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The Textile Association (India), Mumbai Unit to organize International Conference on "Automation and Robotics in Textile & Apparel Industry".

The Textile Association (India), Mumbai Unit is organizing an international conference "Automation andRobotics in Textile & Apparel Industry" on Friday, 15th November 2024 at Hotel The Lalit, Mumbai. Automation and robotics have become buzz words in the textile industry during last 5-6 years. The textile and garment industries are not only labour intensive, but also have heavy consumption of precious energy and water. The textile researchers are working hard to reduce all these factors, so that the final product becomes competitive by increasing the production efficiency and reducing manpower costs. Added to that there is substantial rejection of products due to man/machine errors. Automation and robotics are the answer to overcome these issues.

This conference will explore the key applications, benefits and future outlook of automation and robotics in the textile & apparel industry. We have made all-out efforts to cover most of the topics. This conference will be addressed by policy makers, reputed textile professionals and renowned experts from different parts of the world and India who are experts in the technologies. This high profile conference will be attended by 400 quality participants who will get the rare opportunity to listen to such high quality experts. We are sure that the participating delegates will be benefitted immensely from this conference.

The Textile Association (India), Mumbai Unit is the largest Unit of the Association having around 4000 members. The Unit has reputation of organizing events of topical interest both at national and global level.

Topics to be covered

- Role of Automation and Robotics in Textile Manufacturing
- Innovation in Apparel Production: Insights into Robotics
- End to End Automation opportunities in Textile Value Chain
- Textile Machinery Industry's role in automating the textile processes
- Automation applications in Textile Chemical Processing
- Concept of 'Smart Factory'
- New emerging trend: Storage Automation
- Role of Industry 4.0 in the textile machinery development
- Application of Artificial Intelligence and BlockChain Technology in the Textile Value Chain
- 3D Printing and its textile applications
- Role of ERP in Textile and Apparel Production
- Upgradation of old machines through automation

Speakers & Panelists

All the conferences organized by The Textile Association (India), Mumbai Unit have always selected contemporary & innovative topics presented by high profile speakers. This Conference is also no exception to this.

We appreciate your support to The Textile Association (India), Mumbai Unit in its activities and it is our pleasure to invite you to be part of this event. Let us join hands to make this conference a great success.

Rajiv Ranjan	G. V. Aras	V. C. Gupte	Rahul Bhajekar
President	Conference Chairman	Chairman & Convenor	Jt. Convenor

For more details please contact:

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Impact of Union Budget 2024 on Textiles & Apparel

Impact of Union Budget 2024 on Textiles & Apparel Sector

The Indian government has announced several strategic measures in the latest Union Budget. These initiatives aim to enhance the global competitiveness of India's textile, leather and MSME sectors, which are vital to the country's economy.

The budget allocation for the Ministry of Textiles for the financial year 2024-25 has been significantly increased, highlighting a commitment to enhancing the sector's growth and global competitiveness. The total budget allocation for the Ministry has been raised from Rs 3,443.09 crore in the revised 2023-24 budget to Rs 4,417.03 crore in the 2024-25 budget.

The Union Budget 2024 presents a strong emphasis on manufacturing and sustainability which will propel a holistic approach to India's economic growth. This lays a solid foundation for industrial growth. The budget priorities such as employment and skilling, social justice, and manufacturing are a step in the right direction in pursuit of Viksit Bharat 2047. The employment incentives for the manufacturing sector will further stimulate job creation and strengthen our workforce. Additionally, the announcement of a ₹3 lakh crore corpus for women-centric schemes will increase their participation in the workforce. The budget holds great promise in addressing the labour and skill shortages, which are crucial for labour-intensive sectors like textiles. The commitment to skilling and employment support, including youth programs, ensures a future-ready workforce for the retail sector.

Additionally, measures announced to support bank credits to MSMEs and the easing of foreign investment will also benefit the textile and apparel industry. Emphasis on MSMEs and start-ups, enabling more lending and abolishing angel tax, is a positive step.

The import relaxation on some of the important raw materials, trims, and accessories required for garment manufacturing will also help garment manufacturers to be more competitive, especially in the export markets.

Initiatives like monetary support for farmers, higher personal income tax exemptions, and increased standard deductions will boost disposable income and stimulate spending, driving economic growth.

The budget's energy sustainability measures, particularly the rooftop solar scheme, will transform energy consumption at both household and industrial levels.

The government has rightly renewed its focus on four major pillars: the poor, women, youth, and farmers.

Prof. (Dr.) Bhawana Chanana
Member – JTA Editorial Board
Director-
Amity School of Fashion Technology,
Amity University Mumbai

T. L. PATEL, President

Embracing Sustainable Technology for a Resilient Textile Industry

T. L. PATEL, President

Dear Members and Industry Stakeholders,

As we navigate the complexities of the global textile landscape, I am reminded of the immense potential that lies within our industry. As the President of the Textile Association (India), I am committed to fostering innovation, collaboration, and growth.

In recent years, the textile industry has faced numerous challenges, from environmental concerns to fluctuating market demands. However, I firmly believe that these challenges present opportunities for us to adapt, innovate, and thrive.

Sustainable Technology is no longer a buzzword, but a necessity. We must embrace eco-friendly practices, reduce our carbon footprint, and invest in research and development to stay ahead of the curve. Our industry has the potential to be a leader in sustainability, and I encourage each of you to join me in this pursuit.

As we move forward, I am excited to announce several initiatives aimed at promoting sustainable technology and best practices within our industry. These include workshops, webinars, and collaborations with international organizations.

"As we strive for excellence in the textile industry, I urge all members to embrace sustainable practices and cutting-edge technology. Our industry has immense potential, and together, we can drive growth and innovation.

Let us work together to build a resilient and sustainable textile industry. I wish you all a successful and prosperous future. Thank you for your continued support."

Sincerely,

T. L. PATEL
President
The Textile Association (India)

A Study of Factors Affecting on Apparel Buying Behaviour

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Abstract:
The world-wide women's clothing market has shown a fast growth pattern. Women have become a significant part of buying clothes. They pay a lot of attention to clothes, thus changing the behaviour of consumers. Forecasting a women's buying habits is a major challenge in meeting these needs. The use of fashion clothes by women has increased considerably.

This article reviews the literature on females' apparel purchasing behaviours. The key intention of the research paper is to categorise altered perspective that can support and monitor future researchers. Researchers reviewed the research literature on women's clothing choices and purchasing behaviour. The overall aim of these studies is to better understand women's clothing preferences and purchasing behaviours. However, the research revealed that rural women prefer to dress more than women in urban areas. The recommendations show that understanding the preferences of women consumers can help clothing companies design quality, well-fitting clothing for women and meet their needs.

Keywords: *behaviour, Clothing Preferences, Purchasing Behaviour, Retail, Women's Clothing*

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1. Introduction

Apparel and ready-to-wear industry ranks high and consumer spending on apparel is also increasing, given these opinions, it is vital to study the fluctuating behaviour of consumers. Clothing is important to everyone as it reflects people culture, personality and interests. People use clothes to improve their personal image, to protect them from hot weather and various weather conditions. People around the world also see clothing as a reflection of current fashion and culture. At the same time, it is an indisputable fact that customers have values that change from customer to customer, such as cooperation, fashion and brand awareness, trust, and emotions.

Indian apparel consumers are experiencing an alteration and are quickly adjusting to fashion trends. Rising disposable earnings, introduction to global trends and apparel brands, and increased stages of trust have led to changes in consumer behaviour. At this intersection, it's fair to say that a successful salesperson should be able to appeal to customers of different ages and classes. This requires improved product packaging and careful product design. Many retailers have begun to analyse the buying behaviour of different types of customers and cut product segmentation, reducing product and promotion based on the characteristics of each customer segment. Product packaging and product presentation are also gaining traction as a way to engage consumers in their in-store shopping experience. This study aims to analyse the clothing purchasing behaviour of retailers. This study shows clothing stores in local stores, international clothing stores and international stores selling different kinds of Indian and Western clothing.

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a). Objective:

This article presents a literature review on women's clothing preferences and purchasing. The core agenda of this study is to disclose the clothing preferences of female consumers and their purchasing behaviours. The study also purposes to determine the aspects that affect consumers' decision to buy ready-made clothing from in-store and out-of-town stores.

b). Literature Review:

Researchers investigated the purchasing habits of mature women through observations at department stores and interviews with Finnish women. They identified clothing fashion, fit preference, brand affinity, preferred retailers, and pricing as key factors influencing their buying decisions. Building on these insights, they devised an innovative model to understand mature female consumers' behaviour. [1]

Researchers examined women's purchasing patterns from various perspectives, including customer appearances, reference groups, product specifications, store characteristics, and promotional activities. They noted that women are discerning about brands, with brand image significantly influencing their decision-making process. Effective product branding and loyalty programs can enhance foot traffic for retailers. The purchasing factor is closely tied to the customer's income level. The quality of merchandise emerges as a crucial aspect influencing purchasing behaviour. Additionally, factors such as price, colour, design, style, and comfort are linked to customer buying patterns. Preferences in purchasing aligns with both the age and income of the customer. [2, 3]

Quality stands out as a pivotal feature influencing customers' purchasing decisions. Given the ever-evolving nature of fashion, tailored to the choices and preferences of customers, brand reputation remains a crucial factor in their buying choices. Apparel retailers must carefully heed the demands and requirements of customers to effectively meet their needs and preferences. Various factors influence the purchasing behaviour of working women. Online shopping is particularly favoured by this demographic as it saves time and offers convenience. It allows them to browse products, add items to their shopping carts, and make purchases at their convenience, even during their leisure time. [4, 5]

Impulse buying behaviour exhibits a notable correlation with gender, age, and marital status. Women tend to display more pronounced impulse buying tendencies compared to men. Particularly, unmarried women under the age of 30 are demonstrating a higher propensity for impulse buying. The association of a brand with prestige is strong. Brand awareness exerts a significant influence on customer purchasing behaviour, particularly in the realm of clothing. The perception of a brand profoundly influences consumer buying decisions. Interestingly, men tend to exhibit higher brand consciousness regarding apparel compared to women. Retailers can cultivate a strong brand image in customers' minds through strategic advertising, offering competitive prices, and delivering high-quality products. [6, 7]

Women may alter their brand loyalty based on factors such as brand image, pricing, and the quality of products offered by competing brands. Additionally, the influence of friends plays a significant role in shaping women's purchasing behaviour and can affect brand loyalty. Research on women's compulsive buying behaviour emphasizes the significance of customer attitude in purchasing decisions. Positive moods often lead to increased purchases, whereas negative emotions or dissatisfaction can alter buying behaviour. Retailers capitalize on this by offering enticing deals, prompting customers to buy products they may not necessarily need. Customers typically feel content when they plan their purchases and stick to their intended shopping lists. [8, 9]

The impact of demographic traits, including age, gender, marital status, income, cultural background, occupation, education, and geographic location, on consumer behaviour is well-documented. Consumer behaviour is dynamic and can vary based on the context and situation. Changes in various demographic factors can result in shifts in consumer behaviour patterns. Women tend to be more frequent purchasers of apparel compared to men. Purchase behaviour in this regard is closely linked to consumer behaviour. Women make their buying decisions based on the quality and price of apparel items. They are often willing to travel to find apparel that meet their preferences. [10, 11]

