parallel plate geometry to know their shear thickening behaviour. The diameter of plate is 25 mm and the gap between two plates is set to 1 mm. The tests were performed at 25°. The fluids with the good shear thickening behaviour were selected for impregnation over 3D spacer knitted fabric. After preparing and selecting STF, it was diluted with ethanol at 1:3 (STF to ethanol ratio) to reduce the viscosity. 3D spacer knitted fabrics were dip coated into diluted STF in padding mangle. Wet fabrics were then squeezed using 2-roller mangle to remove excessive STF making sure that the amount of STF in the STF impregnated fabric is continuous. Finally, the impregnated fabrics were placed in oven heated to 80° for 8 hours for ethanol to volatilize. The STF infused 3D Spacer knitted fabric was then tested for thermo-physiological comfort properties like air permeability, thermal conductivity, water vapour permeability, compression and impact protective properties like puncture resistance, impact energy absorption, ball bursting strength. This study meticulously optimizes the incorporation process of STF on 3D-knitted fabrics. The outcomes of our research hold substantial promise for elevating both the comfort and efficiency of protective gear, offering athletes an advanced solution to mitigate impact-related risks, thereby nurturing their careers in the face of these challenges.

Acknowledgments

The author acknowledges the financial support received from the Ministry of Textiles, Govt. of India under National Technical Textile Mission (NTTM).

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Application of Mosquito Repellent Finish on Cotton Fabric

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The present study was undertaken to assess the effect of natural mosquito repellent agents on cotton fabric. Protective finishes are important as in the present scenario there is increased global competition in textiles which has created many challenges for the textile researchers and textile industries, therefore, there is a need for development of textile product which have a functionality of giving protection to the wearer. A mosquito repellent textile is one such textile product. For this purpose the present study was undertaken to evolve mosquito repellent textiles in order to advance the textile fields by providing the much needed features of driving away mosquito, etc. In the present study methanol extract of neem, eucalyptus, Chrysanthemum were prepared in different concentration. Then these extracts were applied on cotton fabric by using pad-dry-cure method, followed by mosquito repellent test on cotton fabric to assess the mosquito repellence of the above three extracts. Then the fabric was visually evaluated on the basis of color, textile and depth. Then finally the best sample which gave the maximum properties of mosquito repellence was tested for physical properties such as crease recovery, tensile strength, bending length. It was concluded that all the three extracts were suitable for application on cotton fabric for adding mosquito repellent properties but chrysanthemum gave the best result. Then also eucalyptus showed good results thus it can be said that above extract (chrysanthemum) can be used as a house hold finish for the application on textile substrate.

Keywords

Mosquito repellent, cotton, finishes, pad-dry-cure.

Aim of the Study

to develop mosquito repellent fabric for the house hold textile materials. To obtain this aim the study was undertaken through following objectives:

- To optimize the concentration of mosquito repellent finish to be applied
- To apply the formulated finishes on the fabric
- To study the finished fabric for mosquito repellent properties
- To study the finished fabric for its physical properties

Result & Discussion

It was observed that for chrysanthemum treated sample the knock down % and mortality was maximum in compared to neem and eucalyptus. For all three treated samples for (3 days), it was found that knock down % and mortality% was more compared to the treated sample with extract kept for (20 days). The samples treated with all three extracts (3 days) the result of chrysanthemum was found to be best. When all the three samples were visually evaluated for texture, color and evenness the chrysanthemum showed best result among other two. When stiffness was assessed for the selected sample (chrysanthemum treated) it was found that as the concentration increases the stiffness also increases in both directions. It was found that crease recovery of the chrysanthemum treated sample was found to be good in both warp and weft direction as compared to the controlled sample.

Conclusion

Apart from industrial use, mosquito repellent has become essential in day-to-day life to live to free from diseases and hygienic atmosphere. The results of this work show that the different extracts formulated for mosquito repellent finish, out of the three extracts chrysanthemum extract was found to have best mosquito repellent properties and so it can be successfully used on textile substrate. Although many synthetic products have come but natural products also hold good scope of future in the mosquito repellent industry to be used for house hold purposes.

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Development and Characterization of Hydrogel Infused Flame-retardant Fabric

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Hydrogels have many applications in agriculture, medicine, food, and textiles due to their unique properties. They are considered flame retardants for fabrics because of their high-water content, thermal stability, and ability to form protective barriers. These qualities make hydrogels suitable for protective clothing, home textiles, and automotive and aerospace applications. Water, which has a high heat capacity and enthalpy of vaporization, made up approximately 90% of the hydrogel. A significant quantity of heat energy is absorbed when the hydrogel is exposed to fire as water evaporates, thus quenching the flame. Moreover, the hydrogel network's ability to contract and expel water or other solutions at the volumetric phase transition point is unique. The main objective of this study is to develop flame-retardant cotton fabric coated with hydrogel using polyvinyl alcohol (PVA) and orthophosphoric acid (OPA). The OPA acting as a cross-linker and flame retardant for the cotton fabric is a distinctive aspect of this research. The cotton fabric was coated with PVA/OPA solutions of

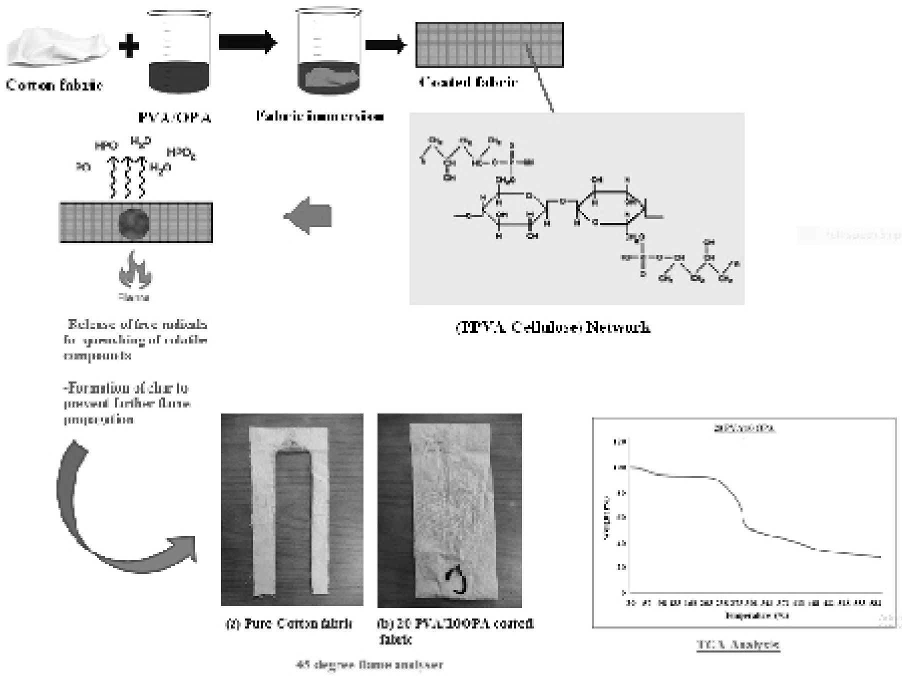

Figure 3: Coating process and characterization of coated fabric

varying concentrations and then subjected to tests for flame retardancy, swelling behaviour, tensile strength, tear strength, bending rigidity, and air permeability. In distilled water, the 20PVA/10OPA sample exhibited the highest swelling percentage (360%), indicating enhanced water absorption that prevents ignition by flame. This sample also demonstrated superior tensile and tear strength values compared to the other samples. Among all the samples, 20PVA/10OPA displayed the least bending rigidity, indicating flexibility and improved air permeability. Therefore, the developed 20PVA/10OPA sample, potentially a highly effective flame-retardant fabric, offers a bright future for flame retardant in textiles. Figure 1 provides an overview of the coating process and the coated fabric's characterization, highlighting the promising potential of this research.

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Evaluation of Tensile Failure and Energy at Break in Hybrid High-Performance Yarns

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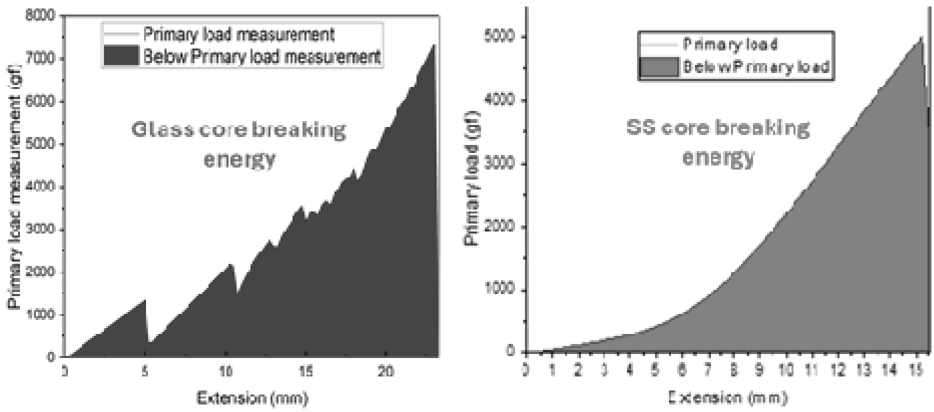
This research primarily examined the tensile failure behavior, and the energy required to break component yarns under applied tensile force. The study utilized stainless steel (SS) and glass yarn as core materials, with polyester yarn as the inner sheath layer and ultra-high molecular weight polyethylene (HPPE) as the outer sheath layer. The sheath layers were twisted in the same and alternate directions across different samples. Twelve samples were prepared following the sheath layer architecture in the hollow spindle spinning technique and underwent tensile strength performance. Tensile performance was assessed using an Instron 3365 universal tensile strength tester. Results indicated multiple cracking tendencies in glass-core hybrid yarns, while SS core yarns exhibited this phenomenon infrequently. A mathematical model was developed to address the challenge of measuring breaking energy with conventional equipment, achieving 92-97% accuracy. This model applies to any fabric or composite material where multiple cracking tendencies are observed.



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POSTER PAPERS

Alginate Based Sustainable Textile Fibre & Film and Their Application

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There has been growing interest in sustainable materials including textiles, mainly due to rising awareness regarding the negative environmental impacts of petroleum-based textiles. The process parameters and the pollution caused in the production of these petroleum-based fibres has opened new avenues for the biodegradable fibres that are produced from renewable resources like biomass. One such renewable biomass which is abundantly available and is yet to be exploited to its fullest potential is seaweed.

This research dwells on investigating on the synthesis of alginate fibres and films for medical, textile and other applications such as packaging. It also aims at characterising the properties of alginate-based films and fibres including tensile strength, diameter and thickness, degradation rate, water absorption and improving these properties by addition of co-deposits and other materials to make commercially viable end-use products.
As a part of this research, sodium alginate-based films were developed using different additives, namely, cotton fibres, gelatin, pectin and fructose. Glycerol is used as a plasticizer for these films. It is found that adding cotton fibres and pectin in sodium alginate improved the tensile strength of the film.

Figure 1: Sodium Alginate fibre with glycerol and fructose holding 1 Kg of weight

The films with gelatin have improved elongation and the films with fructose are smooth and have good flexibility as compared to alginate only films.

Likewise, fibres obtained by wet spinning of sodium alginate and fructose are found to be strong and have a smooth surface. As shown in the figure, a single fibre composes of sodium alginate, glycerol and fructose fibre hold1 kg of weight.

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Application of Ph-sensitive Red Cabbage Sourced Anthocyanins (Natural Pigment Dye) - For Baby Diaper

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Abstract

Previous studies have demonstrated that natural dyes possess properties that contribute to eco-friendly production, antimicrobial activity, sustainability, and colour change in response to factors such as temperature and p^H.

Concerning medical textiles- focusing on the category of baby care products, textiles currently used in this field often cause skin allergies such as rashes and boils and are chemically unsafe. Considering the positive potential outcome of natural dyes in other textile categories owing to their anti-microbial activity, a study was conducted using red cabbage as a proven natural dye source with healing properties. Anthocyanins, found in red cabbage, are crucial for the colour-changing ability of a natural dye due to their sensitivity top^H.

Table 1: Colour Change Analysis with varying p^H levels

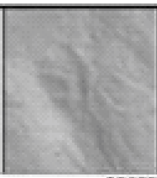
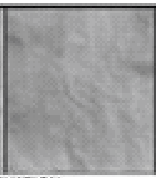
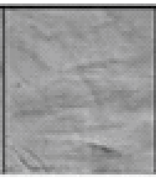
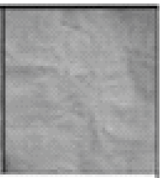
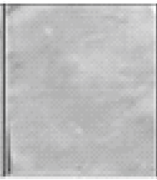
DYE SOURCE	MORDANT	pH 2 (ACIDIC - VINEGAR)	pH 5 (ACIDIC - VINEGAR)	pH 7 NEUTRAL	pH 10 (ALKALINE- BAKING SODA)
RED CABBAGE	SOYMILK				
OBSERVATION					
		LIGHT VIOLET COLOUR CHANGE	LIGHT VIOLET COLOUR CHANGE	VIOLET COLOUR CHANGE	LIGHT GREEN COLOUR CHANGE

Table 2: Observations recorded after the Soil Burial Test

DYE SOURCE	MORDANT	pH 2 (ACIDIC - VINEGAR)	pH 5 (ACIDIC - VINEGAR)	pH 7 NEUTRAL	pH 10 (ALKALINE-BAKING SODA)
RED CABBAGE	SOYMILK				
OBSERVATION					
		LIGHT BLUE COLOUR SLIGHTLY FADED	LIGHT BLUE COLOUR SLIGHTLY FADED	LIGHTBLUE COLOUR SLIGHTLY FADED	LIGHT BROWN COLOUR COMPLETELY FADED

During the study, the dye substrate (red cabbage) was analysed under different p^H conditions (vinegar for acidic conditions and baking soda for alkaline conditions). The resulting colour changes were recorded on cotton samples. Soy milk was used as a mordant. Samples under the four selected p^H categories (2,5,7,10) were put under the soil burial test for 10 days to check their anti-microbial activity evident through observation of colour change and degradation after the test.

Further, we have experimented with dyeing a pad made out of banana fibre with red cabbage as an alternative to the commercially-available harsh diapers.

It is observed that red cabbage dye is efficient under different p^H conditions and can resist microbial growth in medical textiles, such as baby diapers. Red cabbage has shown different colour shades indifferent p^H conditions via its indicator property and is a promising sample for further research.

Acknowledgments

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Initial study of red cabbage as a natural dye- Shalini Kumari, Amisha Sharma, Bhumika Roy, Ananya Goel, Divakar Singh

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Architectural Ornamentation of Kodandaramaswami Temple: From Historical Motifs to Digital Designs

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India has history of beautiful art and architecture. Indian architecture was influenced by the rulers of particular region. Andhra Pradesh is a state in India which has temples of Vijayanagara architectural style. The Rayalaseema region of Andhra Pradesh have many historical temples of Vijayanagra architectural style. The Kodandaramaswami temple is a good example of Vijayanagara architectural style. It is situated in Vontimitta village in Kadapa district of Andhra Pradesh. Vijayanagara style architecture is known for its carved pillars with mythological stories like Ramayana and Mahabharata and also flora and fauna. Kodandaramaswami temple is carved with the scenes of Ramayana, flora, fauna, devotees, geometrical motifs etc. The temple has a remarkable element Gopura (fig1) on the three sides (north, east, south). Some of the friezes are scenes of wedding of Rama and Sita (fig2) and read from right to left, scene of bulls and elephant fight in which two animals share one head (fig3). Ganga-Yamuna sculptures are carved on the entrances of the gopuras. These types of motifs were used in the handloom weaving of Dharmavaram sarees and Kanjeevaram sarees till now and mostly motifs are taken from the temple lepakshi in Hindupur, Ananthapur district of Andhra Pradesh. One of the craft from Andhra Pradesh named Kalamkari is also an example for temple inspired motifs and this craft extract motifs from Srikalahasti temple in Andhra Pradesh. As designers are experimenting crafts and designs, these crafts are also been experimented in various motifs like abstract, contemporary and geometrical motifs. Temple motifs should be preserved as they carry the significance and cultural heritage of the region. The objective of the paper is to extract the motifs from the Kodandaramaswami temple and digitalize the motifs. This paper contains the sources of knowledge and experience in the art of temple ornamentation. The ornamentation on the temple have been chosen as the resources for developing motifs and patterns. Using descriptive analytical method of approach, this research aims to identify the unique characteristics of the Kodandaramaswami temple as a source of knowledge and inspiration and to perform experimental studies in order to develop new motifs. This research is done to explore the ornamentation and sculptures of Kodandaramaswami temple. Initially motifs were drawn manually and were judged by the judges. Later on, the selected motifs were adapted on Adobe Illustrator and Adobe Photoshop. The outcome of the motifs developed were appreciated by the judges. These motifs can be used on textiles, apparels through various printing techniques. The main Purpose of the study is to document the historical significance of the Kodanadaramaswami temple and extraction of motifs from the ornamentation of the temple.