The study delves into the purchasing behaviour of females aged 16 to 45. Middle-aged women within this cluster tend to buy clothing according to the occasion, with a preference for formal wear. The buying decisions of middle-aged females are often influenced by their spouses. Social factors and product characteristics play pivotal roles in shaping women's purchasing behaviour. The study focuses on the apparel buying behaviour of college-going girls. Among young girls, the design of apparel holds paramount importance. Design and style serve as the primary factors guiding apparel selection for this demographic. Additionally, fabric selection plays a crucial role, with priority given to comfortable fabrics in apparel choices. Retailers should ensure their apparel stock aligns with these preferences by prioritizing design, style, and the use of comfortable fabrics. [12, 13]

The shifting consumer behaviour among women can be attributed to trends such as delayed marriage and declining fertility rates. Identifying impulse buying behaviour in women poses significant challenges. This behaviour presents a major concern for retailers. To address this issue, retailers should focus on strategies such as visual merchandising, offering enticing deals and discounts. Predicting women's purchasing behaviour prior to the point of purchase is highly challenging, as it can change unexpectedly. [14]

The lifestyle of women plays a significant role in shaping their consumer behaviour. Various factors such as demographics, religious beliefs, and cultural norms are intertwined with lifestyle choices, influencing how women make purchasing decisions. Gender plays a pivotal role in influencing buying decisions, with male and female customers exhibiting distinct consumer behaviours even when purchasing the same products. Men typically approach buying decisions analytically and logically, while women tend to make more emotionally driven choices. [15, 16]

A study on the consumer buying behaviour of women's apparel in Malaysia reveals that women prioritize the fit and size of garments, leading them to favour online retailers. Online platforms offer a wide range of size options and varieties, catering to women's preferences. Additionally, women are increasingly opting for online retailers due to time-saving benefits and the availability of discounts on apparel purchases. Women are drawn to online retailing due to factors such as economic growth, increased education levels, and widespread internet access. The plethora of options available for purchasing products online, coupled with post-sales services, makes online shopping appealing to them. The adoption of hassle-free return policies emerges as a crucial element contributing to the triumph of online retailing. Companies should prioritize understanding consumer behaviour to capitalize on these trends and drive profitability. [17, 18]

2. Results and Discussion

Females are influenced by several performance factors while taking a buying decision of apparels that includes price, quality, and assurance. These elements display substantial shares in determining consumer selections in the zone of fashion and clothing.

Women's spending behaviours and decision-making processes are inclined by several elements such as personal values, cultural norms, socioeconomic status, and individual personality traits. Women's profession has an influence on their buying power. Factors such as earnings, employment security, and career development forecasts have an impact on an individual's capability to make purchases and support their family. Additionally, numerous studies have highlighted that working women possess price, quality, and product knowledge.

Price is generally a main concern for many customers. Female assess whether the price of an apparel supports with their perceived worth and affordability. Factors such as personal budget, earnings, and the observed value of the merchandise can influence the price compassion of individual customer. Quality is another fundamental factor that influences apparel purchases. Customers generally seek apparels that are well-made, long-lasting, and can withstand regular wear and washing. The awareness of quality can fluctuate among individuals based on their likings, beliefs, and earlier involvements.

Return policies can also be prevailing elements when it comes to apparel buying. Customers may sense more confident buying apparel items when there is a good return policy in place. Such promises can provide peace of mind and a sense of safety. Also, style, shape, and design are vital concerns for various females when selecting apparels. Women often seek apparels that links with their personal choice, fashion styles, and preferred aesthetics. The style and shape of clothing can add to an individual's self-expression, personality, and overall pleasure with the merchandise. Additionally, cultural inspirations, social customs, and personal beliefs can also impact apparel selection and customer behaviour.

Women's openness to advertising messages is motivated by a different of factors, including personal benefits, traditional background, education, and individual behaviour. Certain types of advertisements, such as those highlighting emotional links or communal connections, may resonate more with females. Many studies have emphasis on understanding the buying behaviour of younger females, there is also value in exploring the buying patterns and preferences of middle-aged and older females. The consumer behaviour of women can change during different life stages, influenced by aspects such as personal development, standard of living, and evolving priorities. Middle-aged and older women often have different requirements, preferences, and buying power, which can considerably influence their buying decisions.

The study of women's consumer behaviour in India, especially the emphasis on metro cities while ignoring the buying patterns in smaller cities. Consumer behaviour can fluctuate substantially between metro cities and smaller cities due to differences in aspects such as income levels, traditional influences, standard of living, and availability of merchandises and services. It is vital to consider the exclusive features and dynamics of consumer behaviour in smaller cities to develop a comprehensive understanding of women's purchasing patterns. This comprises understanding the influence of local culture, availability of retail infrastructure, and specific merchandise preferences that may differ from metro cities.

Escalating research to smaller cities can help marketers and businesses develop more custom-made policies to encounter the requirements and preferences of women consumers in these areas. It can also contribute to a more common understanding of consumer behaviour in India and assist targeted marketing efforts that resonate with a broader range of customers.

The research gap identified revolves around a study that only emphases on the apparel buying behaviour of younger women, excluding the middle-aged and older women. This gap highlights the absence of understanding or knowledge regarding the apparel preferences, motivations, and buying patterns of middle-aged and older women.
To fill this research gap, it is important to conduct studies that specially target middle-aged and older women. Such research can discover numerous dimensions, including their style preferences, brand faithfulness, decision-making processes, the influence of societal factors, and the influence of promotion approaches on their purchasing decisions.

By conducting investigation that comprises a varied age range, a more comprehensive understanding of apparel buying behaviour across different generations can be attained. This awareness would prove supportive for marketers, retailers, and fashion designers as they can modify their merchandises, sales promotions, and policies to encounter the certain requirements and likings of middle-aged and older females.

To initiate this research, surveys, interviews, focus groups, or observational studies can be utilized, precisely targeting the desired age groups. Gathering data on demographics, spending habits, motivations, and dominant factors will yield valuable insights into the apparel buying behaviour of middle-aged and older women. The resulting insights can inform promotion plans and decision-making processes in the apparel industry, allowing for improved alignment with the needs and preferences of middle-aged and older women.

Conducting studies precisely targeting women's apparel and accessories is needed for a more detailed understanding of their consumer behaviour. By exploring several features such as buying motivations, product preferences, decision-making processes, fashion styles, community influences, and the impact of advertising strategies, researchers can gain deeper insights into how females make buying decisions in this precise product category. Narrowing the emphasis to women's apparel and accessories permits for a more targeted analysis of their preferences, shopping habits, and the factors that drive their buying decisions. This information is very much valuable for marketers, retailers, and garment manufacturers, as it permits them to mould their merchandises, advertising campaigns, and policies to encounter the definite needs and desires of women in the apparel and accessories segment.

Studying apparel buying behaviour in metro cities of India, neglecting the specific buying patterns and behaviours observed in small cities. This gap proposes that there is a lack of understanding regarding the apparel preferences, motivations, and buying patterns of customers in small cities. To address this research gap, it would be substantial to conduct studies that precisely target small cities in India to gain insights into their unique apparel buying behaviour. This research could discover numerous features, such as fashion preferences, brand varieties, decision-making processes, shopping channels, the impact of local ethos, and the influence of socio-economic issues on their buying decisions.

By conducting research in small cities, a more comprehensive understanding of apparel buying behaviour in different urban contexts can be achieved. This knowledge would be beneficial for marketers, retailers, and garment manufacturers, as it would enable them to modify their merchandises, promotions policies, and distribution channels to justify to the exact requirements and preferences of customers in small towns. Conducting relative studies that analyse the similarities and differences between metro cities and small cities, in terms of apparel buying behaviour, would be advantageous for understanding the deviations in consumer preferences and patterns across different urban areas. The research gap identified concerns to studies that have mostly focused on online apparel buying behaviour, neglecting the apparel buying behaviour within retail outlets. This gap suggests that there is a lack of awareness regarding the issues that power consumers' apparel buying decisions and behaviours explicitly when shopping in physical retail stores.

To address this research gap, it would be important to conduct studies that precisely target the apparel buying behaviour inside retail outlets. This research could explore various traits, for example the impact of store layout and design, merchandise display and presentation, customer service, pricing policies, and the influence of community relations on consumers' buying decisions within the physical retail atmosphere. By conducting research inside retail outlets, about the features that drive consumers' apparel buying behaviour in offline stores. This information would be favourable for retailers, store managers, and apparel brands as it would permit them to boost their in-store strategies, enhancement the shopping experience, and modify their offerings to encounter the definite requirements and preferences of customers who choose shopping in physical stores.

By addressing this research gap with focused studies on apparel buying behaviour inside retail outlets, researchers can contribute to a more inclusive understanding of consumer behaviour in offline stores. The resulting perceptions can notify retail strategies, store design, customer service practices, and overall decision-making processes, allowing retailers and retail brands to develop the in-store shopping experience and cater to the needs of their customers. Lack of apparel buying behaviour of women studies conducted specifically in India. To address this research gap, it would be appreciated to conduct studies specially focused on apparel buying behaviour within the Indian context. This research could explore several aspects, involving consumer preferences, inspirations, decision-making processes, brand varieties, shopping channels, and the effect of cultural, societal, and commercial factors on apparel buying decisions in India.

By addressing this research gap with focused studies on apparel buying behaviour in India, scholars can contribute to additional comprehensive understanding of consumer behaviour in the Indian apparel market. The resulting insights can update promotion policies, merchandise assortment, and decision-making processes, permitting companies to better fulfil to the requirements and preferences of Indian customers.

3. Conclusion

In this investigation, researchers examined women's preferences and buying habits regarding clothing. They found that women's occupations have a direct impact on their purchasing power as well as that of their families. Furthermore, the study indicates that employed women possess a keen awareness of price, quality, and product specifications, often influenced by others during their shopping endeavours. The study concludes that an individual's clothing purchasing decisions are influenced by various performance factors, including price, quality, and warranty, as well as aspects such as style and fit.

The findings suggest that women generally outperform men in interpreting dress syntax, indicating a higher level of knowledge and sensitivity to clothing cues among women. A study revealed that consumers wearing Indian attire exhibit significant knowledge about clothing. Moreover, these consumers prioritize factors such as quality, variety, and comfort when making purchasing decisions. While research highlights gender disparities in attitudes toward fashion and brands, it also indicates that men share an equal interest in clothing shopping compared to women.

Research has established that women exhibit greater sensitivity to information and content, and are more inclined towards considerations such as education, employment, and marital status while shopping. This response provides insight into the comparative analysis of evolving perceptions and purchasing behaviours between employed and non-employed females in rural India. The findings suggest that the employment status of females significantly impacts their own and their families' purchasing behaviours

4. Scope

The research is based on the age, gender, occupation, income, etc. of female consumers. It includes clothing purchasing behaviours according to variables such as recommendations, influence of sellers and price, quality, advertising, image type, style, etc. The influence of certain factors will impact consumers on their purchase regret.

This study helps marketers and stakeholders understand the purchasing behaviour of female consumers and design products based on their needs. It will also be useful for new entrepreneurs who want to enter the women's clothing business. This will enable them to understand the current customers and future prospects of the same segment.

References:

[1] Holmlund, M., Hagman, A. and Polsa, P. (2011), "An exploration of how mature women buy clothing: empirical insights and a model", Journal of Fashion Marketing and Management, Vol. 15 No. 1, pp. 108-122

[2] Balanaga Gurunathan and Krishna Kumar (2013), "Factors Influencing Apparel Buying Behaviour in India: A Measurement Model", PARIPEX- Indian Journal of Research, 2(3), pp 218-224

[3] K.Maran J. Badrinarayanan and T. Praveen Kumar, (2017)," A Study on Branded Apparels Customers Purchase Behaviour with Reference to India", International Journal of Applied Business and Economic Research, Volume 15, Number 21 (Part 2)

[4] Aleena Johnson (2019)," A Comparative Study on The Buying Behavior and Brand Preference of Men and Women with Regard to The Purchase of Readymade Apparels", International Journal for Research in Engineering Application & Management (IJREAM) ISSN : 2454-9150 Vol-04, Issue-10, Jan 2019

[5] S.Tamilarasi and R.Angayarkanni (2016), "A study on customer's e - shopping behavior and satisfaction: special reference to working women in Chennai", SEUSL Journal of Marketing, Vol. 1, No. 2, 2016

[6] Mitushi Sharma, Radhika Rana, Shambhavi Tripathi, Dr. Ashwini Kumar, (2020), "The study of impulse buying behavior in context with age, gender and marital status", The International Journal of Indian Psychology, Volume 8, Issue 4, Oct- Dec, 2020

[7] Hafiza Ayesha Riaz (2015)," Impact of brand image on consumer buying behavior in clothing sector: a comparative study between males and females of central Punjab (Lahore) and southern Punjab (Multan)", Kuwait Chapter of Arabian Journal of Business and Management Review Vol. 4, No.9; May. 2015

[8] Anjali Sharma, Shruti Bhola, Shweta Malyan and Neha Patni (2013), "Impact of Brand Loyalty on Buying Behavior of Women Consumers for Beauty Care Products- Delhi Region", Global Journal of Management and Business Studies, Volume 3, Number 7 (2013), pp. 817-824

[9] Dr. Prashant Ravindrakumar Pandya, Dr. Kerav Pandya (2022), "A study of women's compulsive buying behaviour, with a special focus on fashion-related products", IJIRT, Volume 8 Issue 11

[10] Rakesh Kumar (2014), "Impact of Demographic Factors on Consumer Behaviour - A Consumer Behaviour Survey in Himachal Pradesh", Global Journal of Enterprise Information System, Volume 6, Issue 2

[11] G. Vaishnavi (2021), "Factors affecting Purchase of Apparels among Working & College Going Women – A Consumer Behaviour Perspective", Annual Research Journal of SCMS, Vol. 9, March 2021

[12] Meenakshi Mishra and Sudha Babel (2020), "Female consumers buying behaviour for fashion apparels: an exploratory study", Asian journal of home science, Volume 15. Issue 1

[13] Garima Tiwari (2015), "A Study on Factors Influencing Buying Decision of College Going Girls towards Kurta", IJMBS, Vol. 5, Issue 3, July

[14] Chitrali Chhabra, Harshvardhan Todi, Shantam K Handa (2018), "Impulse Buying Behaviour among Female Consumers", IJCRT, Volume 6, Issue 1

[15] Zaeema Asrar Mohiuddin (2015), Journal of Accounting, Business and Finance Research, Vol. 2, No. 1, pp. 12-15

[16] Greeshma A (2016), "A Study on the Purchasing Behaviour of Male and Female Consumers in Kannur District", SSRG International Journal of Economics and Management Studies, Volume 3 Issue 12

[17] Arasu Raman (2021), "An Empirical Study on Consumer Buying Behaviour towards Online Shopping with special reference to Women Apparels in Malaysia", Turkish Journal of Computer and Mathematics Education, Vol.12 No.13

[18] Ritu Singh (2020), "Online shopping in Lucknow: a study of women consumer buying behaviour with reference to clothing wear", international journal of advance scientific research and engineering trends, Volume 5, Issue 12

[19] Kapoor, Avinash & Kulshrestha, Chinmaya. (2023), the effect of perception on Indian urban female consumer buying behaviour

A Study on Attributes and Buying Behaviour of Females towards Intimate Apparels

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Abstract:

Lingerie as a product category now boasts a wide product range, with creative advances serving as the industry's backbone. Consumers today have an array of options, ranging from fashion and styling to high end fashion. The fact that women fashion has always been reflected as advancements in society which is undeniable. And, as Indian women reach adulthood, the statement takes on added significance when discussing what they wear. Financial freedom is one of the top concerns for Indian women, particularly in urban areas, and with it comes the opportunity to live a lifestyle that suits one's interests and inclinations. Women enjoy wearing expensive jewellery, carrying high-end electronics, and purchasing clothing and footwear that make them look beautiful, feel comfortable, and express their style statement subtly. When it comes to asking for innerwear or lingerie, the faces that used to be hesitant and 'do not pass your limit' have become less aggressive and more argumentative. Like many Indians who enjoy arguing about anything, Indian ladies now want to discuss their innerwear with persons who can help them get the right things they want. Women used to be at the sole discretion of salesmen who used to pick on the perfect piece of lingerie for them based on size, fit, and brand. The study is concerned with the attitudes, characteristics, and purchasing decisions of young women towards lingerie, as well as its role in today's quickly changing times. A systematic questionnaire is used to collect data from 100 young women between the ages of 18 and 30 years.

Keywords : *attitudes, attributes, Consumer behaviour, lingerie, intimate apparel, sales promotion*

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1. Introduction

The introduction of several major multinational brands into the Indian market in recent years indicates that India has enormous growth potential for the lingerie business. When it comes to purchasing lingerie, Indian women are still highly hesitant. However, they are gradually becoming bolder when it comes to their choice of selecting lingerie and as a result, the Indian scenario of the lingerie market is changing rapidly as one can find the rise of branded national and international lingerie flooding in India. Indian women have become more conscious about their looks because of reasons such as an increase in the number of working women, changing fashion trends, improved knowledge and media exposure, and the influx of well-known multinational companies into the Indian market. Demographic factors like age, education, occupation, income, and city of residence also influence the buying behaviour. Most of researches available on lingerie till date majorly focuses on one factor i.e., the age of consumer depicting their various buying motivations related to body size, shape, and social acceptance because of their intimate apparels [1].

The old practise of storing lingerie in a closet corner is no longer practiced in modern times. Rather, women's taste in undergarments has reached new heights, and it is not overstated to suggest that it has become a fashion statement. A closer look of the reasons behind this transformation points to various trends, the most prominent of which is women's shifting attitude towards their innerwear. There may be several factors which can influence the purchasing decisions of intimates: aesthetic, functional, physical, religious, etc. Out of these, the aesthetic factors play an important role during the process of purchasing intimate [6].

Women's outerwear has changed significantly in recent years, from salwar-kameez and saris to denims, t-shirts, and feminine tops, particularly in urban regions. As a growing number of women join professional lives where they require smart outerwear for the office, parties, and recreation, they choose innerwear that matches the outerwear. The fitness aspect has fueled sales of sports brassieres and briefs designed for women's athletic activities. Finally, significant occasions such as a wedding or social gatherings necessitate a unique look. The aesthetic aspects involve the colour, style, shape, material, texture, line, form, fitting and finishing of the intimate which denotes the appearance or the attractiveness. Colour is considered as a key issue and obvious noticeable fact at glance in a product [3].

The main objective of the Study were:

1. To study the attitudes of young women towards lingerie and its purpose in today's rapidly changing times.

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2. To analyze the factors that influence women's lingerie purchasing decisions.
3. To analyze the most preferred brands of intimate apparel.
4. To study the effect of sales promotion of buying of the intimate apparel

Limitations of the study

1. The study has been done only for women consumers in the age group of 18-30 years.
2. The sample has been taken only from Jaipur.
3. The type of lingerie has been restricted to brassieres and knickers.

2. Material & Methods

Locale of study: The locale of the study was Jaipur.
Selection of method: Close-ended Questionnaire was prepared for collection of data.

Selection of sample: A total of 100 women between the ages of 18 and 30 were approached to complete out the questionnaire and provide information. The samples were chosen at random.

Data collection: Primary data was gathered using questionnaires, and secondary data was gathered through books, journals, magazines, and the internet.

Analysis of data: The questionnaire data was transferred to the coding sheet by assigning numerical values to the responses. This enhances data tabulation and analysis by reflecting the percentage of data.

3. Analysis of Data & Interpretation

Table 1: Family type (n=100)

S. No.	Family type	Frequency (n=100)	Percentage (%)
1.	Nuclear	62	62%
2.	Joint	38	38%

According to the data presented above, 62% of respondents belong to a nuclear family, while 38% belong to a joint family. As a result, it can be stated that the size of the family has a direct impact on the family's clothes consumption pattern.

Table 2: Monthly income of family (n=100)

S. No.	Monthly income of family (in rupees)	Frequency (n=100)	Percentage (%)
1.	Up to ₹50000	16	16%
2.	₹50001- ₹75,000	35	35%
3.	₹75001- ₹1,00,000	37	37%
4.	₹1,00,001- ₹1,25,000	12	12%

According to the above table, majority (37%) of the respondent has a monthly income above ₹75001- ₹1,00,000, followed by 35% with an income bracket of ₹50001- ₹75,000, 16% earned up to ₹50000, and the remaining 12% earned up to ₹1,00,001/-1,25,000. As a result, it is assumed that family income plays a major and influential role in purchasing the products.

Table 3: Most preferred intimate apparel by women (n=100)

S. No	Most preferred intimate apparel	Frequency	Percentage (%)
1.	Branded	72	72(%)
2.	Non-Branded	28	28(%)

According to the above table, 72% of women preferred branded intimate apparel over 28% who selected non-branded intimate apparel. In conclusion, women today choose branded intimate apparel over non-branded intimate apparel because of the style, fit, and comfort.

Table 4: Preference towards shopping style (n=100)

S. No.	Preferences	Frequency	Percentage (%)
1.	Mass merchandiser	16	16%
2.	Shopping Mall	56	56%
3.	Mono Brand Store	20	20%
4.	Specialized store	30	30%
5.	Online store	38	38%

The above mentioned table reveals that 56% of women went to the shopping malls to purchase intimate apparel, 38% women visit online stores, 30% women go to the specialized store, 20% of women visit the mono branded store and the remaining 16% purchase intimate apparel by mass merchandiser. Hence, it can be concluded that women are more prompt to malls and online store so that they may get a quality and wide range of products under one roof.

Table 5: Preferred Brand for Intimate Apparel (n=100)

S. No.	Branded means	Frequency	Percentage (%)
1.	H & M	20	20%
2.	Zivame	06	6%
3.	Jockey	42	42%
4.	Enamor	03	3%
5.	Triumph	05	5%
7.	Marks & Spencer	06	06%
8.	Body care	12	12%
9.	Others	06	6%

From the above table, it can be revealed that 42% of women preferred Jockey as intimate apparel which means quality assurance to them, followed by H & M (20%), Body care (12%), Zivame, Mark & Spencer and Others (6%), Triumph (5%) and Enamour (3%). It can be concluded that Jockey is the most favourite intimate apparel among the youth due to the affordability, and durability of the product.