Keywords

Digital design, Kodanadaramaswami temple, Motifs, Ornamentation, Vijayanagara architectural style.

Figure 1. Gopura of Kodandaramaswami Temple

Figure 2. Scenes of wedding of Rama and Sita

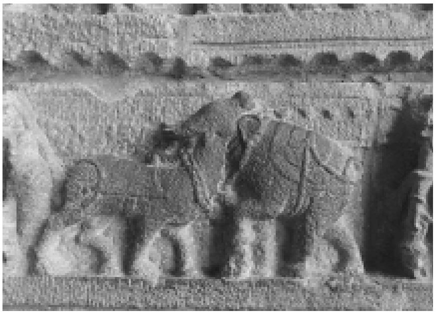

Figure 3. Bull and Elephant fight in which animals share one head

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Bio Preparation of Jute Using Waste Potato Peel

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Jute is comparatively hard and brittle in its raw state. Due to its scaly and stiff surface, it is used for gunny bags, ropes, mats, carpet backing, etc., but not much for apparel. Efforts are made to soften or descale jute to make it breathable and comfortable, increasing its end-use value. Potato peels, a waste product of the food industry, are being processed to produce enzymes in the biotech industry. This research aims to optimize the fermentation process of waste potato skin for maximum enzyme activity and assess its impact on the physical properties of jute fabric as a preparatory process before dyeing and printing. In the present study, a liquor was made using potato peel waste in different concentrations (10, 20 and 30%) and left for fermentation in ambient conditions for a certain number of days. The fermented solution was used to treat raw jute fabric under both static and agitation conditions. The treated samples were eventually checked for surface defibrillation by calculating weight loss, absorbency, bending length, and SEM analyses. An enzyme assay was also performed to assess enzymatic activity.

The results indicate that the absorbency of the jute fabric improved significantly after treatment with fermented potato peel liquors. Weight loss was observed in most samples, indicating the removal of impurities and fibrils. On days 5 and 7, samples treated with the agitation method for 60 minutes at 30% concentration showed a significantly greater reduction in bending length. The surface morphology of jute fibers reveals that the treated sample is cleaner and smoother. Additionally, the dye uptake of the samples improved, as intense colors were seen in the samples treated with fermented liquors. Amylase, cellulase, and protease activity were detected in the fermented broth. This study concludes that using potato peel waste is a one-stop solution for cleaning and smoothing jute. The weight loss of 6-8% could be due to the removal of hemicellulose, pectin, or lignin, or the removal of impurities or microfibrils, indicating a combination of scouring and biopolishing. The introduction of a simple and inexpensive process using potato peel waste can be a viable solution for cottage industries, serving as a sustainable alternative to chemical scouring and biopolishing, which use expensive enzymes.

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'Closing The Loop;' Kantha, from Need to Luxury

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When we use the present resources to meet needs without negating the ability of the future generation to meet the needs, thereby attaining an equilibrium, leads to sustainability. Thoughtfully contemporizing coexistence, developing and achieving economic and social growth. Circularity is metaphorically an offspring of sustainability, a crucial concept defining the practices that lead to sustainability. Immersing deeper, a circular economy would be one of severalizing growth from adverse spill-over effects by fabricating on the 3 prime principles; viz, fashioning out waste, recycling products and materials and restoring regenerating source systems. India's textile heritage, a rich drapery of culture, mood, values, and lifestyles, notorious for its archaic techniques and intricacies, is a testament to enduring sustainability and circularity, even before this was a concept. Stretching from the classical Harappan civilization to contemporary practices, Indian crafts and craftsmanship set forth the story of continuously embracing principles of resource efficiency and biological equilibrium. Plunging into how traditional Indian textiles, with their characteristic weaving methods, complex designs, and innovative use of local materials, display an engraved commitment to circular practices. How the Indian textile crafts thrive through historical disarray and evolving cultural landscapes highlights their significance and undeniable resilience. Kantha: A Quintessential Example of 'closing the loop', has followed the principles of circularity ever since. 'Closing the loop' means returning to the source without hampering the ecological balance. As a traditional embroidery technique from Bengal, Kantha imbibes sustainable and circular fashion practices deeply rooted in cultural heritage. Paving its roots in rural communities, Kantha evolved from the artful stitching of old or discarded fabric pieces to creative, vibrant, textured textiles. This technique reflects reimagined resourcefulness and includes principles of environmental harmony and circularity. It has existed as a circular craft. The foundation lies in its use of recycled materials. The Kantha protagonists repurpose/upcycle threadbare garments, frayed saree fabric, and miscellaneous textiles, breathing new life into these pieces through diligent hand-stitching. This innovative effort shrinks waste and brings down the need for fresh resources, aligning with contemporary sustainability objectives. Kantha is also known as the running-stitch, and it continuously finds its place in modern age designs.

Research Objectives

- To evaluate and discover the relativity between traditional Indian crafts and modern sustainability goals.
- To understand circularity in design, emerging as a thoughtful innovation in Kantha.
- To discover the potential space for Kantha as a craft in Luxury design segment.

Findings

Kantha as a craft is intrinsically circular and has already positioned itself in the modern age design expectations for the mass market. Intertwining kantha with the present design silhouettes has restored the value of existing craftsmanship. We understand that there lies a huge scope to explore the amalgamation of Kantha into occupying the luxury design space with innovations and an edge. The modern era high couture designers often inculcate running stitch (Kantha) in the collection, however, have not been able to give Kantha its due identity.

Conclusion

"Closing the loop": The circularity of Kantha is spoken in volumes in its process. Repurposing and remodelling scrap fabrics into new, functional items, Kantha silhouettes a circular style, restoring materials for extended times. The technique expands the life cycle of textiles and paves the route to the concept of 'closing the loop' in fashion. Owing to its sturdiness, Kantha's has remained relevant through generations and its employment can be seen in today's high couture fashion as well. Positioning itself among the modern fashion trends, Kantha as a sustainable technique has emerged as adaptable and sought-after as a craft in the modern age. This versatility exhibits how historical crafts can evolve and remain relevant in today's sustainable fashion landscape. Kantha can attain high signatures in the avant-garde fashion as well.

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Colour and Craft: Presenting the Rich Hues of Madhya Pradesh's Woven Sarees

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Textiles with vibrant colours and prints have been associated with the Asian continent and more so with the traditional Indian craftspeople. Colour appears to be the primary element of design in manufacturing traditional Indian textiles, separating them from the rest of the world. In this study, we investigate the relationship between colour and Indian traditional textiles, with a special emphasis on the timeless design approach seen in Madhya Pradesh sarees. Indian traditional textiles have a deep-rooted regional and cultural significance. However, these crafts face both challenges which can be converted into opportunities through colour trend forecasting. The traditional textiles in India are uniquely placed in considering their colour palette and styling, most of the textile pieces adapt organically to the prevalent fashion, drape, or colour trends. An exploratory methodology is adopted which includes qualitative interviews with saree weavers and case studies of woven sarees from Madhya Pradesh. A survey will be conducted to evaluate how craftspeople blend cultural preservation with global market preferences. The survey will gather input from consumers, and craftspeople, to understand their colour preferences and acceptance of season-less/classic designs in sarees and their product diversification as dupattas and stoles.

The objectives of the study are as mentioned below:

1. To explore the relationship between color and design in traditional Indian textiles, with a focus on Madhya Pradesh sarees, and how these elements contribute to their timeless appeal.
2. To understand the role of color in maintaining the cultural significance of traditional textiles while adapting to modern fashion needs.
3. To explore the potential of seasonless designs as a sustainable approach to preserving traditional Indian crafts while enhancing their relevance and appeal in the global market.

This will help to understand can seasonless designs provide a sustainable alternative to quick fashion while also retaining the cultural significance of traditional textiles. This study investigates the use of modern colour with the rich heritage of traditional crafts to maintain their relevance in the global market. The scope of research and its results will offer practical insights into how traditional Indian textiles can evolve with modern fashion needs.

Figure 1. Researcher with Waraseoni, Madhya Pradesh saree weaving cluster

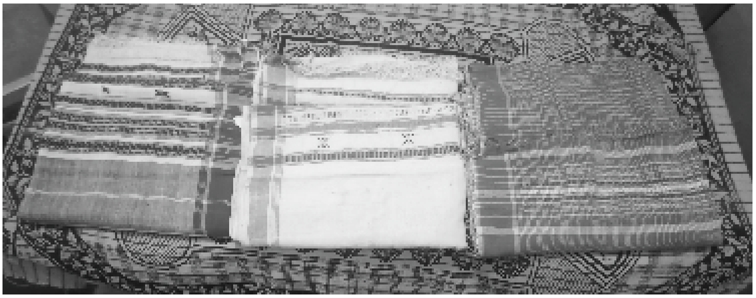

Figure 2. Traditional Baiga Sarees from Dindori, Madhya Pradesh

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Cultural Sensitivity Guidelines for Global Luxury Fashion Brand Communications Targeting Chinese Generation Z and Millennials

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Introduction

This paper will address the *'Innovation in Fashion'* topic from a cultural point of view by exploring how global luxury fashion brands can leverage culture awareness to achieve culturally sensitive communication strategies with respect to local cultures. The study focuses on the global luxury fashion brands, since they operate in a diverse market [1]. Moreover, post pandemic, global luxury fashion brands became more influenced by cultures and local communities [2]. It was observed that global luxury fashion brands have often taken inspiration from local cultures in order to connect with their consumers. Nevertheless, cultural appropriation and insensitivity have always been an underlying issue in the industry. Cultural appropriation and insensitivity not only led to loss of sales and boycott of the brands, but also resulted in the loss of loyalty and reputation [3]. Hence, there has been a growing demand for culturally sensitive branding campaigns, driven by a diverse customer base who are highly aware about social issues around the world. This research will concentrate on the Chinese market, since it is considered the biggest market for all luxury brands. The Chinese market tripled in size between 2017 and 2021. Although it has been decreasing slightly due to the pandemic and economic issues [4], the Chinese market recovered rapidly and showed a strong growth in 2020-2022 [5]. The aim of this research is to develop a brand communication guideline for global luxury fashion brands targeting Gen Z and Millennials in China to help them create successful communication strategies that reflect and respect Chinese cultures.

Methodology

The research would be divided into three stages: 1) Discover, 2) Define) and 3) Develop and Deliver. Literature review was employed in the first stage to gain a better understanding of the relevant theories in the fields of brand communication strategies, design thinking, human centred design principles and culture sensitivity which are related to the research topic. Six case studies (e.g., Burberry's Lunar Year Campaign) were used in the second stage to examine both successful and unsuccessful cultural campaigns launched by global luxury brands across various sectors. The third stage included six expert interviews and a questionnaire survey with Generation Z and Millennials (90 respondents in total), who are the main target audience of global luxury fashion brands in China. The former was employed to gain in-depth knowledge from experts who have a wealth of experience and the relevant know-how in the field of fashion and the latter was used to understand different perceptions of consumers and get an idea of how cultural branding plays an impact on the customers. This method helps the research gather data regarding attitudes, behaviours, opinions and demographics from a diverse population. It also enabled the researcher to identify patterns, trends, and correlations within the data set.

Principal Findings

Findings from primary and secondary research suggest that the global market nowadays prioritises **cultural sensitivity** and **awareness.** This can be achieved by deeply engaging with cultural differences and emphasising respect and authenticity. **Co-creation** and **collaboration** with cultural insiders and experts can help global luxury fashion brands ensure that their communication campaigns are rooted in genuine understanding. **Inclusivity** has become essential, especially as modern consumers, particularly Millennials and Gen Z, value diversity and cultural relevance over exclusivity. Global luxury fashion brands need to ensure authentic cultural representation, steer clear from mistakes that could potentially damage trust, and foster long-term loyalty. Appropriate use of **semiotics** and **symbols** is essential, as it allows brand narratives or messages to resonate with diverse audiences without reinforcing harmful stereotypes. By collaborating with **local artists** and **communities**, global luxury fashion brands can co-create experiences that are meaningful and culturally relevant, which can enhance inclusivity and strengthen the connection with Chinese consumers.

Recommendations

Based on the findings discussed above, the researcher proposed the *"4Cs"* framework (see Figure 1) including: 1) Co-Creation, 2) Conscientiousness, 3) Culture Sensitivity, and 4) Credibility. This framework aims to provide global luxury fashion brands with a strategic approach to design campaigns that respect cultural heritage, avoid misrepresentation and foster genuine connections with diverse communities in China. The details of each components as shown below:

- ***Co-Creation:*** Collaborating with local artists, designers, and cultural consultants
- ***Conscientiousness:*** Conducting thorough research into the cultural, social, and historical context; and respecting cultural symbols, traditions, and practices while being mindful.
- ***Clarity:*** Transparent communication about the design process, publicly acknowledging contributions from designers and cultural consultants.
- ***Credibility:*** Brands can build credibility by sharing real stories and involving authentic voices from the culture they aim to represent.

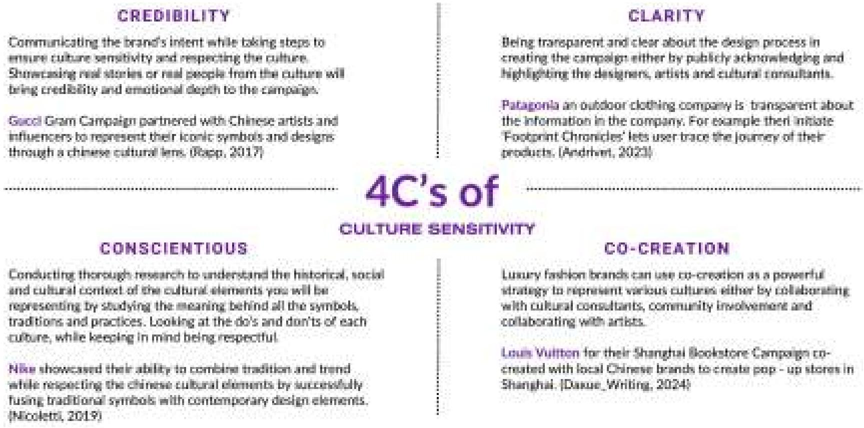

Figure 1: The 4Cs framework

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Design Innovations in Post-Workout Apparel: Addressing Common Recovery Challenges

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This research addresses the common discomforts and recovery challenges faced by individuals with demanding schedules, such as working professionals and college students, who often struggle to find sufficient time for recovery after intense physical activity. Most existing sportswear garments fall short of effectively supporting muscle recovery, regulating body temperature, and providing mental relaxation after activities. This project aims to develop an innovative post-workout garment that integrates features to alleviate these issues, offering a solution designed to enhance the overall post-exercise experience through advanced recovery technology and superior comfort. The development process involves creating and testing prototypes with fitness enthusiasts to ensure their effectiveness and practicality. The garments feature relaxed silhouettes, strategically placed compression pads, temperature-regulating fabrics, and integrated scent technology to aid in muscle recovery and mental relaxation. These elements are meticulously tested to evaluate their performance in real-world scenarios, with feedback guiding refinements to optimize the garment's functionality and comfort. Advanced fabric technologies are key to addressing post-exercise discomforts and supporting effective recovery. The anticipated outcome of this research is introducing a new category of sportswear that bridges the gap between fitness apparel and recovery wear. By addressing key challenges such as inadequate recovery time and post-exercise discomfort, the project aims to set a new standard in post-workout clothing design. At an early stage of development, with plans for wider testing and market expansion, this research seeks to provide a practical, multifunctional solution that meets the needs of athletes and fitness enthusiasts, paving the way for future advancements in sportswear.