Table 6: Attributes when buying intimate apparel (n=100)

S. No.	Attributes means	Frequency	Percentage (%)
1.	Comfort	88	88%
2.	Fit	80	80%
3.	Colours	58	58%
4.	Style & Design	45	45%
5.	Price	68	68%
6.	Availability of matching lingerie	18	18%

According to the above table, branded means comfort for 88% of women, fit for 80% of women, price for 68% of women, colours for 58% of women, style and design for 45% of women, and availability of matching lingerie for 18% of women. As a result, it can be inferred that comfort and fit play a significant part in brand for women in terms of product longevity.

Table 7: Money spend on average on intimate apparel (n=100)

Sr. No.	Money spend on average for intimate apparel	Frequency	Percentage (%)
1.	₹500- ₹1000	46	46%
2.	₹1000- ₹1500	34	34%
3.	₹1500- ₹2000	18	18%
4.	₹2000- ₹2500	02	2%

The above table shows that the majority (46%) of women spend ₹500- ₹1000, followed by 34% who spend ₹1000-₹1500, whereas 18% of women spends ₹1500-₹2000, 2% spends ₹2500- ₹3500 on an average for intimate apparel. The results of this survey showed that family income has a direct impact on purchasing branded intimate apparel.

Table 8: Preferred style of intimate apparel (Bra) (n=100)

S. No.	Preferred style of intimate apparel	Frequency	Percentage (%)
1.	Soft cup Bra	54	54%
2.	Sports Bra	12	12%
3.	Push -Up Bra	05	5%
4.	Balconette/ Demi Cup Bra	02	2%
5.	Full Support Bra	16	16%
6.	Underwire Bra	06	6%
7.	Strapless Bra	02	2%
8.	Bralette	03	3%

According to the findings based on the facts presented on above data depicts 54% of the respondents preferred soft cup bra, 16% preferred full support bra, 12% preferred sports bra, 6% underwire bra, 5% push-Up bra, 3% bralette and remaining 2% of the respondents preferred demi cup bra and strapless bra for intimate apparel. Thie result revealed that most of the women preferred soft cup bra in comparison to others because of the stretchability and level of comfort.

Table 9: Preferred style of intimate apparel (Panties) (n=100)

S. No.	Preferred style of intimate apparel	Frequency	Percentage (%)
1.	Boylegs/ Boy shorts	02	2%
2.	Classic brief	34	34%
3.	High Cut	08	8%
4.	Hipsters	24	24%
5.	Bikinis	09	9%
6.	Thongs	02	2%
7.	Seamless	21	21%
8.	G-String	--	--

According to the findings based on the facts presented above shows that 34% of the women preferred classic briefs, 24% preferred hipsters, 21% preferred seamless, 9% bikinis, 8% high cut, and remaining 2% of the respondents preferred boys shorts and thongs for intimate apparel. In accordance with this survey it can inferred that most of the women choose classic briefs in comparison to others because of the ease and comfort level.

Table 10: Preference regarding Fabric of intimate apparel (n=100)

S. No.	Preference regarding the Fabric of intimate apparel	Frequency	Percentage (%)
1.	Lace	02	2%
2.	Satin	06	6%
3.	Lycra	28	28%
4.	Cotton	44	44%
5.	Polyester	08	8%
6	Nylon	05	5%
7	Spandex	07	7%

According to the findings based on the facts presented above shows that 44% of the women preferred cotton, 28% preferred lycra, 8% preferred polyester, 7% spandex material 6% satin, 5 % nylon and remaining 2% of the respondents preferred lacey material for intimate apparel. In accordance with the results of this survey, most of the women preferred cotton and lycra material in comparison to others because of the stretchability and level of comfort.

Table 11: Frequency for purchase intimate apparel in a year (n=100)

S. No.	How many times women purchase intimate apparel	Frequency	Percentage (%)
1.	Once	10	10%
2.	Twice	52	52%
3.	Thrice	25	25%
4.	More than thrice	13	13%

According to the above table, 52% of women purchased intimate apparel twice per year, 25% purchased three times per year, and 13% purchased more than three times per year. The remaining 10% of women bought intimate wear only once a year. As a result, it can be stated that women purchased personal items more frequently in response to a need.

Table 12: Does sales promotion influence women for intimate apparel (n=100)

S. No.	Sales promotion influence women	Frequency	Percentage (%)
1.	Yes	74	74%
2.	No	26	26%

According to the above table, 74% of females were impacted by sales promotion, while 26% were unaffected by sales marketing techniques. As a result, it can be inferred that most women were impacted by sales promotion since it attracts young consumers to intimate clothing and inspires existing customers to make larger purchases. Buy one get one free promotions are a great way for marketers and manufacturers to clear out their inventory rapidly [3].

Table 13: Sales promotion tools which influences women (n=100)

S. No.	Sales promotion tool	Frequency	Percentage (%)
1.	Coupons	16	16%
2.	Discounts	67	67%
3.	Gift cards	13	13%
4.	Scratch card	02	2%
5.	Buy two get one free	04	4%

According to the above table, most (67%) of the respondents were impacted by discounts, followed by 16% of respondents who were influenced by coupons in sales promotion tools, 13% of respondents who were influenced by free-samples/free gifts. Buy two get one free deals impacted 4% of respondents, while scratch cards affected 2%. From the above data it can be pertained that most of the women were impacted by discounts and eagerly awaited the discount price and attractive plans for the purchase of branded intimate clothing.

Buy one get one free is defined as one of the most used sales promotion tools, in the sense that buy one and get one free for no cost is a technique in which the customer is easily enticed to buy the product because there is no additional cost and it should be more valuable from the customer's perspective, so the customer can't ignore such a great deal. Bonus packages and free supplementary products encourage people to acquire the product since they have a positive attitude towards such offers, especially if they are in large sizes and adequately publicised. Furthermore, such promos boost product trial and client switching [4]

From the table, it can be depicted that majority(46%) of the respondents generally purchase the same brand even when they have a sales promotional tool for other brand, followed by 20% who responded that sales promotional tool has allowed them to buy the product earlier than planned, 16% of the respondents revealed that sales promotional tool has prompted them to purchase another brand that what they do not regularly purchase and 10% quoted sales promotional tool has prompted them to purchase another brand that they do not regularly purchase and 8 % of them quoted that sales promotional tool has encouraged them to purchase a product that they have never used before. It may be stated that most of the females were influenced by sales advertising tools and waited patiently for discounted rates and good schemes for buying goods.

Brand plays a major role in female consumer's decision-making process. Three points emerged as drivers in process of decision making in retailing. The first one is emotional (Brand), second is service (Outlet atmosphere) and third is experience (consumption and shopping) [2].

Table 14: Sales promotional tool affect the behaviour of buying of the intimate apparel (n-100)

S. No.	Effect of sales promotional tool	Frequency	Percentage
1.	A sales promotional tool prompted me to purchase a brand that I do not normally purchase.	16	16%
2.	I normally purchase the same brand even when I have a sales promotional tool for other brands.	46	46%
3	A sales promotion tool prompted me to purchase the product earlier than expected.	20	20%
4.	A sales promotional tool has prompted me to purchase another brand that I do not regularly purchase.	10	10%
5	A sales promotional tool has prompted me to purchase a product that I have never tried before	08	8%

4. Conclusion

The consumer behavior of young women towards intimate apparels is influenced by various factors such as brand familiarity, perceived risk, attitudes, purchase intentions, fashion trends, peer influence, quality, comfort and price. Intimate apparels are not only functional but also symbolic of personal identity and self-expression. Therefore, marketers need to understand the preferences and motivations of this segment and design products and strategies that appeal to them.

Reference :

[1] Chen, C. M., Labat, K., & Bye, E. Bust prominence related to bra fit problems. International Journal of Consumer Studies, vol. 35, pp 695–701, (2011)

[2] Granot, E., Greene, H., & Brashear, T.G. Female consumer: decision making in brand –driven retail. Journal of Business Research, vol. 63(8), pp 801-808, (2010)

[3] Li, S., Sun, Y., & Wang, Y. 50% Off or Buy One Get One Free? Frame Preference as a Function of Consumable Nature in Dairy Products. The Journal of Social Psychology, vol, 147(4), pp 413–421. https://doi.org/10.3200/socp.147.4.413-422(2007)

[4] Sinha, I. & Smith, M. F, Consumers perceptions of promotional framing of price. Psychology & Marketing, vol, 17(3), pp 257-275, (2000)

[5] Solomon, R. M., & Rabolt, J. N. Consumer Behaviour: In Fashion. Retrieved from https://www.pearson.com/us/higher education/product/Solomon-Consumer Behavior-In Fashion/9780130811226.htm. (2006)

[6] Tsaousi, C. Consuming underwear: Fashioning Female Identity. Retrieved from https://figshare.le.ac.uk/articles/thesis/Consuming_Underwear_Fashioning_Female_Identity/10100939, (2014)

Antimicrobial Finish in Textiles

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Abstract

The consumers are now increasingly aware of the hygienic life style and there is a necessity and expectation for a wide range of textile products finished with antimicrobial properties. In the development of fabrics, functional aspects such as anti-bacterial and UV protection are playing an increased important role. To protect the mankind and to avoid cross contamination, a special finish like antimicrobial finish has become necessary. As consumers have become more aware of hygiene and potentially harmful effects of microbes, the demand for antimicrobial finished clothing is increasing. The population explosion and the environmental pollution in recent years have forced researchers to find new health and hygiene related products for the wellbeing of mankind. The threats caused by microbes are numerous and the problem is aggravated even more in tropical and subtropical regions. Pathogenic microorganisms transfer infectious diseases and cause lung related disorders. Mould and fungi cause staining, discoloration and degradation of textile substrates, particularly those made of natural fibres (protein and cellulosic fibres). Nowadays, there is a good deal of demand for fabrics with antimicrobial finishes to protect human beings against microbes. The application of antimicrobial textile finishes includes a wide range of textile products for medical, technical, industrial, home furnishing and apparel sectors.

Keywords: *Antimicrobial, Antibacterial, functional, Hygienic, Microbes*

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1. Introduction

Hygiene has become essential to human beings way of life. Consumers' attitude towards hygiene and active lifestyle has created a rapidly increasing market for a wide range of functional textiles, which in turn has stimulated intensive research and development. Value addition in clothing has changed the global textile scenario. Research has quite convincingly shown that apparel consumers all over the world are demanding functionality in the products that they use. When textile assumes an additional function over and above the conventional purpose, it may be regarded as speciality or functional textile. To realize our dream of new fibres and environment friendly wet processing, it is essential to invest in future research and "researchers" [1, 2].

The textile industry of the future looks very promising – something to revive our spirits considering the fact that it is considered an obsolete technology. However, the textile industry is required to shift its emphasis from "quantity" to "quality" and adopt itself to the dynamism of the market economy. As a result, the number of bio functional textiles with an antimicrobial activity has increased considerably over the last few years. Some of the best examples of functionality are the products attributes such as wrinkle resistance, soil release, flame retardant, oil repellency, fade resistance, UV resistance, anti-allergy, insect repellent, stain release, anti odour, microbial resistance, fragrance release, protective finishes, skin care additives, insect repellent, deodorizing fragrance, antimicrobials, cool finish and thermal insulator finish, water proofing finish and UV stabilizers. Functional finishes represent the next generation of finishing industry, which make textile materials act by themselves. This means that they may keep us warm in cold environments or cool in hot environments or provide us with considerable convenience, support, and even fun in our normal day-to-day activities [3].