Acknowledgement

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Designing Clothing that Empowers: Adaptive Wear for Visually Impaired High School Students

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Eyes are our windows to the world, allowing us to perceive, navigate, and engage with our surroundings. For visually impaired high school students, however, the world presents daily challenges that sighted individuals might take for granted—one of the most significant being the simple act of getting dressed, which can deeply impact their autonomy and self-esteem. Traditional clothing designs often fail to meet the specific needs of visually impaired individuals, which could potentially lead to frustration and dependence on others. This research, grounded in a human centric design approach, aimed to identify the primary challenges faced by visually impaired high school students during the dressing process and develop a framework to guide the design of adaptive clothing solutions. The methodology involved gathering insights from key stakeholders through unstructured interviews conducted at the Hellen Keller Institute for Deaf and Deafblind in Mumbai. Participants included four visually impaired students, five teachers, and one caretaker. This approach helped uncover the underlying desires and needs of the participants. A literature review was conducted to analyze existing research on adaptive clothing for visually impaired individuals, identifying gaps and best practices. Key findings revealed that color identification and matching are significant challenges. Preferences for loose-fitting, trendy, and comfortable styles were also noted, along with a desire for simple, intuitive designs. These insights informed the development of innovative design elements aimed at enhancing the dressing experience for visually impaired students, focusing on solutions that engage multiple senses and offer tactile feedback. A new design framework, VOWEL, was developed to guide designers in creating adaptive clothing. Just as vowels are fundamental to word formation, the VOWEL framework emphasizes the essential elements of Accessible, Empowering, Inclusive, Optimized, and Usable design, offering a structured approach to address the needs of visually impaired individuals. By addressing the unique challenges faced by visually impaired high school students, these adaptive clothing solutions go beyond mere functionality—they empower individuals to reclaim their independence and enhance their daily lives. The thoughtful integration of sensory cues and intuitive design elements ensures that visually impaired individuals can dress with confidence and ease. Ultimately, these innovations contribute to a more inclusive and accessible environment for all, fostering a society where everyone, regardless of their abilities, can participate fully and with dignity.

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Digital Threads: Revolutionizing Fashion through Virtual and Augmented Reality

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The emergence of digital fashion marks a transformative shift in the apparel industry, where the integration of virtual and augmented reality (VR/AR) technologies is redefining design, production, and consumer interaction. This paper explores the evolution of digital fashion, examining how virtual garments and accessories are created, showcased, and consumed in digital environments. It delves into the implications of digital fashion on sustainability, brand identity, and consumer behavior, while also addressing the technical challenges and opportunities in developing immersive fashion experiences. The study provides a comprehensive overview of the current state of digital fashion, its potential to disrupt traditional fashion paradigms, and its future trajectory in a rapidly evolving technological landscape.

Keywords

Digital Fashion, Virtual Reality, Augmented Reality, Fashion Technology, Virtual Garments, Sustainability in Fashion, Consumer Behavior, Brand Identity, Immersive Experiences, Fashion Innovation

Introduction

The fashion industry is undergoing a significant transformation driven by technological advancements, particularly in the realm of digital fashion. As the lines between the physical and virtual worlds blur, fashion is no longer confined to tangible fabrics and materials. Instead, it extends into the digital space, where virtual garments, augmented reality (AR) experiences, and immersive fashion environments are becoming increasingly prevalent. This paper seeks to explore the innovative domain of digital fashion, analyzing its impact on traditional fashion paradigms and the broader implications for the industry.

Background

The concept of digital fashion has been catalyzed by the rapid growth of virtual and augmented reality technologies. Initially emerging as a niche trend, digital fashion has evolved into a mainstream phenomenon, driven by the demand for sustainable practices, the influence of social media, and the rise of virtual worlds like the metaverse. As consumers increasingly seek personalized and interactive experiences, digital fashion offers a unique opportunity to meet these demands while also addressing environmental concerns associated with traditional fashion production.

Problem Statement

Despite the growing interest in digital fashion, there is still a lack of comprehensive understanding of its full potential and the challenges it poses. The integration of digital technologies in fashion design, production, and marketing raises questions about authenticity, intellectual property, consumer acceptance, and the sustainability of digital garments. Furthermore, the technical limitations and high costs associated with developing digital fashion experiences present significant barriers to widespread adoption.

Aim

The aim of this study is to critically assess the current state of digital fashion, exploring its impact on the fashion industry, consumer behavior, and sustainability. The research seeks to identify the key drivers of digital fashion adoption and to evaluate the potential of virtual and augmented reality technologies in shaping the future of fashion.

Objectives

- To analyze the evolution of digital fashion and its integration into the fashion industry.
- To investigate the impact of digital fashion on consumer behavior and brand identity.
- To assess the sustainability implications of digital fashion compared to traditional fashion.
- To explore the technical challenges and opportunities in developing digital fashion experiences.
- To propose strategies for overcoming barriers to the adoption of digital fashion.

Design Theory: The design theory underpinning this study is rooted in the intersection of fashion design, technology, and consumer psychology. By examining how digital tools and platforms are transforming the creative process, the study explores the implications of this shift on fashion aesthetics, production methods, and consumer engagement. The theory also considers the role of digital fashion in fostering sustainability by reducing waste and promoting more efficient production cycles.

Literature Review: Virtual reality (VR) and augmented reality (AR) are revolutionizing the fashion industry, offering new ways to interact with digital information and transforming how we perceive and engage with clothing (Yin et al., 2021)These technologies are creating immersive experiences that powerfully engage users in ways no other medium can, allowing for innovative applications in fashion design, retail, and consumer experiences (Memarsadeghi & Varshney, 2020).

In the realm of digital fashion, computer technology is used to simulate the visual representation and physical properties of clothing textures (Guo & Hou, 2022). This has led to the development of virtual clothing and digital fashion, which are exploring innovative directions to revolutionize the virtual experience. These technologies rely on virtual apparel design systems that provide designers with convenient 3D virtual interaction platforms, greatly improving efficiency in the design process (Guo & Hou, 2022). The integration of AR and VR in the fashion industry has significant implications for retail experiences. A study exploring the barriers and enablers influencing consumer adoption of virtual try-on (AR) and 3D virtual stores (VR) found four key factors: consumption vision, interactivity, enjoyment, and novelty (PARK & Kim, 2022) These technologies have the potential to enhance the shopping experience by allowing customers to virtually try on clothes or explore immersive 3D store environments. In conclusion, digital threads are indeed revolutionizing the fashion industry through VR and AR technologies. From design and prototyping to retail experiences and consumer engagement, these immersive technologies are transforming how fashion is created, presented, and consumed. As hardware evolves and integration improves, the impact of AR and VR in fashion will continue to grow, offering new possibilities for creativity, personalization, and interactive experiences in the digital age.

Research Methodology

This study employs a mixed-methods approach to provide a comprehensive analysis of digital fashion, integrating both qualitative and quantitative research techniques. The methodology is designed to explore the multifaceted nature of digital fashion, encompassing industry practices, consumer behavior, and sustainability implications. The research methodology is structured into four key phases: literature review, qualitative data collection, quantitative data collection, and data analysis.

1. **Research Design**

   The research is structured in three phases:

   1. **Literature Review**: A thorough review of existing literature is conducted to establish a theoretical framework for the study.
   2. **Case Studies**: Detailed case studies of leading fashion brands and designers who have adopted innovative practices are developed.
   3. **Empirical Analysis**: Quantitative data is collected through surveys and interviews with industry experts, designers, and consumers.

2. **Data Collection Methods**

   a. **Literature Review**
      - **Sources**: The literature review includes scholarly articles, industry publications, white papers, and relevant case studies.
      - **Scope**: The review focuses on innovations in fashion design processes, material technology, and sustainable practices, identifying key trends, challenges, and opportunities.

   b. **Case Studies**
      - **Selection Criteria**: The case studies are selected based on the prominence of the brands or designers in adopting innovative practices and their impact on the industry.
      - **Data Collection**: Data for case studies is gathered from public sources, including company reports, interviews, press releases, and industry analyses.
      - **Analysis**: Thematic analysis is used to identify common patterns, strategies, and outcomes across different case studies.

   Surveys and Interviews
   - **Survey Design**: A structured survey is designed to gather quantitative data from a broad sample of industry professionals and consumers.
   - **Interviews**: Semi-structured interviews are conducted with industry experts, including designers, technologists, sustainability officers, and policymakers.
   - **Sample Size**: The survey targets a sample of 200 respondents, while 20 in-depth interviews are conducted with selected experts.

3. **Data Analysis**

   a. **Thematic Analysis**: Thematic analysis is applied to qualitative data from the case studies and interviews. This method identifies key themes, patterns, and insights that emerge from the data,

   b. **Quantitative Analysis**: Quantitative data from the surveys is analyzed using statistical methods, including descriptive statistics and regression analysis

   c. **Comparative Analysis**: A comparative analysis is conducted across different case studies to identify common factors that contribute to successful adoption of innovations.

4. **Validity and Reliability**
   a. **Triangulation**: The study employs triangulation by using multiple data sources and methods to ensure the validity of the findings.
   b. **Reliability**: To enhance reliability, the survey and interview instruments are pre-tested and refined based on feedback.

5. **Ethical Considerations:** Informed consent is obtained from all interview participants, and data confidentiality is maintained.

This methodological approach provides a comprehensive and rigorous analysis of innovation in the fashion industry, enabling a deeper understanding of how emerging technologies and sustainable practices are shaping the future of fashion.

Data Analysis: The data analysis for this study on digital fashion is conducted in two primary phases: qualitative data analysis and quantitative data analysis. Each phase is designed to address the research objectives and to provide a comprehensive understanding of the key factors influencing digital fashion's development, adoption, and impact on the fashion industry.

Qualitative Data Analysis

- **Thematic Analysis of Interviews** The qualitative data, gathered through in-depth interviews with industry professionals and consumers, is analyzed using thematic analysis.
- Familiarization with Data The first step involves transcribing the interview recordings and immersing in the data by reading through the transcripts multiple times
- Coding Initial codes are generated to label significant statements or concepts in the data. These codes are applied to segments of the text that relate to the research objectives, such as attitudes toward digital fashion, perceived benefits and drawbacks, technological challenges, and sustainability considerations.
- Theme Development The codes are then grouped into broader themes that capture the underlying patterns in the data. For example, codes related to "consumer engagement" and "brand loyalty" might be combined under the theme "Consumer Interaction with Digital Fashion."
- Reviewing and Refining Themes The identified themes are reviewed and refined to ensure they accurately reflect the data. This step involves comparing themes across different interviews to check for consistency and coherence.
- Defining and Naming Themes Each theme is then clearly defined and named, providing a concise summary of what the theme represents and how it relates to the research questions. For example, the theme "Technological Barriers" might encompass challenges like the high cost of digital fashion tools
- Interpretation and Reporting The final step involve interpreting the themes in the context of the research questions and objectives. The themes are presented in a narrative format, supported by direct quotes from the interviewees to illustrate key points.

Quantitative Data Analysis

Descriptive Statistics: The quantitative data, collected through surveys, is first analyzed using descriptive statistics to summarize the basic features of the data. This includes measures of central tendency (mean, median) and dispersion (standard deviation, range) for key variables, such as:

- Demographic Information: Age, gender, location, and other relevant demographic details of the respondents.
- Consumer Attitudes: Levels of interest in digital fashion, willingness to purchase digital garments, and perceptions of digital fashion's sustainability.
- Technology Adoption: Familiarity with digital fashion technologies, frequency of use, and perceived ease of use.

These descriptive statistics provide an overview of the sample population and set the stage for more complex analyses.

Results

The results of the data analysis are presented in the study's findings and discussion sections. Tables, charts, and graphs are used to visually represent the quantitative data, making it easier to understand and interpret. The qualitative findings are presented through thematic narratives supported by quotes, offering a rich, detailed account of the digital fashion landscape. Together, these results contribute to a deeper understanding of how digital fashion is reshaping the fashion industry and its implications for the future.

Conclusion

The data analysis methodology employed in this study ensures a thorough examination of the digital fashion phenomenon from multiple perspectives. By integrating qualitative and quantitative data, the study provides a nuanced understanding of the drivers, barriers, and opportunities in digital fashion, offering valuable insights for both academia and industry.

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Effect of Selecting Natural Mordants for Dyeing Silk Fabric with (Beta Vulgaris) Beetroot Peel

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The regeneration of natural dyes to solve environmental issues relating to synthetic dyes is the focus of this research. Natural dyes that are extracted from plants animals, and minerals have been in use for centuries but later they were replaced by synthetic dyes after they were discovered to produce vivid intense colours and were also durable. However, there has been a problem of high wastage and environmental pollution from synthetic dyes, which has led to a revived focus on natural dyes. This research can help to prevent wastage of valuable natural resources and promote the usage of environmentally friendly products in conforming to evolved global trends in resource utilization and also examines extraction, characterization, and application of Beta Vulgaris (beetroot peel), which is normally thrown away, as a natural dye for processing silk fabrics. Research objectives is to enhance the extraction process, identify appropriate natural mordants, investigate mordanting methods, and assess the physical and color fastness characteristics of the natural dye-washed fabrics.

Keywords

Eco-friendly Dyeing, Sustainable Practices, Mordants, Color Fastness, Environmental Impact

Introduction

The textile industry widely uses synthetic dye for the coloring of fabrics and finished products with 90% of garments normally dyed in this manner. It is worth noticing that 735,000 tons of 10,000 synthetic dyes and pigments are produced every year. This is dangerous in several ways because most synthetic fabric dyes are derived from petroleum while several of the dyes contain toxic or carcinogenic materials [1]. Therefore, as a result of the effects the synthetic dyes have on the environment and human health, natural dyes are gradually being adopted. These natural dyes derived from plants, animals, and minerals are environmentally friendly since they are biodegradable, non-toxic and less prone to cause allergy. This is because many customers nowadays embrace the use of natural dyes since they produce exquisite and pastel shades and are eco-friendly and environmentally sensitive [2].

Textile dyeing involves complex interactions between dye molecules and fabric fibers. Many natural dyes need mordant or water-soluble metal salts to form a complex with fibers, which makes the colors more vibrant and long-lasting. While some natural dyes are substantive and do not need mordants, many rely on these agents for optimal color intensity and stability. Research continues to refine mordanting techniques, crucial for achieving vibrant, long-lasting colors while supporting sustainable practices [3].

Source and Methods

This research optimized the dye extraction process from Beta Vulgaris peel and selected various natural mordants, including alum, Aloe Vera, and Myrobalan. Pre-mordanting, post-mordanting, and simultaneous mordanting techniques were applied to dye silk fabrics. The dyed fabrics were then evaluated for their physical and color fastness properties.

Selection and Pre-treated fabric: Silk fabric was chosen for its lustrous appearance, smooth texture, and excellent dye absorbency, due to its protein fibers. The degumming process removed sericin from silk fabric using a soap solution, heated to 70°C over 45 minutes. After that silk fabric was rinsed, squeezed, and dried in the shade.

Selection and Dye extraction from Source: Beetroot was chosen for its colorant properties, particularly its vitamin C content, which imparts a pinkish-red hue. The vibrant red shade of beetroot peel made it ideal for dyeing silk fabric. Beetroot peels were cleansed, shade-dried, and ground into a paste. The paste was filtered to obtain dye extract, which was stored in sterilized glass containers and refrigerated for future use.

Selection and extraction of natural mordants: Aloe vera gel, myrobalan powder, and alum were selected for mordanting. Aloe vera gel, tannin-rich myrobalan, and potassium alum were extracted and prepared for direct use in mordanting.

Mordanting Techniques: Pre-mordanting, simultaneous mordanting, and post-mordanting were performed using soaking and boiling methods.

Evaluation

The physical properties and mechanical properties of the fabric were tested using thickness test, weight test and stiffness test. Colour fastness of the fabric was tested using dry and wet crocking, light and washing test.

Results

The research demonstrated that Beta Vulgaris peel is an effective natural dye, producing a range of pink, purple, peach, and grey hues. The use of different mordants and dyeing techniques resulted in varied color outcomes, confirming its versatility for textile applications with good fastness properties. Additionally, the study assessed the physical properties of silk fabrics pre- and post-treatment. Results indicated a slight decrease in thickness after degumming, alongside a more significant reduction in fabric weight. Stiffness measurements showed a consistent increase in the weft direction, while the warp direction remained unchanged. Furthermore, color fastness properties were notably improved when using Alum as a mordant and the simultaneous mordanting technique with the soaking method.

Conclusion

The study emphasizes the use of waste materials like Beta Vulgaris peel to enhance sustainability in dyeing while improving textile aesthetics. By refining extraction methods and exploring natural mordants, it advocates for eco-friendly dyeing alternatives to mitigate synthetic dye environmental issues.