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2. Antimicrobial finish

2.1 Need for Antimicrobial Finish in Textiles

The term 'antimicrobial' refers to a broad range of technologies that provide varying degrees of protection for textile materials against microorganisms. Antimicrobials are very different in their chemical nature, mode of action, impact on people and the environment, handling characteristics, durability, costs, regulatory compliance, and how they interact with microorganisms. The purpose of imparting antimicrobial activity to textiles is to protect the material from microbial attack, prevent the transmission and spreading of pathogenic microorganisms, inhibit odour development resulting from microbial degradation, and creating a material that will act as preventive and/or curative treatment. Ideal antimicrobial finishing needs to fulfill a number of requirements in order to achieve the maximum benefit from antimicrobially functionalized textile products. An antimicrobially-treated material is defined as being hygienic and, therefore, should have the following requirements. Effective inhibition against a broad spectrum of bacterial and fungal species, non-toxicity to the consumer, manufacturer and the environment, durability, compatibility with resident skin micro biota, and other finishing processes, avert from irritations and allergies, applicability with no adverse effects on the quality or appearance of the textile [4].

In recent years, great interest in the antibacterial finishing of fibres and fabrics for practical applications has been observed. Most textile materials currently used in hospitals and hotels are conducive to cross-infection or transmission of diseases caused by micro-organisms. Textiles for medical and hygienic use have become important areas in the textile industry. In general, antimicrobial properties can be imparted to textile materials by chemically or physically incorporating functional agents onto fibres or fabrics. The antimicrobial properties of such textile materials can be grouped into two categories, temporarily or durably functional fabrics [5].

Temporary biocidal properties of fabrics are easy to achieve in finishing, but easy to lose in laundering. Durability has generally been accomplished by a common technology, a slow-releasing method. According to this method, sufficient antibacterial agents are incorporated into fibres or fabrics by means of a wet finishing process. The treated fabrics deactivate bacteria by slowly releasing the biocide from the materials. However, the antibacterial agents will vanish completely if they are impregnated in materials without covalent bond linkages. The inherent properties of the textile fibres provide room for the growth of microorganisms. Besides, the structure of the substrates and the chemical processes may induce the growth of microbes. Humid and warm environment still aggravate the problem. Infestation by microbes causes cross infection by pathogens and develop odour where the fabric is worn next to skin. In addition, the staining and loss of the performance properties of textile substrates are the results of microbial attack. Basically, with a view to protecting the wearer and the textile substrate itself antimicrobial finish is applied to textile materials [6].

Antimicrobial are used on textiles to control bacteria, fungi, mold, mildew, and algae and the problems of deterioration, staining, odour and health concerns that they cause. In the broad array of microorganisms there are both good and bad types. Control strategies of the bad organisms must include consideration of being sure that non-target organisms are not affected or that adaptation of microorganisms is not encouraged.

Microorganisms cause problems with textile raw materials and processing chemicals, wet processes in the mills, roll or bulk goods in storage, finished goods in storage and transport, and goods as they are used by the consumer. This can be extremely critical to a clean room operator, a medical facility, or a food processing facility, or it can be an annoyance and aesthetic problem to the athlete or normal consumers. The economic impact of microbial contamination is significant and the consumer interests and demands for protection is at an all-time high.

Antibacterial fabrics are important not only in medical applications but also in terms of daily life usage. The application of antimicrobial finishes to textiles can prevent bacterial growth on textiles. Antibacterial textile production has become increasingly prominent for hygienic and medical applications. The antimicrobial agents can be antibiotics, formaldehyde, heavy metal ions (silver, copper), quaternary ammonium salts with long hydrocarbon chains, phenol and oxidizing agents such as chlorine, chloramines, hydrogen peroxide, ozone. Antimicrobial Finish is important for general textiles and high performance applications where the chance of microbial growth is high [7].

Antimicrobials fabrics gained significant importance due to their wide acceptance as surgical apparels, baby clothing and undergarments. In the last few decades, with the increase in new antimicrobial fibre technologies and the growing awareness about cleaner surroundings and healthy lifestyle, a range of textile products based on synthetic antimicrobial agents such as triclosan, metal and their salts, organometallics, phenols and quaternary ammonium compounds, have been developed and quite a few are also available commercially. Although the synthetic antimicrobial agents are very effective against a range of microbes and give a durable effect on textiles, they are a cause of concern due to the associated side effects, action on non-target microorganisms and water pollution. Hence, there is a great demand for antimicrobial textiles based on ecofriendly agents which not only help to reduce effectively the ill effects associated due to microbial growth on textile material but also comply with the statutory requirements imposed by regulating agencies [8].

Cellulose fibres have found a broad application in medical textile field owing to the unique characteristic, such as high moisture and liquid adsorption, low impurity content, antistatic behavior, and good mechanical properties. However, cellulose fibres provide an excellent surface for microorganisms' growth. Due to their molecular structure and a large active surface area, cellulose fibres, may be an ideal matrix for the design of bioactive, biocompatible, and intelligent materials. According to the literature cellulose fibres are one of the most interesting basic materials for antimicrobial fictionalization. The surface modification of the cellulose fibres is currently considered to be the best route for obtaining modern functionality on textiles for the use in medical applications. However, in spite of various techniques used for fibre fictionalization in order to impart antimicrobial properties and to develop biomedical products, there is still a large gap within the research field of interactions between bacterial and fungal systems and bioactive surfaces of medical textile materials. Standard test methods are commonly applied to determine the efficiency of antimicrobial agents. These methods do not usually reflect in-use circumstances, because the majority of tests have only been performed in liquid media and not on dry, complex heterogeneous systems such as functionalized fibrous materials. Testing and evaluating antimicrobial efficiency in laboratory conditions with respect to the real-life environment is rather challenging. Thus, the test selected and interpretations made may vary on the basis of the different capability of antimicrobial action. The evaluation of any antimicrobial test results requires a thoughtful and basic understanding of microbiology, understanding the strengths and limitations of each test and understanding the mode of action of the antimicrobial agent in question [9].

Following are the major requirement for an effective antimicrobial finish:

1. Durability to washing, dry cleaning and hot pressing
2. Selective activity to undesirable microbes
3. It should not produce harmful effects to the manufacture, user and the environment
4. It should compile with the statutory requirements of regulating agencies
5. Compatibility with the chemical processes
6. Easy method of application
7. No deterioration of fabric quality
8. Resistant to the body fluids
9. Resistant to disinfectant/sterilization
10. Quick acting and effective in killing or inhibiting the growth of a broad spectrum of microbes
11. Non-selective and non-mutable to pathogens
12. Fast to repeated laundering, dry cleaning and exposure to light
13. Safe and comfortable to wear (No irritation to skin)
14. Minimal environmental impact
15. Compatible with other finishing agents
16. Low cost

Antimicrobial treatment for textile materials in necessary to fulfill the following objectives:

1. To avoid cross infection by pathogenic microorganisms.
2. To control the infestation by microbes
3. To arrest metabolism in microbes in order to reduce the formation of odour.
4. To safeguard the textile products from staining, discoloration and quality deterioration

2.2 Need for Herbal Antimicrobial Finish

There is significant development in investigation of eco-friendly, natural antimicrobial finish for application on textile substrate.

The following requirements need to be satisfied to obtain maximum benefits out of the finish:

1. Durability to washing, dry-cleaning and hot pressing.
2. Selective activity to undesirable microorganisms.
3. Should not produce harmful effects to the manufacturer, user and the environment.
4. Should comply with the statutory requirements of regulating agencies.
5. Compatibility with the chemical processes.
6. Easy method of application. No deterioration of fabric quality.
7. Resistant to body fluids; and resistant to disinfections / sterilization

The natural variants possess more potential for investigation because of following reasons:

1. Eco-friendly
2. Least toxicity
3. Suitability for next-to-skin innerwear
4. Vast scope of research to counteract microbe's resistant development towards antimicrobial finishes
5. Safe handling.

Nature has been a source of medicinal agents and has been isolated from natural sources. Many of these isolations were based on the uses of the agents in traditional medicine. The plant-based, traditional medicine systems continue to play an essential role in health care [10]. Among these, development of antimicrobial textile finish is highly indispensable and relevant since garments are in direct contact with human body. Though a number of commercial antimicrobial agents have been introduced in the market, their compliance to the regulations imposed by international bodes like EPU is still unclear. The herbal antimicrobial finishes overcome the disadvantages of chemical finishes. They will not cause damage to the fabrics, are eco-friendly, non-toxic, non-allergic and since naturally occurring herbs are used, the cost factor is also feasible [11]. Extracts of medicinal herbs-in particular essential oils-have shown many potential applications in folk medicine, fragrance, cosmetic, phyto-preparations and food technology as reported by several researchers [12]. Several medicinal and herbal plants are indigenous to the Mediterranean region [13-16] the unique geographical locations of Jordan led to the diversity in its ecological and climate regions. Aromatic plants have been used in folk medicine as antimicrobial agents since ancient times.

3. Microorganisms involved in textiles

Mould, mildew, fungus, yeast, bacteria and virus (micro-organisms) are part of our everyday lives. There are both good and bad types of microorganisms. The thousands of species of micro-organisms that exist are found everywhere in the environment, on our garments and on our bodies. Microbes, their body parts, metabolic products and reproductive parts, cause multiple problems to textiles. These are human irritants, sensitizers, toxic-response agents, causers of disease and simple discomforting agents.

3.1 The Microbial Growth Promoters

The human skin is usually crowded with innumerable microbes. In favourable conditions certain bacteria can grow from a single germ to million in a very short period of time. They can double every 20 to 30 minutes in a warm and most micro climate that has plenty of food for them, e.g. perspiration and other body secretion, skin particles, fats and leftovers from worn out threads. The common promoters are as following:

1. Temperature
2. Moisture
3. Dirt
4. Receptive Surface
5. Perspiration
6. Food Particles
7. Textile Finishes

Although microbes can be useful in many ways e.g. in brewing, baking and biotechnology, they can also be harmful to both textile and humans. The various effects of microbes are stated as follows:

1. Bad Odour
2. Skin and Soft Tissue Infections
3. Staining of Fabric
4. Slick slimy handle
5. Loss of Functional Properties
6. Decrease in Life of textile

Cotton textiles in contact with the human body offer an ideal environment for microbial growth. Microbes are the tiniest creature not seen by naked eyes. They include a variety of microorganisms like bacteria, fungi, algae and virus. Bacteria are unicellular organisms which grow rapidly under ideal condition like moisture and warmth. Subdivision of the bacteria family includes two classes Gram positive and Gram negative, of which Staphylococcus aureus and Klebsiella pneumoniae respectively are the typical examples. Some specific types of bacteria are pathogenic and cause cross infection. Fungi, moulds or mildew are complex organisms with slow growth rate. They stain the fabric and deteriorate its performance properties. To protect the textiles and mankind from pathogen and to avoid cross infection, a special finish like antimicrobial finish has become necessary [17].

The mechanism is either on the cell during the metabolism or within the core substance (genome). Oxidizing agents such as aldehydes, halogens and proxy compounds attack the cell membrane, get into cytoplasm and affect the enzymes of the micro-organism. Coagulants, primary alcohols irreversibly denature the protein structure. Radical formers like halogens, isothiazones and peroxy compounds are highly reactive due to the presence of free electrons. These compounds virtually react with all organic structure in particular risk to nucleic acids by triggering mutations and dimerization. There are many natural/herbal products which show antimicrobial activities [18].