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Embroidered Legacy: Documentation and Revival of Bishnoi Shawls from Rajasthan

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Rajasthan has a rich diversity of intangible cultural heritage, some of which has survived despite rapid urban expansion. The rapid urbanisation, westernisation has affected the traditional crafts in myriad ways, more so with skilled, time consuming crafts like the embroideries in indirect ways within the state. From the accessible data, it can be inferred that both the domestic and commercial embroideries survived in the numerous styles such as *Mochi-bharat*, Sindhi embroidery, Meghwal embroidery, *Sufbharat*, *Kharak, Pakko* embroidery which were used to ornament their own household textiles and costumes. Amongst the different articles adorned, the embroidered shawls of Bishnoi community enjoyed a prime status in the Thar desert region of the Rajasthan. The combinations of various styles of embroideries were used to fabricate the rare *chopata* layout in the shawls. The glimpse of traditional tie-dyed *bandhani* was also seen combined with the embroidered styles with native motifs of flowers, camels, peacocks etc. In contemporary times, the survival of this embroidered craft is under considerable threat, resulting in a lack of historical records concerning the origin of the Bishnoi shawls. Consequently, this research aims to systematically document Bishnoi embroidered shawls, establishing a comprehensive database to aid in the preservation of the region's crafts. The study also seeks to revive this endangered heritage by enhancing its social, cultural, and economic significance through a structured training program designed to enrich the skills of local artisans. Given the descriptive and exploratory nature of this research, both primary and secondary data were collected. The study was conducted in two phases. The first phase involved data collection and analysis, where an examination of antique Bishnoi shawls was conducted alongside semi-structured interviews with members of the Bishnoi women community. The second phase focused on the implementation of a structured training program designed for women artisans skilled in embroidery in the Barmer district of Rajasthan. Antique samples collected from various collectors were analysed based on motifs, design layouts, color combinations stitch type and length. The Bishnoi shawls were found to share elements with other embroidery styles from northwestern India. The research revealed that these shawls were predominantly used in Rajasthan's western region. The arrival of embroidery in this area is attributed to the migration of Indo-Aryans and Indo-Scythians from Central Asia, who became known as the Jat community and later as Bishnoi. The fundamental embroidery technique of Thar shawls involves counting the warp and weft threads of a coarsely woven base cloth, resulting in geometric designs with dense embroidery stitches that cover the base fabric. Influenced by neighbouring regions, the common stitches identified include *soof*, phulkari, *kharek,* and *kambiri,* which utilize herringbone, buttonhole, double running, running, darning, satin, and chain stitches. Through the structured training program, participants were educated on Bishnoi embroidery craft, color appropriateness, layout concepts, and marketing strategies. This approach successfully revived the nearly extinct craft, providing women artisans with opportunities to earn from their traditional skills and heritage. The revival efforts focused on preserving traditional techniques and motifs while adapting layouts and color combinations to align with contemporary market.

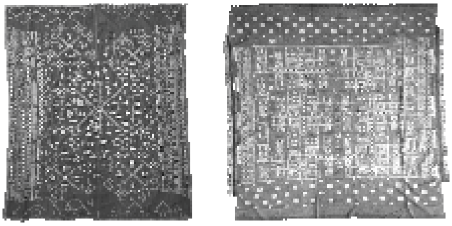

Figure 1. Traditional embroidered Bishnoi Shawls of Rajasthantrends, thereby offering artisans new avenues for income and creative expression.

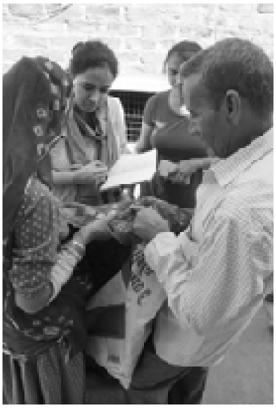

Figure 2. Researcher with Bishnoi community women and antique collector

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Enhancing Surface Properties and Pulverisation of Coir and Banana Fibres through Chemical Treatment and Ball Milling

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The study explored the influence of chemical treatment on the properties of natural fibres, specifically focusing on coir and banana fibres, followed by their pulverisation. The objective of the study is to improve the properties of lignocellulosic fibres for possible use in composites, insulation, and packaging sectors. Chemical agents such as caustic soda, potassium permanganate, and silane were utilised to modify the surface characteristics of the fibres by removing non-cellulosic constituents. The alkali treatment was conducted under optimal conditions using a 3% NaOH solution for 3 hours. For the permanganate treatment, the most effective results were achieved with a 0.5% $KMnO_4$ concentration applied for 3 minutes following a NaOH pretreatment. Silane treatment involved the application of 0.6% 3-(2-Aminoethylamino) propyltrimethoxysilane for 90 minutes, followed by thorough washing and drying. Subsequently, ball milling was employed to refine both treated and untreated fibres. A comparative analysis was conducted on coir and banana fibres, which were subjected to ball milling using a planetary machine to produce fine particles. The milling process was performed under varying durations (30, 60, and 90 minutes) at a speed of 350 rpm in a dry environment, maintaining a ball-to-material ratio of 15:1. Surface morphology and mechanical characteristics of coir and banana fibres were compared before and after the chemical modification. The findings revealed that NaOH treatment effectively eliminated lignin and enhanced the tensile strength of the fibres, whereas silane and permanganate treatments showed minimal impact on tensile strength. Moreover, chemical treatment facilitated defibrillation during milling, reducing particle size to 200–300 nm by silane treatment. These chemically modified and pulverised fibres exhibited improved properties suitable for diverse applications such as composites, insulation, and packaging, thereby contributing to sustainable development by efficiently utilising natural resources.

Table 1: Sample codes used in this study

Sample codes for fibres		Sample codes for pulverised fibre	
UCF	Untreated coir fibre	UCP	Untreated coir particle
NCF	NaOH-treated coir fibre	NCP	NaOH-treated coir particle
KCF	KMnO4-treated coir fibre	KCP	KMnO4-treated coir particle
SCF	Silane-treated coir fibre	SCP	Silane-treated coir particle
UBF	Untreated banana fibre	UBP	Untreated banana particle
NBF	NaOH-treated banana fibre	NBP	NaOH-treated banana particle
KBF	KMnO4-treated banana fibre	KBP	KMnO4-treated banana particle
SBF	Silane-treated banana fibre	SBP	Silane-treated banana particle

Table 2: Chemical analysis of treated and untreated fibres

Sample	Cellulose	Hemi cellulose	Lignin
UCF	45.85	11.58	43.77
NCF	67.87	5.97	27.53
KCF	78.54	3.06	21.18
SCF	73.8	5.04	28.76
UBF	67.96	22.67	15.12
NBF	77.24	10.38	11.07
KBF	81.45	7.88	8.46
SBF	83.02	9.67	6.07

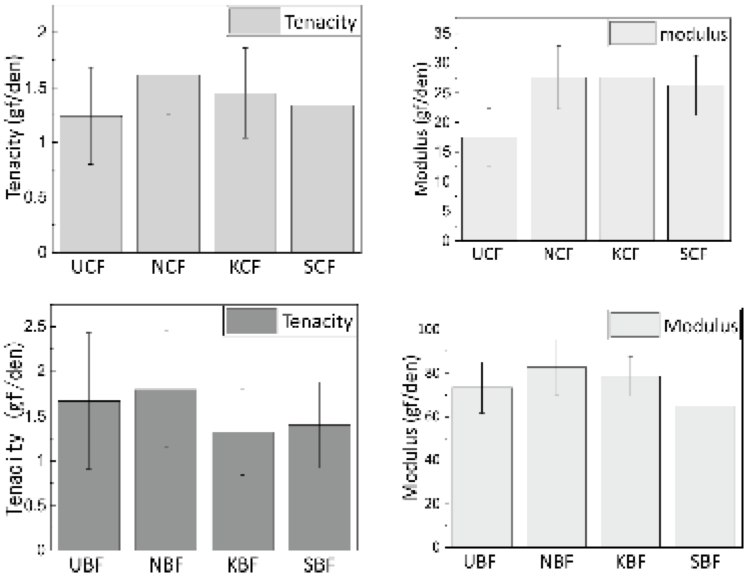

Figure1: Mechanical properties of treated and untreated fibres

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Fashionable Fusion: Redesigning Back Pain Belts into Stylish Corsets for Enhanced Comfort and Wellness

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This research paper explores the innovative transformation of conventional back pain belts into fashionable corsets, aiming to merge therapeutic functionality with aesthetic appeal. The study investigates the potential benefits of such a design shift, emphasizing enhanced comfort and overall wellness. By combining medical expertise with fashion-forward considerations, the research seeks to contribute to the development of a new generation of supportive garments that not only alleviate back pain but also cater to individuals' desire for stylish and versatile accessories.

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Gen Z Drives Innovation: Detachable Components for a Sustainable future

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Interchangeable component (s) can be paired with an existing garment to create the illusion of variety without adding cost to wearer's clothing collection. These interchangeable component (s) can be sleeves, collars, cuffs and capes or any combination thereof. In the times of fast fashion, where Gen Z (born between 1997 to 2012) accounts for world's 30% of the population believes in having variety and buying a lot of clothes leads to spending a lot of money and discarding lot of clothes. Gen Z prefers comfortable and expressive clothing like loose-fitting jeans, crop tops, stylized shirts, capes, cuffs and oversized pieces. Fast fashion brands are producing twice as many garments today as they did in 2000. To combat this overproduction, the five R's of waste management—Refuse, Reduce, Reuse, Repurpose, and Recycle—are crucial. As we know a garment has various components such as collars, capes, cuffs and sleeves and all these elements complete the garment. These components might seem like small details in the grand scheme of fashion, but their significance is profound. These versatile accessories possess a transformative power, elevating an outfit from simple to sophisticate with ease. They can be reused which would reduce the usage of fabric consumption. A semi structured questionnaire was administered for the females in the age group of 16 to 27 years. The survey ascertained the interest of Gen Z in purchasing various components as sleeves, collars, cuffs and capes. A range of components has been meticulously engineered for Gen Z, aimed at enhancing the existing wardrobe of any wearer. Given that collars, cuffs, and sleeves endure the most wear and are prone to abrasion and pilling, these elements have been prioritized. By allowing a base garment to be styled in multiple ways through interchangeable attachments, this approach significantly increases the garment's utility while minimizing fabric waste. Consequently, it enhances the aesthetics, functionality, and versatility of the piece, fostering innovation, reusability, and sustainability in fashion.

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Guarding Heights: Enhancing the Efficacy of Performance Clothing for High-Rise Painters

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Introduction

The art of painting high-rise buildings presents unique challenges and demands, not only in terms of technique and equipment but also concerning the safety and well-being of the workers involved. High-rise outdoor painters currently use basic cotton blend shirts and trousers for work, lacking specialized finishes or safety features tailored to their profession. Their Personal Protective Equipment (PPE) includes high-visibility vests, conventional hard hats, and full-body harnesses, which address some safety concerns but are insufficient against the specific hazards faced [1]. These workers frequently encounter Volatile Organic Compounds (VOCs), transient weather conditions, and exposure to paint chemicals like toluene and xylene, which can cause immediate irritation and long-term health issues such as respiratory problems and organ damage [2]. The need for multifunctional clothing designed to address these challenges—offering protection from chemicals, enhanced comfort, and practical features for tool storage—has been highlighted. This paper aims to find a design solution to reduce discomfort and provide convenience and ease in addition to safety and protection.

Objectives

To develop and test innovative, multi-functional protective clothing designed specifically for high-rise building painters, aiming to enhance their safety, comfort, and efficiency. This involves addressing the unique challenges faced by these workers, such as exposure to hazardous chemicals, mechanical hazards, and varying weather conditions. The goal is to design apparel that integrates advanced fabric technologies, ergonomic features, and practical tool storage solutions to mitigate health risks and physical discomfort, thereby improving overall performance and well-being in high-altitude painting tasks.

Research Methodology

To develop innovative protective clothing for high-rise building painters, the research methodology involves several key steps. Initially, a comprehensive literature review will assess existing protective apparel and identify its limitations. Stakeholder engagement, including interviews and surveys with painters, contractors, and safety managers, will gather insights into specific needs and challenges. A needs assessment will analyze this data to pinpoint common issues. Following this, fabric and material exploration will identify suitable textiles for durability, comfort, and chemical resistance. Design development will create prototypes featuring ergonomic elements and practical tool storage, incorporating feedback from real-world testing. The prototypes will undergo rigorous field testing to evaluate their functionality, comfort, and safety, with results informing subsequent refinements. Finally, the effective designs will be implemented and evaluated in operational settings, with findings documented and shared with stakeholders to guide future improvements.

Results and Conclusion

Fabric explorations for high stain resistant material fabrics of polyester blends consisting of wool and cotton, microfibres and Crypton performance fabrics have been explored as the foundation material for an overall or a utilitarian jacket comprising of compartmentalisation of the tools and their storage pockets and attachment areas for the mechanical full body harness [3,4]. Addition of mesh and cushioning for the knees and elbows to reduce exposure and abrasion, in addition to introducing breathability and comfort while keeping in focus, the weather conditions and exposure to sun and heat. Secure coverings in the forms of protective equipment for the mouth, nose and eyes while maintaining guard and reducing exposure of the skin to these paints and their toxins is a vital need that has been studied. In terms of the mechanical shortcomings, continuous abrasions caused by the full body harnesses against skin surfaces and the absence of utilitarian provisions for the storage and efficient access to the painting tools and equipments has been observed. With focus on areas requiring attention like the knees and elbows, a solution to minimise constant contact resulting in friction and injuries can be obtained with fabric choice placements and solutions. Designs have been created by the author considering the needs ergonomically and approaching the exigency by adapting a utilitarian pathway that focuses on protection, comfort and efficiency in ease of movement.

Figure 1: Existing uniform for high rise construction painters

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Investigating the Potential of ocimum tenuiflorum *(tulsi)* in Antimicrobial and Sustainable Textile Solutions

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This study offers a comprehensive exploration of the significance of antimicrobial finishes on textiles, with a particular focus on the ancient use of Tulsi. This herb, derived from the Ocimum tenuiflorum plant, has been historically recognized for its potent antimicrobial properties, making it a compelling choice for textile applications. The in-depth exploration provides insights into various species of tulsi and their geographical significance in shaping the nature and properties of Tulsi oil, ensuring that the audience is well-informed and knowledgeable. The diverse composition of Tulsi essential oils imparts robust antimicrobial capabilities by targeting bacterial cell membranes. Mechanisms, including lipid bilayer disruption and interference with essential cellular processes, inhibit bacterial proliferation. This understanding is crucial for leveraging Tulsi oils' therapeutic potential as natural antimicrobial agents, with future research aiming to enhance efficacy against diverse bacterial strains for innovative therapeutic interventions. An in-depth analysis of the primary bioactive compounds found in Tulsi oil illuminates its potent antimicrobial capabilities, showcasing its efficacy in inhibiting various pathogens. Moreover, this study elucidates the methods and techniques for applying Tulsi oil in textiles, considering its implications across different fibre substrates. By evaluating its current applications and future prospects, this review underscores the promising potential of Tulsi oil as a versatile antimicrobial agent in textile manufacturing. The investigation focuses to contribute to a deeper understanding of the antimicrobial properties and scope of Ocimum tenuiflorum, paving the way towards innovative, sustainable and functional textile solutions that not only meet emerging consumer demands but also inspire future advancements in the field.

Keywords

Antimicrobial mechanism, Bioactive, Essential oil (EO), Herbal, Pathogens, Sustainable, Tulsi, Textile.

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Kinetic Energy Integration in Innovative Fashion Design Using Textile Waste

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This research explores the integration of kinetic energy harvesting technology into the design of an innovative outfit that also utilizes textile waste. The goal is to create a sustainable garment that challenges conventional fashion norms by incorporating energy-harvesting elements without compromising its aesthetic appeal. By embedding piezoelectric materials and triboelectric generators into textiles repurposed from waste, the study seeks to push the boundaries of fashion design, offering a novel approach where clothing not only serves as a visual statement but also interacts with the wearer's movement while addressing environmental concerns.

Materials and Methods

The innovative design process focused on embedding kinetic energy-harvesting materials into fabrics sourced from textile waste, ensuring that they maintain their visual and tactile qualities. Piezoelectric fibers were strategically placed in high-movement areas to maximize energy generation, while triboelectric generators were integrated into zones with frequent friction. The outfit was assessed for its aesthetic impact, sustainability, and how well it preserved the original design intentions while incorporating technological and eco-friendly elements.

Results and Discussion

The resulting garment generated measurable amounts of energy while prioritizing sustainability. The integration of energy-harvesting technology was achieved without detracting from the garment's visual appeal, showcasing that fashion can be a platform for artistic expression, technological innovation, and environmental responsibility. The use of textile waste in the design process added an additional layer of significance, highlighting the potential for sustainable practices in high-fashion contexts.

Conclusion

This research demonstrates the potential for merging fashion with kinetic energy-harvesting technology and sustainable practices in a way that prioritizes innovation over function. By embedding these materials into repurposed fabrics, the garment not only makes a bold aesthetic statement but also offers a glimpse into the future of fashion where clothing, technology, and sustainability coalesce.

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Modernizing and Upgrading 'Khadi' Production - The Traditional Textile of India for the Masses

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From years on years since the industrial revolution, the businesses in lure of profits were in a state of denial regarding their impact on the environment, leading to ecological problems. Sooner has been the realization watching out these, that there needs to be a co-existence of people, profit and planet. Sustainability has been on the rise, not just it is a buzz but the need to survive. With the growing population and extensive use of resources, we cannot continuously function without making sustainable choices to let the Earth ecosystem be in accord. Businesses now have realized that they can increase profits and work in environmentally safe and sustainable manner simultaneously. 'Going Green' is the only way to grow globally with all nations realizing the dire need of the same. The United Nations Sustainable Development Goals (SDGs) are 17 goals with 169 targets that all 191 UN Member States have agreed to try to achieve by the year 2030 (N.A.). It is time to set new vision with mixing old and new methods for constructing sustainable future. There can be methods to develop solutions on the reservoir of the great knowledge of our ancestors with contemporary technology. India is known for its rich history and culture, which is equally now conflicting with the modern lifestyle. Clothes and dressing up is an essential part of one's identity, to which the fast fashion sellers have already taken the lead, but now clashing with the Sustainable goals, to which the brands are now trying to use the textiles which are sustainable in nature. Contradictory is the situation of the traditional textile 'Khadi', where its value has no way has improved than what it used to be as the fabric of freedom. It is eco-friendly and sustainable due to its natural composition. There have been constant efforts made by Khadi Village Industries Commission and designers for its revival, but there is still a scope for it to be a mainstream fabric. With lot of technological innovations and development all around, its high to modernize and upgrade Khadi production and make it accessible for masses using new systems.

Research Objectives & Methodology

The paper has used primary & secondary research methods data for finding both qualitative and quantitative data. Desk research of past surveys, reports & online websites were done. The key objectives of this research are-

- To understand the quotient of 'Khadi' as a sustainable textile
- To study about the modern-day consumer views on 'Khadi' clothing
- To evaluate the possibility of producing Khadi for masses using new methods and technology.

Findings

Many reports suggest high demand of Sustainable material and methods for a better future and survival of the living beings. Be it community, people and cultures, sustainability can help achieve fair quality of life across the globe. Khadi has always been sustainable as traditionally it uses no energy, has a low carbon foot print, as well it generates income for the rural Indian communities. Khadi has also gained popularity, has become the mainstream conversations due to its characterstics, fashion designers have given this a makeover already. There have been major developments in this sector to improve the produce and sale of Khadi through various measures, KVIC has been signing memorandums with designers nationally and internationally. According the the KVIC, the total average khadi sale was Rs 914.07 crore from 2004 to 2014, and has jumped to Rs 1,828.3 crore between 2015 to 2018, highlighting over a 100 per cent increase. (Khanna, 2020). In a study analysis of technology in Khadi Industry by Gopinath Perumula, new technology will bring a phenomenal change in the produce by use of Spinndle charkhas, there has been a use of solar charkhas already, skill development through efficient training programmes for the Khadi artisans, more ways to grow crops through varied new practices.

Conclusion

Many reforms in Khadi have played a crucial role in revitalising Khadi industry, making it relevant to the modern times. Though there remain still challenges for it to compete with the mass-produced textiles. Rigorous efforts and initiatives can make Khadi a textile of the future, with the new innovations and technology.

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Monsoon Warriors: A User Centric Approach to Uniform Design

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From June to September, Mumbai's monsoons turn chaos into a symphony of resilience. Amidst flooding and waterlogged streets, the Mumbai Traffic Police orchestrate the movement of 2.7 million vehicles guiding the city through this annual deluge with unwavering resolve. Mumbai's Traffic Police are the backbone of the city's road management, tirelessly working to keep traffic flowing smoothly amid the city's chaotic streets. Their dedication is especially evident during the monsoon season, when they navigate challenging conditions to ensure safety and order.

The aim of this research is to identify a design challenge focused on managing waterlogging and traffic congestion during Mumbai's rainy season. The traffic police work hard to keep the roads running smoothly and prevent disruptions, highlighting the need to redesign their uniform for improved functionality and comfort in wet conditions while maintaining their identity and professional appearance. The author follows a user-centric approach on understanding and prioritizing the needs and experiences of the end user during the design process. A comprehensive design framework, referred to as SPACE (Special, Protection, Aesthetic, Confidence and Ergonomics Actionable), was developed to systematically guide the design process. This framework serves as a structured approach to ensure that each phase of the design process is thoroughly addressed.

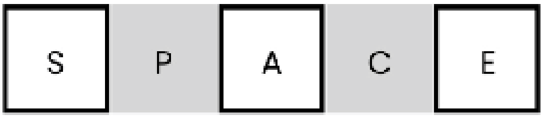

Figure 1: Design Framework

Special: Tailored attire for a particular user during a specific season, Protection: Ensuring resilience against heavy rains., *Aesthetic:* Balancing style and functionality in the design., *Confidence:* Elevating the user's persona through the design, *Ergonomic:* Meeting the end user's needs effectively.

The research process begins with identifying key stakeholders and conducting brainstorming sessions to explore crucial issues. A detailed literature review of existing designs and identical projects laid the groundwork for understanding the context. To gain firsthand experiences, a need assessment survey was conducted followed by interviews with 50 participants, including traffic cops and hawaladars. In addition, the observation approach was used at traffic lights to investigate the interplay between geographical elements and stakeholders.

The gathered data was analyzed to identify shortcomings in the current uniform's effectiveness regarding safety, functionality, comfort, and overall well-being. Using this feedback, the authors developed design solutions that prioritize comfort, mobility,safety and durability while addressing the physiological needs of the traffic police officers. Feedback from the stakeholder was collected at every step of the design process to provide better solutions and meet the needs of the user.

Conclusion

From the research and market survey it has been concluded that there is a need to develop Rain Gear which offers adequate protection against the heavy Mumbai rains while also ensuring the officer's safety and comfort during long hours of exposure to rain so that they can fulfil their duties effectively. Learning to stand in somebody else's shoes, to see through their eyes, that's how peace begins. And it's up to you to make that happen. Empathy is a quality of character that can change the world. - *Barack Obama*

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Optimising the Dyeing Process with Natural Dyes to Enhance Grey-black Colour Combinations While Decreasing Environmental Impacts Using a Microwave

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This study presents a novel approach to optimize the dyeing process using natural dyes to achieve multifunctional properties while minimizing environmental impacts. Chestnut, logwood, and indigo were selected as natural dyes, with chitosan employed as a bio-mordant to enhance dye fixation and colour fastness. The optimization process involved microwave treatment, aimed at reducing energy consumption and environmental footprint. Through rigorous experimentation and optimization techniques, we successfully achieved black colouration on wool, a notoriously challenging task in natural dyeing processes. The utilization of chitosan bio-mordant significantly improved dye uptake and colour retention, enhancing the multifunctional properties of the dyed fabric.

Furthermore, the implementation of microwave optimization not only expedited the dyeing process but also led to a substantial reduction in energy consumption and environmental impact compared to traditional dyeing methods. This innovative approach represents a significant advancement in sustainable textile dyeing practices. The findings of this study underscore the feasibility and effectiveness of employing natural dyes, biomordants, and microwave treatment to achieve desirable colouration while minimizing environmental harm. This research contributes to the ongoing efforts towards sustainable and eco-friendly practices in the textile industry, paving the way for future advancements in dyeing processes.

Keywords

Microwave optimization, Natural dyes, Black colour, Decreasing environmental impact, Water conservation and reuse.

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Preserving the Languishing Craft of Bela Block Printing of Kutch, Gujarat

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Bela Block Printing, a traditional textile craft from Bela village in Kutch, Gujarat, represents a vital component of India's textile heritage. Renowned for its bold patterns and intricate designs, this craft, historically intertwined with the Hindu-Khatri community, faces imminent extinction. Over time, many artisans have stopped practicing the craft of Bela Printing due to changes in their environment, economic challenges, and the drying up of the Sarang River, which once supported their work. As a result, only one family continues this traditional textile art today, putting it at risk of disappearing. Bela Printing, a unique block printing technique from Bela village in Kutch, Gujarat, is not widely known or recognized in the market, making it difficult for the craft to survive and thrive. This study focuses on documenting and preserving the traditional techniques, motifs, and cultural significance of Bela Block Printing. Employing a mixed-methods approach, the research engages with the last remaining artisans, their families, and community stakeholders to capture the essence of this fading art form. Through comprehensive documentation, workshops, exhibitions, and strategic social media engagement, this project aims to raise awareness, revitalize the craft, and ensure its transmission to future generations. Ultimately, this study contributes to the safeguarding of a valuable cultural heritage, fostering its appreciation and promoting its long-term sustainability.

Keywords

Bela Block Printing, Traditional Textiles, Textile Preservation, Craft Revival, Khatri Community, Sustainable Craft Practices

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Revitalizing Sustainability: Transforming Old Woolens into Felt to Replace Non-Wovens and Revive Traditional Crafts like Namda

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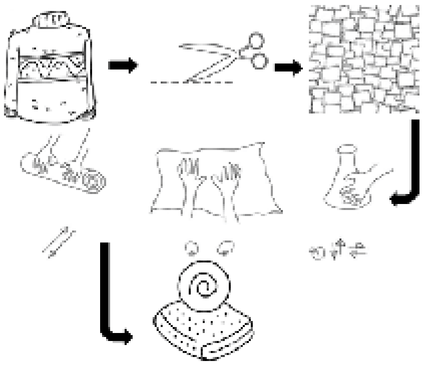
Introduction & Objective

In today's scenario of environmental degradation, the need for sustainable alternatives to conventional materials is the need of the hour. One such innovative solution lies in the utilization and recycling of old woolens to create handmade felt, offering a transformative approach in replacing non-wovens and curbing waste accumulation. This method not only serves as a means of upcycling discarded textiles but also holds the potential to revive age- old traditional crafts like Namda from Kashmir, enriching cultural heritage while promoting sustainable practices.

Materials & Methods

Felt, as an ancient textile has roots tracing back to nomadic times, and is renowned for its versatility, durability, and insulating properties. By using the abundance of discarded woolen garments, blankets and scraps, handmade felt production offers a sustainable alternative to the environmentally hazardous processes involved in manufacturing non-wovens. Blending of heritage techniques and modern innovation, old woolens can be transformed into exquisite felt, breathing new life into age-old traditions. Moreover, the revival of traditional crafts like Namda, a form of felted rug indigenous to Kashmir, underscores the cultural significance and economic potential of felt production. As per people's perspective for sustainability it will also engage local artisans and communities in the creation of felt, which in return will encourage the socio-economic development, empower marginalized populations, and celebrate the richness of cultural heritage.

Results/ Diagrams/ Photographs



Steps for making felt from old woolen clothes:

1. Take old sweater and cut the sweater into small pieces. Spread them on sack uniformly.
2. Sprinkle and spread warm soapy solution all over the wool and soak every part.
3. Use a net to roll the pieces into a log like sushi. Then roll the felt back and forth.
4. Unroll the felt to check and again roll the log from the perpendicular side and roll for another round. Repeat the process another 3-4 times.
5. Squeeze your felt to remove excess soap water and rinse the felt with clear water afterward.

Conclusions

Handmade felt like Namda made from old woolen clothes can replace conventional machine- made felts in various segments of the Fashion industry like outerwear, trims like shoulder pads, accessories, footwear and bags, home textiles, fire fighters protective clothing etc. This wide range also offers sustainable and ethical production, low carbon footprint, unique aesthetic, community empowerment and preservation of traditional craftmanship.

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Reviving the Traditional Textile - Kodali Karuppur Sari

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India, a country rich in cultural heritage, offers several treasures from north to south and east to west. In a world increasingly driven by trends and technology-inspired designs, it is required to revisit the intricacies and innovations of the past. Many ancient art forms and handicrafts were traditionally group endeavors, benefiting multiple artisans and their families. These practices were often environmentally sustainable and culturally rich, yet many remain undocumented and have faced the test of time. With the shift towards modern careers, the art of storytelling through weaving has declined. Artisans struggle to preserve their traditions and meet their needs. The memory of witnessing my grandfather's dedication to handloom weaving, sitting in a pit from dawn till dusk, is deeply ingrained in my heart. Unfortunately, handloom did not continue in my family after him, a common experience among weavers. This paper aims to revive one such forgotten treasure: the Kodali Karupur sari from Tamil Nadu, for which there are no surviving artisans. Kodali Karuppur sari was specifically made only for the Royals given that it took several months to make one sari. While exact replication may not be possible, we can redefine it while preserving its essence. The history and origin of the Kodali Karuppur sari, its unique production process involving a blend of techniques, and potential approaches for its revival given current resource availability is explored. It will also provide a clear picture of the difficulties and improvisations required to make it stand in this time. The impact that this saree could make in the new luxury category and define how slowly made luxury has value to the current customers is also discussed.

Research Objective

- To study about the Kodali Karuppur sari and its status in the present times
- To understand the possibilities of Kodali Karuppur Sari's revival and positing in the current market
- To study several articles and use qualitative research methodology to understand the problems that need creative solution

Findings

The history behind the sari and the origin of it and the techniques that were used in the past to produce the sari by reading research materials and other areas of discovery in both letter and video form. Implementing techniques such as block printing, natural dyeing using the existing raw materials and using finer count cotton yarns in the process of manufacturing the sari. The perfect blend of several value addition techniques made the Kodali Karuppur saree the finest of its time though certain techniques like melugezhuthu do not exist. Keeping the above under consideration and reimagining the Kodali karuppur saree and finding alternatives to keep its essence intact.

Conclusion

Various aspects of the luxury market and the needs of the customers in that specific market have been analyzed. Tamil Nadu's wedding wear clientele is something based on quality conscious, traditional and emotional factors. There is a huge market gap that is not meeting the needs of luxury in the state. Instead of the bling the target customers need understated elegance pieces that they can pass as an heirloom through generations. Tamil Nadu ranks the second in consumption of gold and the consumers are driven by their culture. Reviving this sari might create a demand considering the money for value-based consumption of the target customers. Positioning of the revived product in this specific time and recontributing to the textile archive is done. Past attempts to revive the Kodali Karuppur sari, multiple design explorations and idea proposals which can make this art form sustain is discussed.

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Revolutionising Supply Chain Management and Adaptive Fashion with IoT, AI, and Blockchain Technology: Enhancing Efficiency, Customization, and Sustainability

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The digitization of supply chains, driven by Industry 4.0 technologies like Blockchain, IoT, and Machine Learning, enhances efficiency in planning, sourcing, and procurement. This paper explores key themes in supply chain digitization, identifying major issues and highlighting future research opportunities using a keyword-based framework for classification [4]. The emergence of real-time data collecting and analysis made possible by the Internet of Things (IoT) has had a significant impact on supply chain management and manufacturing. In order to optimise supply chains through predictive maintenance, real-time inventory management, quality control, and energy efficiency, this article investigates the integration of IoT with lean manufacturing [1]. IoT technology improves supply chain visibility, lowers waste, and increases operational efficiency, which improves decision-making and lowers costs. Simultaneously, the fashion industry is becoming more aware of the need for apparel that is tailored to the specific demands of people. These particular requirements are frequently not adequately addressed by conventional supply chain and product development methodologies. This project intends to create a digital platform that streamlines the design, production, and delivery of adaptable fashion items by integrating blockchain, artificial intelligence, and the Internet of Things. Customers will be able to describe adaptive needs using a customised interface on the platform, which will also enable them to quickly iterate their designs using 3D virtual prototyping and use AI to estimate demand accurately. It will also come with AI-powered customer service, digital supplier cooperation capabilities, and a customised management system for real-time order tracking. This project aims to transform the adaptive fashion industry and give people with special needs a more inclusive and responsive fashion experience by increasing product customisation, cutting lead times, and boosting service quality.

Objective

To create a digital platform that enhances real-time supply chain visibility and optimization in apparel manufacturing using IoT, AI, and blockchain, aiming to improve efficiency, transparency, and sustainability.

Methodology

Needs Assessment and Requirements Gathering

- Conduct stakeholder interviews and surveys to understand specific needs and challenges in the current supply chain.