Microbial shedding from our body contributes to microorganism spreading into a textile material either directly in clothes or on surrounding textiles. Recent studies strongly support that contamination of textiles in clinical settings may contribute to the dispersal of pathogens to the air which then settle down and infect the immediate and non-immediate environment. It is one of the most probable causes of hospital infections [19].

Typically, pathogenic microorganisms like Klebsiella pnuemoniae, Pseudomonas aeuroginosa, Staphylococcus epidermidis, Staphylococcus aureus and Candida albicans have been found on textiles. In addition, microorganism proliferation can cause malodours, stains and damage the mechanical properties of the component fibres that could cause a product to be less effective in its intended use. Additionally, may promote skin contamination, inflammation and in sensitive people, atopic dermatitis [20].

4. Functional Finishes on Textiles

Fuctionalization of textile materials can be defined as a process which provides functional properties to textile and clothing materials. Functional properties can be obtained either by:

- The fibre itself (characteristics of the polymer or additives before fibre spinning)
- Yarn, fabric or material construction (for instance, with different fibres or different layers)
- Textile finishing

This can be made by all the traditional technologies, such as: exhaustion, padding, low add-on processes, foam application, printing, coating, etc. The innovative effects are assured by the application of specialty chemicals which can be applied by means of new alternative supports, such as microencapsulation, by using cyclodextrines. These alternatives are now very important for the application of several functional finishes, especially when a long term effect is intended, with controlled release of chemicals. The emergence of the so-called "nanotechnologies" opens also a wide range of new possibilities. In many cases, the functional properties involve a surface modification, which can be obtained by means of chemical modification, by the application of a surface layer or by more environmental friendly treatments such as the use of enzymes or physical modification (based namely on plasma technology).

The consumers are demanding textile products with higher performances, even in the "traditional" clothing and home textiles areas. In fact, significant product differentiation in the area of textiles can be achieved by high performance properties, in parallel with visual appearance. Some of these properties were developed mainly for "protective" clothing but nowadays they are often present in functional textiles used for "normal" clothing. Many fabric producers are devoting more and more attention to try to put into the market products with new effects that can represent an important added value.

The many antimicrobial agents used in textile applications include halogenated salicylic acid, anilides, aromatic halogen compounds, chlorinated diphenylethers (Triclosan), benzoic esters, metal compounds (e.g., Ag, Zn, Cu), quaternary ammonium compounds, and chitosan. Antimicrobial agents can be integrated into the fibres directly or can be applied to textile surfaces by conventional textile finishing processes. The main advantages of finishing are higher productivity and relatively low processing cost. However, many textiles finished this way have lower durability against repeated home launderings than the fabrics consisting of antibacterial fibres.

4.1 Antimicrobial Finishing Methodologies

The antimicrobial agents can be applied to the textile substrates by exhaust, pad-dry-cure, coating, spray and foam techniques. The substances can also be applied by directly adding into the fibre spinning dope. It is claimed that the commercial agents can be applied online during the dyeing and finishing operations. Various methods for improving the durability of the finish include:

1. Insoulbilisation of the active substances in / on the fibre.
2. Treating the fibre with resin, condensates or cross-linking agents.
3. Micro encapsulation of the antimicrobial agents with the fibre matrix.
4. Coating the fibre surface.
5. Chemical modification of the fibre by covalent bond formation.
6. Use of graft polymers, homo polymers and / or co-polymerization on to the fibre.

4.1.1 Types of Antimicrobial Agent

There are several different classifications for antimicrobial agents in the literature according to the chemistry, the mechanism of antimicrobial activity, efficiency, and washing-resistance. Consistent with these studies, antimicrobial substances can be divided into biocides and biostats, leaching and bound antimicrobials, controlled-release and barrier-forming agents, synthetic and natural, and agents of poor and of good washing resistance. In general, the antimicrobial agents can have a biocidal or biostatic effect on microbial growth rates. Whilst the biocides (bactericides and fungicides) cause the death of microorganisms, the biostats (bacteriostats and fungistats) lead to the inhibition of the microorganisms' growth. The mode of action is strongly dependent upon the concentration of the active substance in the textile. The minimum inhibitory concentration (MIC) is required for biostatic activity, while the minimum biocidal concentration (MBC) should be exceeded for biocidal activity. Many commercially-used antimicrobial products, e.g. silver, triclosan, polyhexamethylen biguanid (PHMB) and quaternary ammonium compounds are biocides.

4.1.2 Mechanism of Antimicrobials

Development of antimicrobials for clinical use has been most successful in targeting essential components of 5 general areas of bacterial metabolism: cell wall synthesis, protein synthesis, RNA synthesis, DNA synthesis, and intermediary metabolism. It is beyond the scope of this discussion to cover each of these areas in detail. Instead, focus on some recent developments in novel inhibitors that target dual steps in cell wall synthesis, in understanding the pathways by which antimicrobial agents of diverse types may effect cell killing, and in understanding the interactions of quinolones with their dual targets and the consequences of these interactions.

Mechanisms of action of antibacterial agents are given below

- Interference with cell wall synthesis
  β-Lactams: penicillin, cephalosporin, carbapenems, Monobactams
  Glycopeptides: vancomycin, teicoplanin
- Protein synthesis inhibition
  Bind to 50S ribosomal subunit: macrolides, chloramphenicol, clindamycin, quinupristin-dalfopristin, linezolid.
  Bind to 30S ribosomal subunit: aminoglycosides, tetracyclines
  Bind to bacterial isoleucyl-tRNA synthetase: mupirocin reference with nucleic acid synthesis
  Inhibit DNA synthesis: fluoroquinolones
  Inhibit RNA synthesis: rifampin
- Inhibition of metabolic pathway: sulfonamides, folic acid analogues
- Disruption of bacterial membrane structure: polymyxins, daptomycin.

On the basis of the number of antimicrobials in clinical use, bacterial cell wall synthesis has been perhaps the target area most extensively exploited for antimicrobial development, although bacterial protein synthesis may be a close second. The components of the cell wall synthesis machinery are appealing antimicrobial targets because of the absence of counterparts in human biology, thereby providing intrinsic target selectivity. It is possible to determine the site in the synthesis pathway at which an antimicrobial acts by measuring accumulation of precursors and blocks in development of immature and mature peptidoglycan. β-Lactam antimicrobials are known to interact with transpeptidase directly, forming covalent linkages that have enabled the study of their actions by use of labeled β-lactam molecules to tag these enzymes, which are also designated penicillin binding proteins because of this property.

Bactericidal activity is a general property of β-lactams, glycopeptides, amino glycosides, and quinolones. For all of these classes, however, interaction with their various drug targets, cell wall synthesis for β-lactams and glycopeptides, the bacterial ribosome for amino glycosides, and DNA gyrase and topoisomerase IV for quinolones, although a necessary initial event, is not by itself sufficient to affect bacterial lethality. Subsequent events are required, but the molecular nature of these events has been elusive. β-Lactams as transpeptidase inhibitors thus block the conversion of immature to mature peptidoglycan. Because many bacteria have several distinct but essential transpeptidase, β-lactam resistance by target alteration requires alteration of several targets, making development of high-level resistance by mutation.

4.1.3 Commercial Antimicrobial Agents and Fibres

Thomson Research Associates markets a range of antimicrobials under the trade name Ultra fresh for the textile and polymer industry. Ultra fresh products were developed to be used in normal textile processes. To incorporate antibacterial into high temperature fibres like polyester and nylon, it is necessary to use an inorganic antimicrobial like Ultra fresh CA-16 or PA-42. These must be added as a special master batch to the polymer mixture before the extrusion process. For fibres such as polypropylene, which are extruded at lower temperatures, it is possible to use organic antimicrobials such as Ultra fresh Nm-100, Dm-50 or XQ-32. In the case of Rossari.s Fabshield with AEGIS microbe shield programme, the cell membrane of the bacteria get ruptured when the microbes come in contact with the treated surface; thus, preventing consumption of antimicrobial over a period of time and remain functional throughout the life of the product. The active substance 3-Trimethoxy silyl propyl dimethyl octadecyl ammonium chloride gets attached to the substrate either through bond formation on the surface or by micro polymer-sing and forming a layer on the treated surface; the antimicrobial agent disrupts the cell membrane of the microbes through physical and ionic phenomena. Ciba Specialty Chemicals markets Tinosan AM 110 as a durable antimicrobial agent for textiles made of polyester and polyamide fibres and their blends with cotton, wool or other fibres.

Tinosan contains an active antimicrobial (2, 4, 4'-Trichloro-2' - hydroxyl-dipenylether) which behaves like a colorless disperse dye and can be exhausted at a very high exhaustion rate on to polyester and polyamide fibres when added to the dye bath. Clariant markets the Sanitized range of Sanitized AG, Switzerland for the hygienic finish of both natural and synthetic fibres. The branded Sanitized range functions as a highly effective bacteriostatic and fungistatic finishes and can be applied to textile materials such as ladies hosiery and tights.

4.1.4 Benefits of Antimicrobial Textiles

A wide range textile product is now available for the benefit of the consumer. Initially, the primary objective of the finish was to protect textiles from being affected by microbes particularly fungi. Uniforms, tents, defense textiles and technical textiles, such as, geo-textiles have therefore all been finished using antimicrobial agents. Later, the home textiles, such as, curtains coverings, and bath mats came with antimicrobial finish. The application of the finish is now extended to textiles used for outdoor, healthcare sector, sports and leisure. Novel technologies in antimicrobial finishing are successfully employed in nonwoven sector especially in medical textiles. Textile fibres with built-in antimicrobial properties will also serve the purpose alone or in blends with other fibres. Bioactive fibre is a modified form of the finish, which includes chemotherapeutics in their structure, i.e., synthetic drugs of bactericidal and fungicidal qualities. These fibres are not only used in medicine and health prophylaxis applications but also for manufacturing textile products of daily use and technical textiles. The field of application of the bioactive fibres includes sanitary materials, dressing materials, surgical threads, materials for filtration of gases and liquids, air conditioning and ventilation, constructional materials, special materials for food industry, pharmaceutical industry, footwear industry, clothing industry, automotive industry, etc.

4.1.5 Evaluation of Antimicrobial Efficiency

Testing the antimicrobial activity of functionalized textiles is consisted of two categories of standardized test methods, qualitative (AATCC TM147 and AATCC TM30 (antifungal) (American Association of Textile Chemists and Colorists Test Method), ISO/DIS 20645, EN ISO 20645 and ISO 11721 (International Standards Organization), and SN 195 920 (921 - antifungal) (Swiss Norm) and quantitative (AATCC TM100, ISO 20743, SN 195924, JIS L 1902 (Japanese Industrial Standard) and ASTM E 2149 (American Society for Testing and Materials). Qualitative methods are mostly based on the agar diffusion test. They are relatively quick, cheap, simple and well-defined but subjective (use of ratings) and not appropriate for all kind of textiles and for analyses of efficacy of different antimicrobial agents as they diffuse through agar at different rates or not at all.

Quantitative Bacterial Reduction Test (AATCC test method 100-2004).

Quantitative methods are on the other hand more broadly applicable but more time-intense and expensive as they involve actual microbe enumeration, indicating level of bactericidal/ fungicidal activity. They can be used for all types of textiles and antimicrobials and comparisons can be made between different antimicrobial treatments as well as various treatment levels on the same textile The more commonly used tests for evaluation of the antimicrobial efficiency are Parallel Streak Method AATCC TM147 and ISO 20645, from among qualitative tests and AATCC TM100, JIS L 1902 and ISO 20743, from among quantitative tests.