- Identify key performance indicators (KPIs) for supply chain efficiency, transparency, and sustainability.

IoT Sensor Integration
- Deploy IoT sensors across the supply chain to monitor and track raw materials, work-in-progress (WIP), and finished goods.
- Establish data collection protocols to ensure accurate real-time tracking.

AI and Predictive Analytics Development
- Develop AI algorithms to analyse supply chain data, predict disruptions, optimise inventory levels, and forecast demand.
- Integrate machine learning models to continuously improve the accuracy of predictions based on historical and real-time data.

Blockchain Implementation
- Design and implement a blockchain framework for end-to-end traceability and transparency of materials and products.
- Establish smart contracts to automate and secure transactions between supply chain partners.

Dashboard and Collaboration Portal Development
- Create a user-friendly dashboard for real-time updates on supply chain status, performance metrics, and potential risks.
- Develop a digital platform for seamless communication and collaboration among manufacturers, suppliers, and logistics partners.

Sustainability Tracking and Reporting
- Integrate sustainability metrics into the platform to monitor the environmental impact of supply chain activities.
- Generate reports and analytics to support decision-making aimed at reducing carbon footprints and enhancing sustainable practices.

Pilot Testing and Refinement
- Conduct pilot testing in a controlled environment to evaluate the platform's performance and identify areas for improvement.
- Gather feedback from stakeholders to refine the platform and address any issues before full-scale deployment.

Full-Scale Implementation and Training
- Roll out the platform across the supply chain, ensuring all stakeholders are trained on its use.
- Provide ongoing support and updates to ensure the platform continues to meet evolving needs and challenges

Conclusion

The apparel sector will change as a result of the digital platform that combines blockchain, AI, and IoT. It will improve cooperation, optimise inventory, and give real-time supply chain visibility. This innovation improves efficiency, accountability, and the industry's ability to reduce its environmental effect by guaranteeing transparency, anticipating disruptions, and promoting sustainability.

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Studies on Regenerated Fibres

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This study elucidates the successful extraction of keratin from human hair. Although human hair contains both keratin and melanin, the simultaneous extraction of both components proved impractical. Nonetheless, our research demonstrates that keratin and melanin can be isolated from human hair in their native forms using readily available natural materials. Furthermore, we achieved the successful spinning of fibres from keratin, with the finding that keratin alone does not readily form fibres. To address this, additional chemicals were introduced to facilitate fibre formation and enhance the properties of the keratin fibres. The chemical characteristics of these fibres were thoroughly analysed using various techniques, including X-ray diffraction (XRD), differential scanning calorimetry (DSC), and thermogravimetric analysis (TGA) etc.

Introduction

Concerns for the environment and consumer demand are driving research into environmentally friendly fibres as replacements for part of the 38 million tonnes of synthetic fibre produced annually. While much current research focuses on cellulosic fibres, we highlight that protein fibres regenerated from waste or byproduct sources should also be considered which is also a very abundant polymer provided by nature has unique inherent properties, such as non-toxicity, easy modifiability, hydrophilicity, biocompatibility, and biodegradability. Keratin is a structural protein found in feathers, human and animal hairs, wool, nails, horns, hooves, and claws. These can be considered as waste proteins since they are mostly disposed as landfill, used as low nutritional value animal feed or incinerated.

First, the human hairs are of the extraorganismic materials from self-origin. This means that the human hair proteins have an expected potential for the biomedical applications, which are free from the allergic reaction. Second, the human hair proteins undergo biodegradation by in vivo proteases, suggesting that the human hair proteins be developed as a resorbable biomaterial, which eliminates the need for surgical removal after implantation. Third, the human hair proteins are mainly composed of the a-keratin and small amount of the matrix proteins. As we know Keratin is the most abundant component in animal hairs, nails, horns, and feathers, and is approximately 50% of the total mass. The a-keratin is highly cross-linked with each other by disulfide bonds, resulting in forming the hardened and insoluble extracellular organs. Thus, the human hair protein-based materials are expected to be tough and stable in their mechanical and chemical properties. The most eminent components are cysteine and cysteine, which are sulfur containing amino acids and more the content of cysteine more is the strength. As, it is One of the most abundant keratin sources, which is produced 300,000 tons annually as by-product of the fashion industry. Hair keratin may be considered suitable for this operation as it is annually renewable, commercially abundant, of consistent quality, and have guaranteed supply. And human hair contains 70% of protein in it so would be a great source for regeneration.

Objectives of the Project

1. *Effectively Extract Keratin*: Develop a reliable method for extracting keratin from hair.
2. *Optimize Melanin Differentiation*: Enhance the process to naturally and easily differentiate melanin from keratin.
3. *Form Keratin Fibres*: Create high-quality fibres from the extracted keratin.
4. *Utilize Fibres in Medical Textiles*: Successfully incorporate these keratin fibres into medical textiles for practical applications

Benefits

1. *Biocompatible*: Gentle on the skin, ensuring no adverse effects.
2. *Non-Cytotoxic*: Safe for cells, with no harmful effects.

Materials

Human hair from local sources, chemicals (Ethanol, Petroleum ether (99%), sodium hydroxide, urea (99%), sodium chloride, sodium alginate, potassium chloride, acetic acid, chitosan, polyvinyl alcohol, Thio-urea, Carrageenan, agar-agar, calcium chloride, the ionic liquid was synthesized in lab). For dialysis purpose Dialysis tube (3500 mol^{-1} molecular weight cut off) was used, wet spinning machine, electrospinning machine.

Procedure

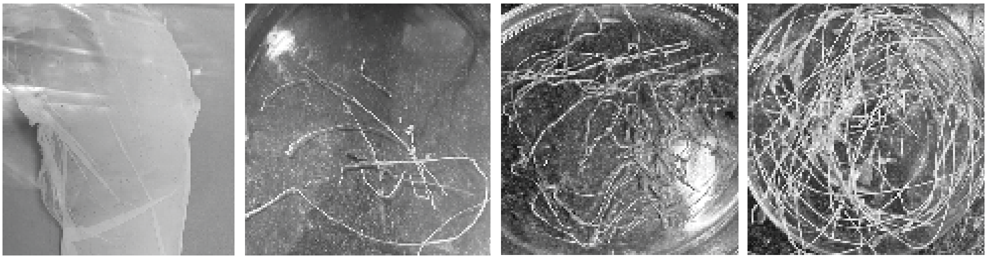
1. *Hair Dissolution*: Hair was dissolved using alkali hydrolysis.
2. *Melanin Differentiation*: Moringa seed powder was employed to differentiate melanin from keratin.
3. *Keratin Purification*: The keratin solution was dialyzed and freeze-dried to produce a powder for purity assessment.
4. *Fibre Formation*: Chemicals such as PVA and sodium alginate were utilized to form keratin fibres.
5. *Testing*: The formed fibres were characterised and then tested for cytotoxicity and biocompatibility.

Characterization

1. *Surface Analysis*: Conducted using laser microscopy to examine surface characteristics.
2. *Functional Group Analysis*: Performed to identify end groups and confirm the presence of keratin.
3. *Thermal Analysis*: Used to assess the temperature behaviour of the fibres.
4. *X-Ray Diffraction*: Employed to investigate the crystallinity of the fibres.
5. *Cytotoxicity*: To ensure that the fibres are compatible with skin and do not harm cells, we will conduct thorough testing in the future.

Result, Diagram, Photographs

Figure 1: Powdered Human Hair Keratin after Lyophilization/ freeze drying



(a) (b) (c) (d)

Figure 2: figures shows that (a) PVA/K electro-spun sheet, (b) Doping of 4 wt. % of sodium alginate in keratin solution, (c) Doping of 5 wt. % of sodium alginate solution in keratin solution with a ratio of 1:1, (d) Doping of 5 wt. % of sodium alginate solution in keratin solution with a ratio of 1:1 mixing additional 4 wt. % poly-vinyl alcohol in it.

Conclusion

Shifting away from synthetic fibres could help reduce the environmental impacts of the fashion industry. This report highlights how chemically regenerating proteins from waste materials like low-value wool, human hair, and spoiled milk can address this issue. The reduction mixed solvent system demonstrates how human hair keratin can be recycled, though separating the protein from melanin, which gives hair its colour, complicates the process. Regenerated protein fibres often need to be blended with other polymers to improve their mechanical properties and processing ability. While blends are common and useful in textiles, it's crucial to consider the environmental impacts of the blending materials, including biodegradability and non-toxicity. Achieving strong regenerated protein fibres has been challenging, often due to protein leaching during fibre formation. Blending with cellulose has been proposed to address this, but other biodegradable polymers were tested instead. These polymers, which were viscous, helped provide strength during spinning. Typically, only about 10% of keratin is retained in the final fibres. Blended fibres with lower protein content showed moderate to good tensile strength, while higher protein content often led to reduced strength due to decreased solution viscosity. Overall, the fibres demonstrated useful intermolecular interactions.

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Influence of Smart Fabrics and Wearable Technology on Kids-wear Clothing and Its Implications on the Future of Kids Fashion

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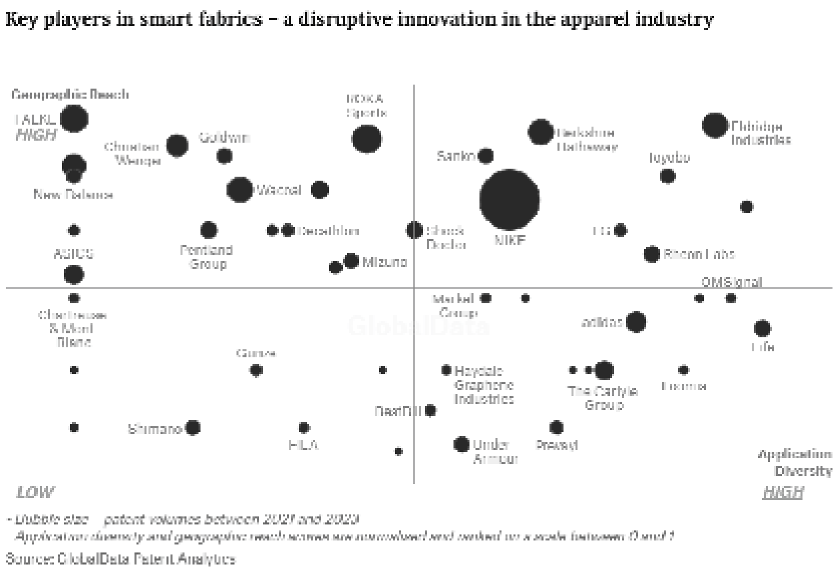
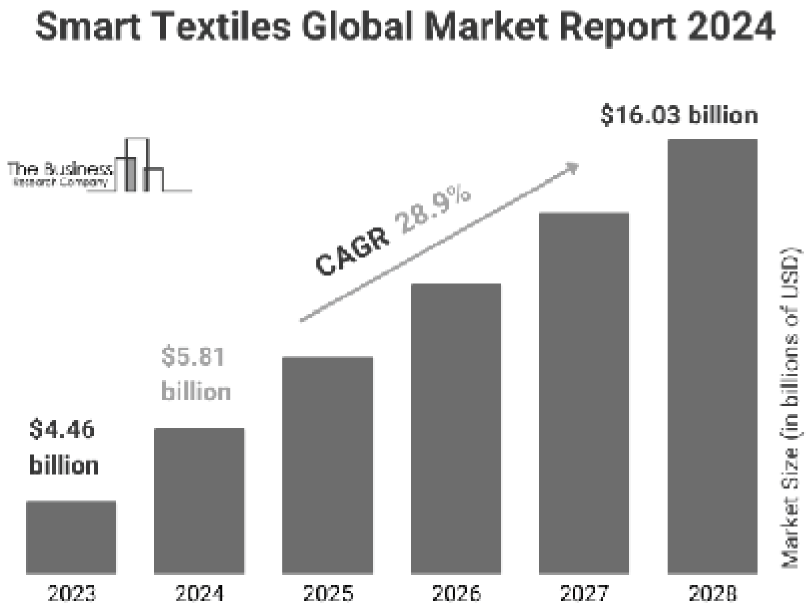
Smart fabrics, also called intelligent fabrics, are a distinct class of advanced materials that directly incorporate electronic components, sensors, and interactive features into the fabric. These cutting-edge materials transcend the passive nature of conventional fabrics, allowing them to sense, respond, and engage with both the wearer and their environment. Technological advancements have revolutionized industries worldwide, including kids' fashion. Recent innovations in smart fabrics and wearable technology have redefined children's clothing, emphasizing more than just style. Modern-day clothing for kids offers functionality, safety, and innovation in mind, making garments that are comfortable, health-monitoring and safe to wear. These technologies are practical and catering to the creative needs of the modern family, and therefore it is changing the way of designing and using clothing for children merely for utility and aesthetics. According to GlobalData, more than 100 companies, including technology providers, established apparel brands, and innovative start-ups, are actively involved in developing and applying smart fabrics and have filed for more than 2600 patents and granted in the last four years alone. The data below shows the same:



Source: GlobalData Patent Analytics, 29 August 2023

According to *The Business Research*, *Jan 2025*; the global smart fabrics market size was worth USD 4.46 billion in 2022, and it is predicted to grow at a CAGR of 28.9% over the forecast period. The worldwide smart textiles market revenue growth is driven by the growing wearable electronic sector, electronics miniaturization, developments in flexible electronics, and technical advancements in smart fabrics.The companies like Adidas AG, AiQ Smart Cothing Inc., Clothing Plus Ltd., Dupont De Nemours Inc., Gentherm Incorporated, Google LLC, Interactive Wear AG, Ohmatex A/S, SchoellarTextil AG and Sensoria Inc are leading the race in making these smart textiles.



These advanced materials surpass traditional fabrics, incorporating temperature regulation, UV protection, moisture-wicking properties, etc. Not only do they enhance comfort for children, but they also promote a safer and healthier experience. Wearable technology, such as jackets with GPS trackers and accessories that monitor vital signs, adds an extra layer of functionality, improving safety and convenience for both parents and children. With children's active lifestyles, parents are increasingly drawn to wearables that monitor vital health indicators like heart rate, body temperature, and hydration levels. As babies struggle to regulate their body temperature, these innovations help adapt to their body heat, keeping them warm in colder environments and cool during warmer conditions. This emerging technology helps alleviate parental concerns about their child's comfort in varying temperatures.

Another trend gaining momentum is intelligent monitoring clothing where garments contain non-invasive sensors that track a baby's sleep quality and overall well-being. These smart clothes monitor vital signs like heart rate, temperature, movement, and oxygen levels, sending real-time alerts to parents' smartphones. Such technology offers Parents peace of mind, especially for newborns or infants with health conditions. These smart garments ensure that parents stay informed about their child's health constantly by combining comfort with advanced functionality. As Sma

This research aims to explore the progress of intelligent fabrics and wearable technology beyond mere aesthetics in kid's clothing, It describes how technology is changing the way of creating kid's apparel and how it can influence the design, production, and adoption of children's fashion, setting new standards for what clothing can achieve and improve the daily challenges life of modern parenting.

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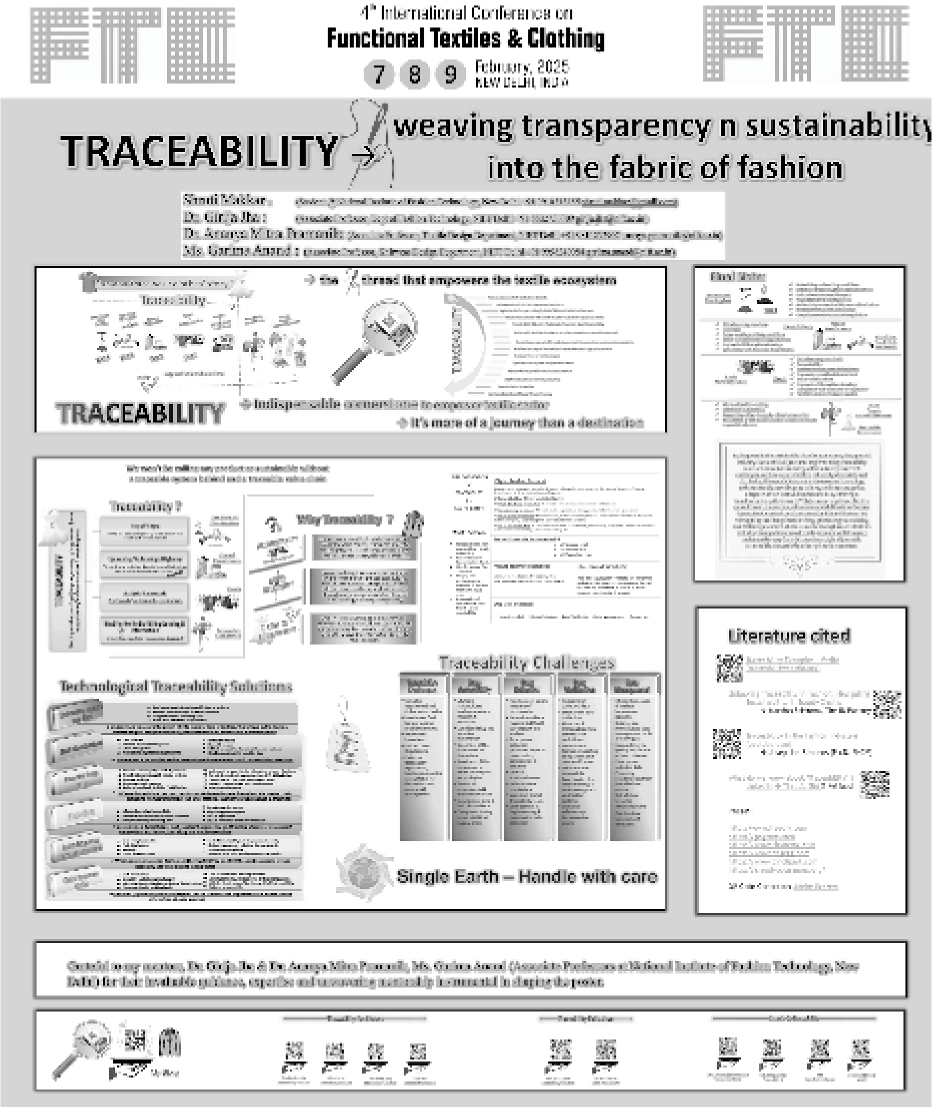
Traceability Weaving Transparency n Sustainability into the Fabric of Fashion

Shruti Makkar



Waste to Wealth: Utilization of Agro-waste Derived Pineapple Leaf Fibre as Reinforcement in Bio-degradable Composites for Protective Clothing

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In order to achieve sustainable environmental growth, agro-waste utilization has received increased attention. Landfilling, burning, and decomposition are some of the traditional methods used to treat the agro-waste, each with its own set of drawbacks. Proper management of the abundance of agricultural residues and products is necessary to reap the commercial and environmental advantages [1]. Pineapple leaf is a seasonally abundant available agricultural waste that has inadequate commercial value. Finding alternative uses for this agricultural cellulose waste is in high demand. A portion of the long fibrous material extracted manually and mechanically from pineapple leaves is known as pineapple leaf fibre (PALF). According to the Food and Agriculture Organization Corporate Statistical Database (2018), the top ten potential PALF production countries are the Philippines, Costa Rica, Brazil, China, Thailand, India, Indonesia, Nigeria, Colombia, and Mexico, with an average annual yield of approximately 79, 53, 74, 96, 103, 133, 18, 240, 31, and 24 thousand metric tons, respectively [2]. This study investigates the potential utilization of the agro-waste PALF as green reinforcement in polypropylene (PP) composites. In this work, the PALF was cut into three lengths and a greener approach, the carding process, was used to remove extraneous materials from the fibre surface without using conventional chemical treatments. The RPM of the licker-in (dia-127 mm), cylinder (dia-406.4 mm), and doffer (dia-152.4 mm) of the lab model carding machine were 1.52, 184.1, and 17.38, respectively. An optimal number of passages in the carding process removed the non-cellulosic materials from PALF, resulting in an increase in the cellulose percentage and surface roughness, leading to an improved fibre-matrix interface. The highest crystallinity (74.63%), roughness average value (291.92 nm), and contact angle (88.65°) were shown by the fourth passage carded longer PALF. For proper distribution of thermoplastic resin in the reinforcement, the PP fibres were pre-distributed in PALF through the carding process at a weight percentage of 50%. A gill drawing machine was used to parallelize the mixed fibres, and compression molding machine was used to fabricate the composites, as presented in Figure 1. Longer PALF and finer PP fibres achieved a homogeneous fibre-matrix distribution, resulting in the highest interfacial shear strength, tensile strength, tensile modulus, flexural strength, flexural modulus, and impact strength of 25.56 MPa, 124.60 MPa, 6.24 GPa, 103.27 MPa, 6.16 GPa, and 104.28 kJ/m^2 of fabricated composites, respectively. This study is the first to demonstrate the use of carding for the processing of PALF and how PALF length and the carding process influence different properties of fabricated composites. The better distribution of PALF and PP fibres, along with the parallelization of those fibres through carding and subsequent drawing processes, made it possible for PALF to be mixed with PP matrix, which reduced the composites' void contents and improved the mechanical performances. Therefore, by employing the newly researched process to fabricate the agro-waste PALF fibre-reinforced PP

composites for high-value added products across diverse protective clothing and technical applications.

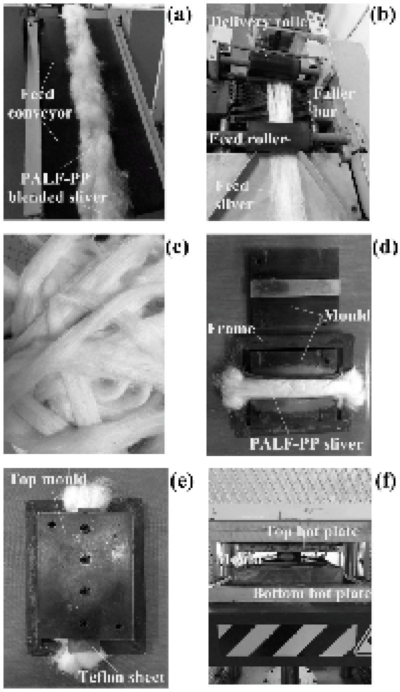

Figure 1: Photograph of ***a*** PALF-PP fibres placed for feeding into the gill drawing machine, ***b*** gill drawing unit, ***c*** drawn roving, ***d*** top and bottom moulds for composite fabrication, ***e*** moulds ready for heat compression, and f heat compression unit of the compression moulding machine.

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Weaving a Sustainable Future: Hemp/Wool Integration in Kullu's Handloom Tradition

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The handloom industry in Kullu, Himachal Pradesh, is a testament to the region's rich cultural heritage and traditional weaving techniques. However, in the face of a rapidly evolving global textile landscape and increasing concerns about sustainability, it is crucial to explore innovative and environmentally friendly textile production methods. This study investigates the feasibility of incorporating hemp-wool blend fabrics into the traditional handloom practices of Kullu. The primary objective of this research is to assess the viability and potential of blending hemp and wool fibres to create sustainable, high- quality textiles that can be seamlessly integrated into Kullu's handloom tradition. The findings demonstrate the significant potential of integrating hemp and wool fibres within the Kullu handloom industry. The successful integration of hemp and wool fibres, enhanced by the use of natural dyes, hand spinning, and traditional weaving techniques, not only promotes environmental sustainability but also provides socioeconomic benefits to the local community. The study concludes that the integration of hemp and wool fibres offers a promising path for the future of the handloom industry in Kullu and beyond, fostering economic growth through sustainable textile innovation.

Introduction

The handloom industry in Kullu, Himachal Pradesh, is a testament to the region's rich cultural heritage and traditional weaving techniques. However, in light of the evolving global textile industry and increasing concerns about sustainability, it is essential to explore innovative and environmentally friendly textile production methods. This study, titled "Weaving a Sustainable Future: Hemp-Wool Integration in Kullu's Handloom Tradition," investigates the feasibility of incorporating hemp-wool blend fabrics into the traditional handloom practices of Kullu. The primary objective of this research is to assess the viability and potential of blending hemp and wool fibres to create sustainable, high-quality textiles that can be seamlessly integrated into Kullu's handloom tradition.

Materials and Methods

For this work, dew-retted hemp stalks and wool fibres weighing approximately 1 kg were sourced from artisans in Gadagushaini, Tirthan Valley. These artisans specialize in traditional hemp-based pulla chappal, and their expertise ensures the quality of the hemp fibres used in the blend (Figure 1).

Upon procurement, the hemp stalks undergo a preparation process to extract the fibres. The retted stalks are treated in a 10% NaOH (sodium hydroxide) solution to soften the pectin and remove impurities followed by heckling process where the fibres are separated from woody stalk. After heckling the hemp fibres were carded using two set of hand carding tool. The process flow of manufacturing is shown in figure 2. After carding the fibres were ready for bleaching and after bleaching, they were blended with wool fibre. For dyeing the hemp/wool blend local variety of marigold flowers were used followed by hand spinning to prepare hemp/wool blend. The weight wise ratio of hemp-wool in the hand spun yarn was 30:70.

Figure 1: Dew retted hemp fibre

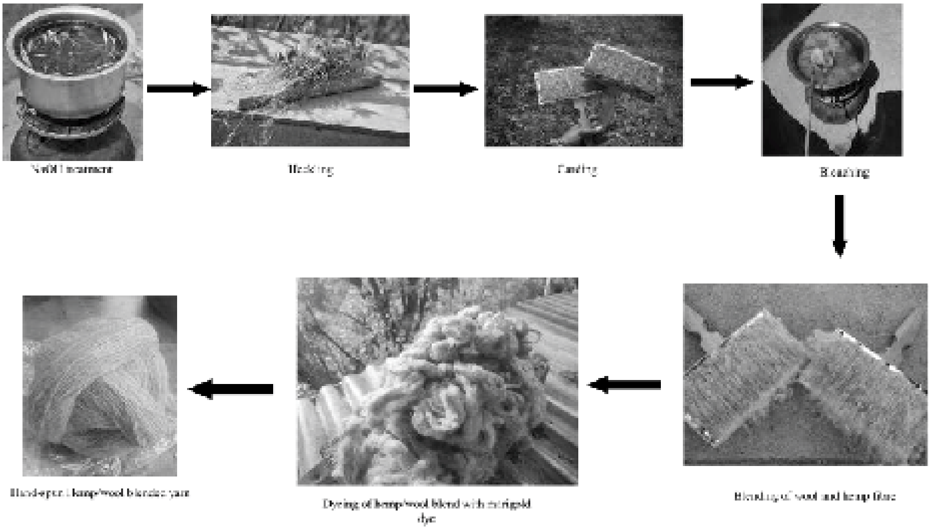

Figure 2: Manufacturing process of hemp/wool blend

After the hemp/wool yarn manufacturing the weaving was carried out to do the make final product. However, due to the low strength of hand-spun hemp/wool yarn, it was difficult to use it in warp direction. Hence the above-mentioned yarn was used in weft direction. For the warp, 100% merino wool yarn with a 2/48 yarn count was used. The final handloom woven fabric was finished and tested for its abrasion resistance, colour fastness and shrinkage properties.

Results and Discussions

This preliminary work on hemp/wool blend showed that the hemp as potential fibre to be used in traditional handicrafts of Kullu. Traditional spinning techniques such as scutching, heckling, and carding, carried out using handcrafted tools to preserve cultural heritage and craftsmanship. Despite technological advancements. The use of traditional tools ensures authenticity and uniqueness in fabric production. Color fastness tests revealed the effectiveness of natural dyes in maintaining color integrity, promoting sustainable practices. The blend ratio of 30% hemp fibres and 70% local wool in the fabric offers a balanced combination of strength, softness, and sustainability.

Conclusion

In conclusion, the research conducted on hemp wool blend fabric production in Kullu, Himachal Pradesh, sheds light on the significant potential of sustainable and culturally significant fabric production practices. By amalgamating traditional weaving techniques, locally sourced raw materials, and community involvement, this study demonstrates how eco-friendly approaches can not only meet market demands but also preserve cultural heritage and stimulate economic growth in the region. Despite certain limitations, such as sample size constraints, regional specificity, and technical challenges, the study provides valuable insights into the production process, market potential, and consumer preferences for hemp wool blend fabrics

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Weaving Culture: The Historical Significance and Future of Navalgund Durries

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Navalgund Durries, also known as 'Jamkhanas,' are a remarkable expression of India's rich textile heritage, originating from the small town of Navalgund in Karnataka. These handwoven rugs, characterized by their intricate geometric patterns and the iconic peacock motifs, have been a symbol of the region's cultural identity for centuries. The weaving technique, utilizing a traditional vertical loom called Khadav Magga, is a unique practice passed down through generations, predominantly by the women of the Sheikh Sayeed community. This craft not only represents the artistic legacy of the region but also reflects the socio-economic fabric of the community that has preserved it against the odds. Historically, the origins of Navalgund Durries can be traced back to the 16th century during the reign of Ali Adil Shah in Bijapur. The craft was brought to Navalgund by weavers seeking refuge from the turmoil between the Deccan Sultanate and the Vijayanagara Empire. Over time, these weavers settled in Navalgund, where the craft evolved and flourished, becoming an integral part of the town's cultural landscape. The designs of the durries, often featuring vibrant colors and symbolic motifs such as the peacock—a reference to the town's name, which means 'Hill of Peacocks'—embody the fusion of artistic innovation and cultural symbolism. This paper provides a comprehensive exploration of the history, cultural significance, and artistic techniques involved in the creation of Navalgund Durries. It also delves into the socio-economic dynamics of the craft, particularly focusing on the role of women artisans who have traditionally been the custodians of this art form. Despite its rich heritage, the craft faces significant challenges in the modern era, including the decline in the number of artisans, economic pressures, and the impact of the COVID-19 pandemic. The paper examines these challenges and the efforts made to sustain the craft, including the recognition of Navalgund Durries under the Geographical Indication (GI) Act of 1999 by the Government of India in 2011. By analyzing the past and present of Navalgund Durries, this research highlights the urgent need for innovative strategies and sustained support to ensure the survival of this ancient craft. The preservation of Navalgund Durries is not just about safeguarding a product but about maintaining a living tradition that embodies the cultural and artistic spirit of a community. This study aims to contribute to the broader discourse on the preservation of traditional crafts in the face of globalization and modernization, offering insights into how such heritage can be adapted and sustained in contemporary contexts.

Research Problem and Aim

Navalgund Durries, also known as 'Jamkhanas,' represent a traditional handwoven textile from Navalgund in Karnataka, India, known for their intricate geometric designs and signature peacock motifs. These durries have been an essential part of the region's cultural heritage for centuries. However, this craft is now at risk due to declining artisan numbers, economic challenges, and the adverse effects of the COVID-19 pandemic. The primary aim of this research is to investigate the historical evolution, current status, and sustainability of Navalgund Durries, while assessing the socio-economic factors impacting their production. Additionally, the study seeks to explore strategies for preserving and revitalizing this endangered craft in the contemporary global market.

Materials and Methods

This research employs a mixed-methods approach, combining historical analysis, fieldwork, and qualitative interviews. The historical analysis focuses on archival records, previous studies, and traditional narratives to trace the origins and evolution of Navalgund Durries. Fieldwork was conducted in Navalgund, involving participant observation and documentation of the weaving process using a vertical loom known as Khadav Magga. Qualitative interviews were held with local artisans, community leaders, and representatives from governmental and non-governmental organizations to understand the socio-economic challenges faced by the artisans. Additionally, the study analyzed the impact of the Geographical Indication (GI) status granted to Navalgund Durries in 2011, using data from trade reports and market analysis.

Results and Discussion

The findings reveal that the production of Navalgund Durries has significantly declined over the past few decades due to a combination of factors, including reduced demand, competition from machine-made alternatives, and the outmigration of younger generations seeking more lucrative employment opportunities. The research also highlights the central role of women artisans, who have preserved the craft despite societal constraints. The study found that the GI status has had limited impact in boosting the commercial viability of Navalgund Durries, primarily due to a lack of effective marketing strategies and inadequate support for the artisans. The discussion emphasizes the need for a multi-faceted approach to revitalizing Navalgund Durries. Key recommendations include developing targeted marketing campaigns to raise awareness of the craft's cultural value, improving access to modern tools and resources for artisans, and creating incentives for younger generations to engage with and sustain the tradition. The study also discusses the potential of integrating Navalgund Durries into the global market through collaborations with designers and ethical fashion brands, thereby aligning the craft with contemporary consumer trends.

Conclusions

This research concludes that while Navalgund Durries embody a rich cultural heritage, their survival depends on proactive efforts to adapt the craft to modern contexts. The sustainability of this tradition requires not only preserving the traditional techniques but also innovating in ways that appeal to current markets. The study underscores the importance of continued research and policy intervention to support the artisans and promote Navalgund Durries as a valuable element of India's cultural identity.