4.1.6 Advantages of antimicrobial finished cotton fabric

The specific antimicrobial activity or bacterio static effects is based on the difference between the bacteria count of the reference value (Mb value) and the sample after 18 h of incubation (Mc value). Due to the limitations of the existing system, a new test system EN ISO20645, SN 195920-1992 /TC/38/WG23 (test methods for antimicrobial finished textile products) has been evolved by considering the technological, dermatological and ecological aspects of the finish.

5. Conclusion

An antimicrobial finish can be applied to most types of textiles. A wide variety of antimicrobial finishes are currently being applied to nonwoven textiles to be used as disposable protective garments in hospitals. Antimicrobials textiles, whether woven, nonwoven, or knit, can also be made out of any type of fibre content that is suitable for garment production. The fibre content of an antimicrobial textile must be chosen carefully. Synthetic fabrics may not be appropriate for some end uses due to the fact that most synthetic fibres are hydrophobic. This means that fabrics made of synthetic fibres hold a large amount of perspiration wetness in their weave structure than do natural fibres. This property can cause an increased chance of irritation and odor due to microbial growth on the body. Antimicrobial textiles with improved functionality find a variety of applications such as health and hygiene products, specially the garments worn close to the skin and several medical applications, such as infection control and barrier material.

References

[1] P. Ramesh, C. Prakash, N.K. Palaniswamy, N. Sukumar & S. Sengottuvelu, "Evaluation of antibacterial efficacy and wound healing activity of natural fibre based wound dressing coated with natural extracts of calotropis gigantean, eucalyptus globules and buds of Syzygium aromaticum enhanced with epidermal growth factor", International Research Journal of Pharmacy, 8/5 (2017) 95-100, https://doi.org/10.7897/2230-8407.08581

[2] K.M. Pachiayappan, C. Prakash & V. Kumar, "Influence of process variables on antimicrobial properties of cotton knitted fabrics", Journal of Natural Fibers, 17/3 (2020) 313-325, https://doi.org/10.1080/15440478.2018.1492487

[3] P.S. Vankar & D. Shukla, "Biosynthesis of silver nanoparticles using lemon leaves extract and its application for antimicrobial finish on fabric", Applied Nanoscience, 2/2 (2012) 163-168, https://doi.org/10.1007/s13204-011-0051-y

[4] R. Rajendran, C. Balakumar, R. Sivakumar, T. Amruta & N. Devaki, "Extraction and application of natural silk protein sericin from Bombyx mori as antimicrobial finish for cotton fabrics", Journal of The Textile Institute, 103/4 (2012) 458-462, https://doi.org/10.1080/00405000.2011.586151

[5] Y.H. Kim, H.M. Choi & J.H. Yoon, "Synthesis of a quaternary ammonium derivative of chitosan and its application to a cotton antimicrobial finish", Textile Research Journal, 68/6 (1998) 428-434, https://doi.org/10.1177/004051759806800607

[6] D. Knittel & E. Schollmeyer, "Chitosans for permanent antimicrobial finish on textiles", Lenzinger Berichte, 85/85 (2006) 124-130

[7] B. Mahltig & T. Textor, "Silver containing sol-gel coatings on polyamide fabrics as antimicrobial finish-description of a technical application process for wash permanent antimicrobial effect", Fibers and Polymers, 11/8 (2010) 1152-1158, https://doi.org/10.1007/s12221-010-1152-z

[8] F.N. Renaud, J. Doré, H.J. Freney, B. Coronel & J.Y. Dusseau, "Evaluation of antibacterial properties of a textile product with antimicrobial finish in a hospital environment", Journal of Industrial Textiles, 36/1 (2006) 89-94, https://doi.org/10.1177/1528083706066438

[9] W. Huang & K.K. Leonas, "Evaluating a one-bath process for imparting antimicrobial activity and repellency to nonwoven surgical gown fabrics", Textile Research Journal, 70/9 (2000) 774-782, https://doi.org/10.1177/004051750007000905

[10] K. Murugesh Babu & K.B. Ravindra, "Bioactive antimicrobial agents for finishing of textiles for health care products", The Journal of The Textile Institute, 106/7 (2015) 706-717, https://doi.org/10.1080/00405000.2014.936670

[11] G. Nalankilli & K. Tadesse, "Antimicrobial cotton textiles by finishing with extracts of an Ethiopian plant (Solanum incanum) fruit", African Research Review, 12/2 (2018) 143-152, https://doi.org/10.4314/afrrev.v12i2.14

[12] S. Bains, R. Kaur & M. Sethi, "Utilization of plant extract as antimicrobial finish for healthcare textiles", International Journal of Farm Sciences, 9/3 (2019) 96-100, https://doi.org/10.5958/2250-0499.2019.00081.8

[13] A. El-Shafei, S. Shaarawy, F.H. Motawe & R. Refaei, "Herbal extract as an ecofriendly antibacterial finishing of cotton fabric", Egyptian Journal of Chemistry, 61/2 (2018) 317-327, https://doi.org/10.21608/EJCHEM.2018.2621.1209

[14] R. Rathinamoorthy, S. Udayakumar & G. Thilagavathi, "Antibacterial efficacy analysis of Punica granatum L. leaf, rind and Terminalia chebula fruit extract treated cotton fabric against five most common human pathogenic bacteria", International Journal of Pharmacy and Life Science, 2/10 (2011) 1147-1149

[15] S. Zaghloul, A. El-shafie, M. El-bisi & R. Refaie, "Herbal Textile Finishes–Natural Antibacterial Finishes for Cotton Fabric", Egyptian Journal of Chemistry, 60/2 (2017) 161-180, https://doi.org/10.21608/ejchem.2017.541.1001

[16] S. Chandrasekar, S. Vijayakumar, R. Rajendran, R. Rajesh & B. Elayarajah, "Herbal-chitosan nanocomposites for durable antibacterial finishing on cotton materials", International Journal of Biopharmaceutics, 4/3 (2013) 219-224

[17] M.S. Yogendra Kumar, T.S. Raghu, F.V. Varghese, R. Indu Shekar, T.M. Kotresh, R. Rajendran, K. Murugesh Babu & V.C. Padaki, "Application of seabuckthorn (Hippophae rhamnoides L.) Leaf extract as antimicrobial finish on aramid fabric", Journal of Industrial Textiles, 45/5 (2016) 1115-1127, https://doi.org/10.1177/1528083714553689

[18] S. Han & Y. Yang, "Antimicrobial activity of wool fabric treated with curcumin", Dyes and Pigments, 64/2 (2005) 157-161, https://doi.org/10.1016/j.dyepig.2004.05.008

[19] N. Gokarneshan, V.B. Nagarajan & S.R. Viswanath, "Developments in antimicrobial textiles—some insights on current research trends", Biomedical Journal of Scientific & Techical Research, 1 (2017) 230-233, https://doi.org/10.26717/BJSTR.2017.01.000160

[20] S. Chandrasekar, S. Vijayakumar & R. Rajendran, "Functional finishing of health care cotton for enhanced efficiency of antibacterial activity by chitosan and herbal nanocomposites", Acta Ecologica Sinica, 40/6 (2020) 473-477, https://doi.org/10.1016/j.chnaes.2020.08.004

Comparison between Water-Retted and Enzyme-Treated Decorticated Banana Fibres

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Abstract

Background

Banana is one of India's most cultivated crops, with an estimated area of 880 thousand hectares. The banana pseudo stems, which are the residue of banana cultivation (accounting for approximately 30 tonnes per acre in one crop season), are generally left in fields or taken to open dumps or burnt along the roadside, where they produce greenhouse gases. Banana fibres extracted from a pseudostem with alpha-cellulose and low lignin content are underutilized for use in different applications.

Method

The present study aimed to optimize the removal of tissues on fibres using the pectinase enzyme at various concentrations and to compare the diameter and strength of the fibres with those of water-retted fibres. The fibre diameter was determined through scanning electron microscopy. The tensile strength was evaluated using a universal tensile tester.

Result & Conclusion

The results indicated the potential of using enzyme-treated banana fibres for textile applications.

Keywords: *Banana Pseudostem Fibres, Enzyme Retting, Fibre Extraction Method, Natural Fibres, Pectinase, Sustainable Fibres*

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1. Introduction

Globally, scientists have been working on utilizing natural fibres for their potential applications [1, 2, 3] owing to the development of global environmental challenges, which include global warming [4] and a decrease in petroleum supplies. Cotton is the most commonly used natural fibre since it provides exceptional qualities, including being easily accessible, biodegradable, strong, renewable, lightweight and highly absorptive as well as having optimized methods and machines for processing. However, cotton production requires a large amount of water and can be chemically intensive, with pesticides [5] compared to other crops. To overcome the problem of cotton, there is increased interest in the field of textiles to develop a portfolio of natural fibres that can replace cotton. The need for eco-friendly and sustainable textiles can be met using nonconventional natural fibres such as fibres extracted from banana pseudostems since they have low density, high tensile strength, low elongation at break and high tensile modulus [6].

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Banana is one of the major agricultural products in the world, with an estimated 119.83 million tonnes produced annually in 2020 [7]. It is cultivated in 130 different countries, making local banana waste widely available[4]. Within 130 countries, India is the world's largest banana producer, growing more than 31 million tons a year in 2020 [8]. The banana plant pseudostem (made with a soft core and surrounding leaf sheaths) accounts for the majority of banana waste biomass [9] and is either dumped or burned in fields, which greatly threatens the environment by releasing greenhouse gases [4]. However, banana biomass waste, which contains significant amounts of cellulose and hemicellulose, can be extracted from fibre with improved fineness and spinnability [11, 12]. This approach helps reduce the dependency on natural (cotton), synthetic, and manmade fibres, which require energy, fertilizer, and chemicals [9] in the manufacturing process. Further development and production of banana fibre in the textile industry will serve as an energetic impetus, providing employment and income for farmers [12], innovators, entrepreneurs, and small-scale industries.

The fibre from the banana plant can be extracted through retting, although its characteristics vary depending on the preparation, separation, processing, and extraction process. Banana fibres are traditionally extracted manually, which is a laborious technique, and the quality of the fibres obtained is based on the laborer's skills [14, 15]. Currently, different extraction techniques commonly used include water retting, dew retting, mechanical extraction, and enzymatic treatment.

Water retting involves immersing the pseudostem in water wherein the water penetrates the plant stems and causes the internal cells to swell, resulting in busting of the outer layer [15]. The fibres were extracted manually, washed, and sundried. This process is widely practiced since it has the advantages of good-quality uniform fibres. However, water retting is considered to be an expensive and time-consuming process, causing environmental pollution [16]. The mechanical decorticating technique involves cutting banana stems, crushing them between two drum rollers, and post cleaning and filtering contaminants to produce environmentally friendly and economical fibres. Natural binding material or lignin cannot be removed by this method [17], resulting in incomplete detachment of fibres [4]. The disadvantages of the mechanical extraction method (limitation of removing naturally binding material from fibre bundles) [1, 4 & 19] and water retting (dependency on clean water) can be met with an alternative sustainable method such as enzyme treatment.