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Woolitmus: An Approach to Minimize E-waste by Using Wool-Based Wearable Sensor for Sweat pH Detection

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This study introduces ***"Woolitmus"***, a textile-based wearable sweat pH indicator developed using pyranine, also known as HPTS (8-Hydroxypyrene-1,3,6-trisulfonic acid), and naturally occurring wool as substrate. Sweat pH analysis is crucial for monitoring health conditions associated with pH imbalance. The sensor exhibits pH responsiveness under visible and UV light, offering the potential as a real-time sweat patch for pH monitoring. The interaction of pyranine with wool substrate is detailed, elucidating the mechanism behind the pH sensitivity backed up by photophysical characterisations. Stability and reversibility tests also confirm the sensor's robustness and performance. The reported sensor can also simultaneously collect and detect pH levels without the support of any additional accessories like electrodes, display, etc. It also offers sensitivity, real-time response, and non-invasive detection. But more importantly, it stands out for its biodegradability, reusability, zero e-waste, and biocompatibility of the substrate. The wool fabric-based pH sensor holds promising health monitoring and lifestyle management applications.

Introduction

Sweat pH analysis is crucial for detecting health issues like cystic fibrosis, infections, and skin conditions and monitoring glucose levels, physical exertion, and dehydration [1–7]. Various pH sensors, including ionic liquid-based, metal complex-based, carbon-based, and graphene sensors, each face challenges related to recyclability, flexibility, and data conversion. They also require separate devices for sweat collection and analysis, increasing electronic waste. Researchers are integrating sweat sensors into textiles because they are flexible, biocompatible, and help with sweat flow [3,21–23]. However, this approach still faces skin irritation, poor breathability, and user discomfort [3].

Objectives

- ***Develop Body-Compatible Sensors***: Create sensors that harmonise with the human body, allowing for simultaneous sweat collection and detection.
- ***Ensure Sensor Performance***: Achieve high sensitivity, real-time response, and non-destructive detection in the sensors.
- ***Integrate Sensory Material:*** Implement a method for directly impregnating sensory material into textile substrates to ensure proper exposure to sweat stimuli.
- ***Utilize Biodegradable Substrates:*** Use wool fabric as the natural, biodegradable substrate for the sensor.
- ***Form Stable Chemical Bonds:*** Leverage hydrogen bonding and acid-base interactions to create stable bonds between pyranine (8-Hydroxypyrene-1,3,6-trisulphonic acid) molecules and wool fabric.

- ***Combine Detection Methods:*** Develop a pH sensor that integrates colourimetric and fluorometric detection methods.

To achieve the above objectives, ***"Woolitmus" is a textile-based wearable sweat pH sensor using pyranine (HPTS) and natural wool.*** It enables real-time monitoring of sweat pH to track health conditions related to pH imbalances.

Functionality:

- pH Responsiveness: Reacts to pH changes under visible and UV light.
- Real-Time Monitoring: Provides immediate pH readings without additional accessories like electrodes or displays.

Mechanism:

- Pyranine and Wool Interaction: Detailed interaction mechanism shows how its bond with wool enhances pyranine's pH sensitivity.
- Characterisation: Supported by photophysical analyses.

Performance:

- Robustness: Proven stability and reversibility.
- Non-invasive: Collects and detects pH levels directly on the skin.

Environmental and Practical Benefits:

- Biodegradability: Made from natural, biodegradable wool.
- Reusability: Can be reused without generating e-waste.
- Biocompatibility: Safe for direct contact with skin.
- Applications: Suitable for health monitoring and lifestyle management.

Materials

Pyranine dye, wool fabric, and various chemicals (formic acid, Glauber's salt, sulfuric acid, hydrochloric acid, NaOH, glacial acetic acid, boric acid, sodium acetate) were used for acid dyeing of wool. pH adjustment was managed with buffer solution and pH tablets.

Processes

1. ***Dyeing Process***:

- Wool was dyed using pyranine with a 1:20 material-to-liquor ratio.
- Steps included adding formic acid, Glauber's salt, pyranine, and additional acids at controlled temperatures for dye fixation.

2. ***Characterization***:

- ***Surface Analysis***: Scanning electron microscopy confirmed dyeing, not surface deposition.
- ***Functional Group Detection***: FT-IR spectroscopy identified changes in functional groups due to pH variations.

- ***Photophysical analysis**:* UV and visible light responses were evaluated using JASCO 6000 fluorescence spectroscopy and a CIE chromaticity diagram.

***pH Colorimetric Sensing**:*

- Tested by immersing fabric in various pH solutions and measuring colour changes with UV and visible light.
- Reversibility and pH sensitivity were assessed using different pH solutions and artificial sweat.

***3. Sensor Stability**:*

- ***Washing Fastness***: Tested with a non-ionic soap solution at 60°C for 30 minutes.
- ***Rubbing Fastness**:* Evaluated for dry and wet rubbing using standard methods (IS 766:1988, ISO 105-X12:2001).

Result, Diagrams and Photographs

Interaction of pyranine with wool substrate -Acid dyeing on wool

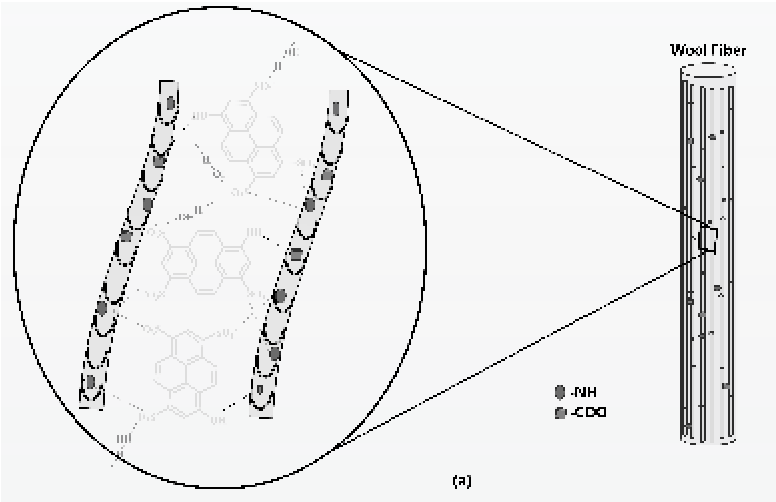

Figure 1: Schematic representation illustrating dye molecules adhering to substrate fibres through different types of interactions

Table 1: Washing and rubbing (Dry and Wet) fastness rating

Shade %	Dry rub fastness	Wet rub fastness	Wash Fastness
5%	5	5	5
Rating: 1- Poor, 2- Fair, 3- Good, 4- Very Good, 5- Excellent			

Mechanism of pH responsiveness:

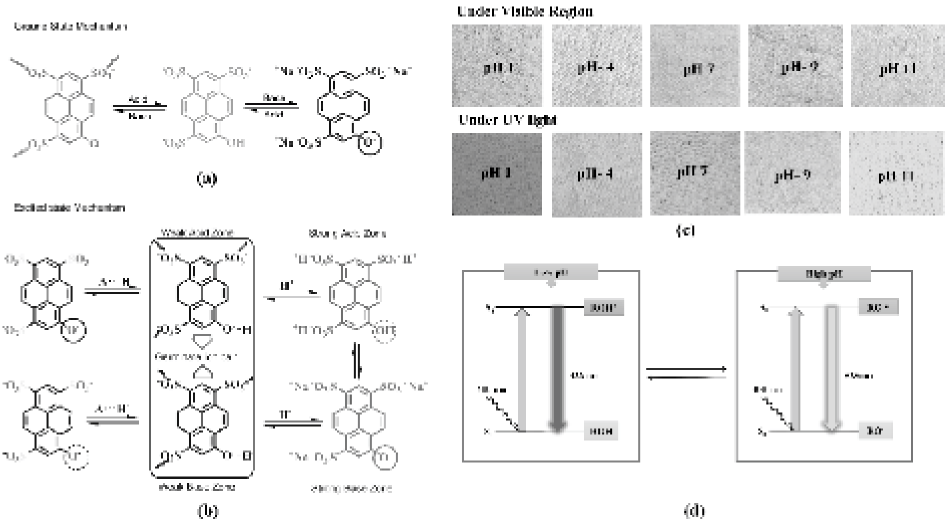

Figure 2: (a) Ground State Mechanism for pH Sensing (b) Excited state pH sensing Mechanism (c) Different pH-treated dyed wool fabric under visible and UV light (d) Illustration of pH sensing mechanism based on energy levels in ground and excited state.

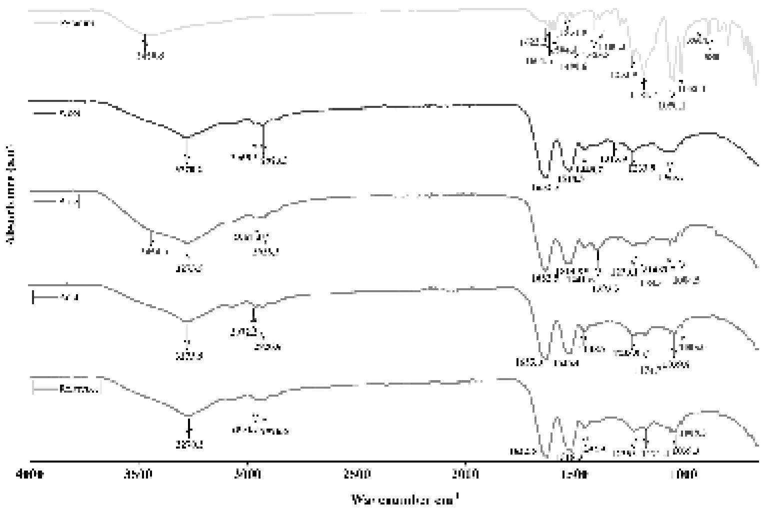

Figure 3: Fourier Transform infrared Spectra of acid-treated, primary treated and reference dyes fabric along with the untreated wool and pyranine dye powder for the reference.

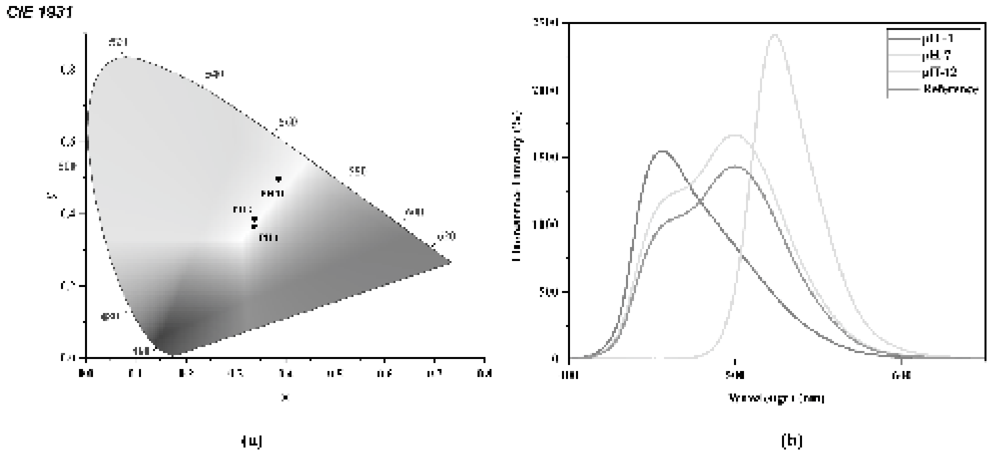

Figure 4: a) CIE 1931 chromaticity diagram of pH 1,7 and 11 (b) Emission Spectra Illustrating Emission Changes at Varying pH Values of *1,7 and* 12 along with reference dyed fabric sample**.**

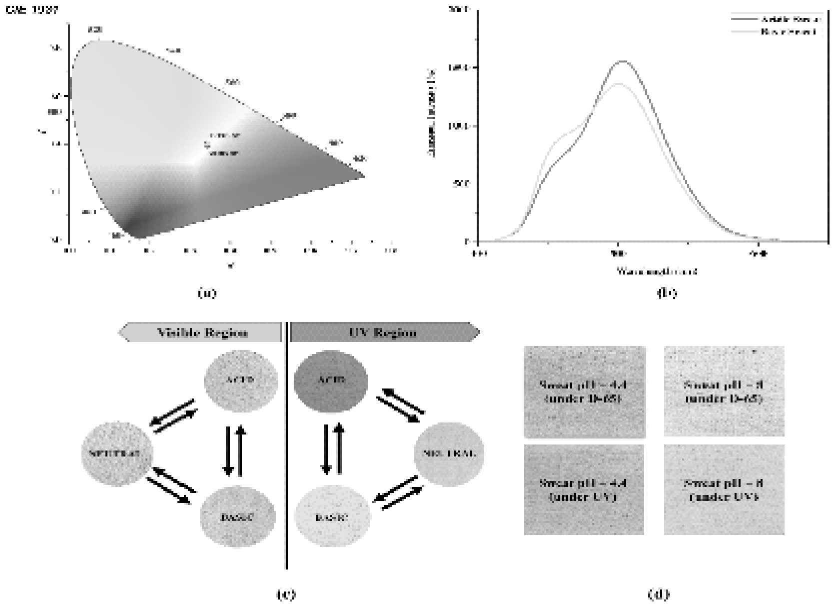

Figure 5: (a) CIE colour space chromaticity diagram of both acidic and basic artificial Sweat (b) Emission Spectra for Acidic Sweat and Basic Sweat pH (c) Exploring Reversibility through Combinations (d) Wool fabric samples after *treatment* with artificial sweats

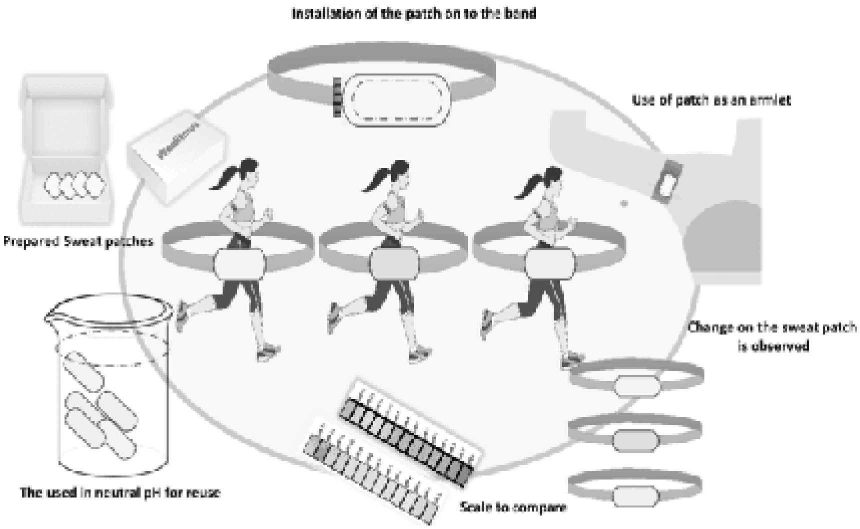

Figure 6: Illustration of proposed sweat patch along with the construction, procedure of application and how to reuse.

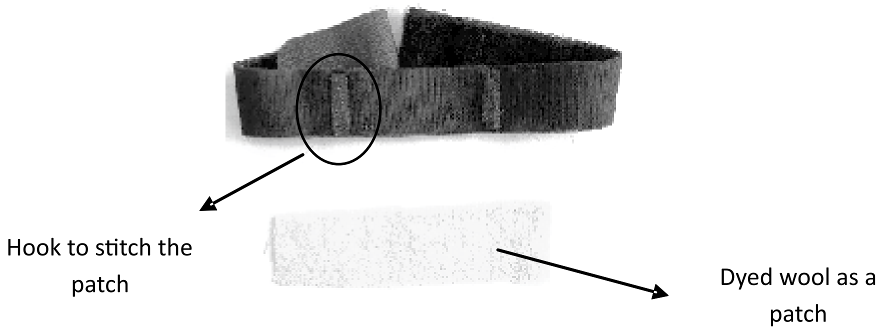

Figure 7: Prototype of proposed sweat sensor

Conclusion

In conclusion, this study introduces a sweat pH detection patch made from wool and HPTS (Pyranine) via conventional dyeing as a fabrication protocol. The sensor detects sweat pH across a wide range under visible and UV light, with high sensitivity and real-time response. It can collect and detect pH levels simultaneously without extra accessories, reducing complexity and waste. Being wool-based, it's biodegradable, reusable, and compatible with the body, making it promising for developing eco-friendly health monitoring applications.

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