A comparative study on mechanically extracted banana fibres with banana fibres subjected to biological extraction using commercial protease and pectinase reported that the biologically extracted fibres exhibited favourable tensile strength and elongation properties [19]. Similarly, another research compared three extraction methods for banana fibres: chemical extraction using sodium hydroxide (NaOH), mechanical extraction, and biological extraction using pectinase. It has been reported that the diameter of fibres extracted using chemicals resulted in a 30% reduction compared to biological and mechanical extraction, whereas biologically extracted fibres have a 40% increase in fibre strength compared to other two fibre extraction methods [20]. The pectinase derived from *Aspergillus Niger* and *Aspergillus fumigatus* was used to develop an environmentally friendly process for degumming and extracting banana fibres [21]. From similar studies, it was evident that the use of pectinase helps in the degumming of fibres by removing interlamellar pectin, leading to enhanced fibre yield compared to alternative methods. Furthermore, this approach contributes to reduced environmental impact, lower water consumption, and a more efficient extraction process [4, 23].

Investigating green manufacturing techniques for extracting fibres from agricultural wastes while ensuring sustainability holds paramount importance in mitigating environmental issues. The present study focused on the utilization and enhancement of fibre extraction efficiency from agricultural waste, specifically from banana pseudostems, through enzymatic treatment using varying concentrations of pectinase enzymes for degumming. The extracted fibres are subsequently subjected to testing and comparison against water-retted fibres to assess their physical and morphological characteristics.

2 Materials and Methods

A mixed study of quantitative, qualitative, and experimental research methods was used in this research to determine the optimal enzyme concentration for the treatment of decorticated banana fibres, thereby ensuring the production of high-quality fibres. Furthermore, the present investigation encompasses the analysis of various properties and characteristics associated with the extracted banana fibres that commenced in March 2022, at Department of Design, MSAP, Manipal. Mechanical decortication machine is used to decorticate fibres from the pseudostem after which the fibres are subjected to treatment with selected enzyme concentrations. For the water-retting process, banana pseudostems are submerged in stagnant water tank until the fibres naturally separate from the pseudostem. A diagrammatic representation of the study is given in Figure 1

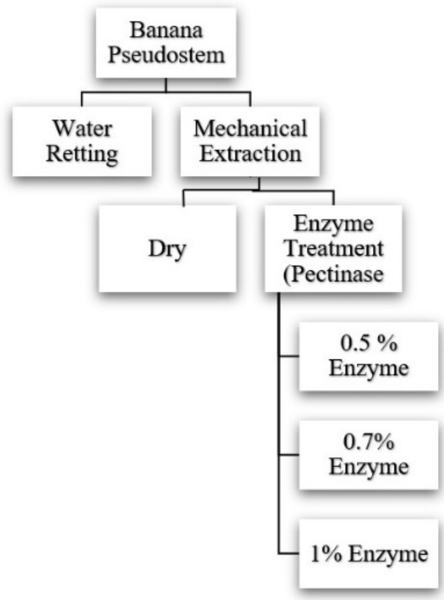

Figure 1 - Flow Chart of the Extraction Process

2.1 Materials

The banana plants were collected from the farmer's field in Coastal Karnataka after fruit harvest in month of April 2022. The taping top and the broad bottom ends of the pseudostems are cut, and the pseudostem is utilized for extracting the fibres. Pectinase for the enzyme treatment was obtained from Sigma Aldrich, while mechanical decortication machines were used for the extraction of banana pseudostems.

2.2 Fibre Extraction Methods

The fibre was extracted by water retting, decortication, and decortication followed by enzyme treatment at different concentrations. The nomenclature and identification of various fibre samples via the extraction method are presented in Table 1.

Table 1 - Nomenclature of various fibre samples

Sample	Nomenclature
Water Retted Fibre	WRF
Decorticated Fibre	DF
Enzyme Treated Fibre 0.5%	ETF 0.5%
Enzyme Treated Fibre 0.7%	ETF 0.7%
Enzyme Treated Fibre 1%	ETF1%

2.2.1 *Water Retting*

During water retting, the cut strip of the banana pseudostem was submerged in the water at 280 to 320 C for 10 days. After 10 days, the decayed stems were removed, cleaned thoroughly with running water and combed with a fine comb to clean the fibres from adhering to the remaining tissues [17].

2.2.2 Mechanical Extraction

The mechanical fibre extraction techniques using a decortication machine help to maintain the length of the fibre, reduce mechanical damage, save water and time [23]. The mechanical fibre extraction was performed by cutting the banana pseudostem in half, and the sheaths were detached layer by layer using a knife. Freshly cut banana pseudostem strips are fed between a scraping and squeezing roller of a decorticating machine that separates the pulp from the sheath [17, 21] and leaves only the fibres. The decorticated fibre was air-dried for 24 hours.

2.2.3 Standardization of Banana Pseudostem Decorticated Fibres for Enzyme Treatment

Banana fibres are treated with pectinase (Sigma–Aldrich) for degumming, it removes pectins, fats, and waxes from the surface and softens the fibre. The freshly decorticated banana pseudo stem fibres were immersed in a 1:20 MLR (material to liquor ratio) enzyme bath at different concentrations [24]. The temperature and pH were maintained according to technical information. After the enzyme treatment, the fibre samples were thoroughly rinsed to prevent additional reactions. The parameters used for different enzyme concentrations are depicted in Table 2.

Table 2 - Optimization of parameters for the degumming of banana pseudostem fibres using the enzyme pectinase

Parameters	Values		
Pectinase Concentration (% owf)	0.5%	0.7%	1%
Time (Min)	15		
MLR	1:20		
Temperature(^{0}C)	100		
pH	5.5		

2.3 Fibre Yield Obtained from the Different Methods

The amount of fibre obtained from each of the different methods was determined using the following formula:
Yield% = [OD weight of the extracted fibre/ OD weight of the plant part used for extraction] X 100 [25].

2.4 Weight Loss of the Extracted Banana Fibres

The reduction in the weight loss of the banana fibres is the decrease in the overall mass due to the loss of hemicellulose, fluid and lignin content, etc. during fibre extraction methods such as water retting and mechanical decortication followed by enzyme treatment. The weight loss of the extracted fibres was calculated using the following formula:

$$\text{Weight loss\%} = [(IW - AW)/IW] \times 100 \ [26]$$

where IW is the mass before treatment (gm) and AW is the mass after treatment (gm).

2.5 Evaluation of the Physical Properties of Banana Fibres

2.5.1 Determination of Tensile Strength

Using a universal tensile tester machine and a 27-centimeter test sample length, the maximum force necessary to break the fibres was measured and the ultimate tensile strength was calculated using the following formula:

$$\sigma = F / A \ [27]$$

where F is the load and A is the cross- sectional area.

2.5.2 Determination of Fibre Length

The direct method was used to measure the length of single banana fibre. Both ends of the single fibre are grasped by tweezers and the fibre is held without much tension alongside the steel ruler. After 50 measurements were taken, the average was calculated [28].

2.5.3 Determination of Fibre Diameter

Fibre samples were tested with an average diameter of 10 readings using an SEM analysis with a magnification factor of 100 to 400X [20].

2.5.4 Determination of the Fibre Color and Texture

The color and texture of the raw fibres are analysed by the naked eye, while hand evaluation is subjective. A panel of 10 members was asked to see, touch, and feel [24] treated samples that were anonymously labelled as per Table 1.

2.5.5 Morphological analysis

The morphological structure of the banana fibre samples was examined using an SEM analysis. The sample was set up on a pin stub and placed on a holder to keep inside the SEM chamber. The samples are observed under a magnification of 100 to 400X [20], and the longitudinal view of the fibres is analysed.

3 Results and Discussion

3.1 Fibre Yield and Weight Loss of Extracted Fibres

A comparison of the extracted fibres shows that the weight loss of the water-retted fibres (WRF) is greater than that of the decorticated fibres (DF). The decorticated fibres treated with pectinase showed considerable weight loss, an increase in enzyme concentration resulted in a decrease in weight loss as shown in Table 3.

Table 3 - Fibre Yield and Weight Loss of Extracted Banana Fibres

Sample	Weight of pseudostem used for extraction	Weight of Extracted pseudostem fibres	Yield %	Weight of the pseudostem/fibres before treatment	Weight of the pseudostem/ fibres after treatment	Weight loss%
WRF	50 gm	23.4 gm	46.8	50 gm	23.4 gm	53.2
DF	50 gm	36.3 gm	72.6	50 gm	36.3 gm	27.4
ETF 0.5%	-	-	-	50 gm	38.6 gm	22.8
ETF 0.7%	-	-	-	50 gm	42.4 gm	15.2
ETF 1%	-	-	-	50 gm	43.8 gm	12.4

3.2 Physical Properties of Banana Fibres

The physical properties of the banana fibres (tensile strength, color, texture, length, diameter, and morphological structure) are described below.

3.2.1 Tensile Strength of the Banana Fibres

The average bundle strength of the extracted banana fibre is shown in Table 4.

Table 4 - Tensile Strength of Banana Fibre Samples

Samples	Ultimate Tensile Strength (UTS)	Maximum Force
WRF	11.53 N/mm^2	12.89 N
DF	17.79 N/mm^2	73 N
ETF 0.5%	4.76 N/mm^2	6.23 N
ETF 0.7%	3.11 N/mm^2	4.08 N
ETF 1%	2.47 N/mm^2	3.24 N

The data presented in Table 4 show that DF has 17.79 N/mm^2 as a UTS and 73 N as the maximum force, followed by WRF, ETF 0.5%, ETF 0.7%, and ETF 0.1%. The tensile strength of the fibres decreased with increasing enzyme concentration.

3.2.2 Fibre Diameter and Length

The average diameter and length of the banana fibres are shown in Table 5.

Table 5 - Length and Diameter of the Fibre Samples

Samples	Length of the stem before extraction/ treatment	Length of the fibres after extraction/ treatment	Diameter
WRF	100 cm	95-98 cm	204µ
DF	100 cm	70-90 cm	503µ
ETF0.5%	100 cm	70-90 cm	502µ
ETF0.7%	100 cm	70-90 cm	573µ
ETF 1%	100 cm	70-90 cm	406µ

The data presented in Table 5 show that after treatment, compared with the other fibre samples, the WRF had 95 cm to 98 cm long fibres. The ETF 0.7% had the greatest diameter of 573µ, followed by DF, ETF 0.5%, ETF 1%, and WRF. WRF had the lowest diameter of 204µ compared to the other samples.

3.2.3 Fibre Color and Texture

Digital photographs of the fibres extracted using three methods, such as water retting, mechanical extraction, and enzyme treatments are depicted in Figure 2. WRF is smooth, clean, and white in color, while DF is stiff and light yellow in color.

The banana fibres are evaluated for hand properties by a panel of 10 staff members of the Department of Design. The panel has rated WRF being the best for hand properties followed by ETF 0.5%, ETF 0.7%, ETF 1%, and DF. The stiffness of the decorticated enzyme-treated fibres increased with increasing enzyme concentration. The ETF 0.5% treated fibres were softer, cleaner, and brighter than the ETF 0.7% and ETF 1% treated fibres. The ETF 0.5% is brighter than ETF 0.7% fibre, which is found to be a light brown colour, and ETF 1% fibre is yellowish in color.

3.2.4 The Morphological Properties of Banana Fibres

The longitudinal structure of the banana pseudostem fibres was examined using SEM micrographs at magnifications ranging from 100X to 400X. The SEM images revealed the presence of partially separated binder materials on the surface of WRF, DF, ETF 0.5%,

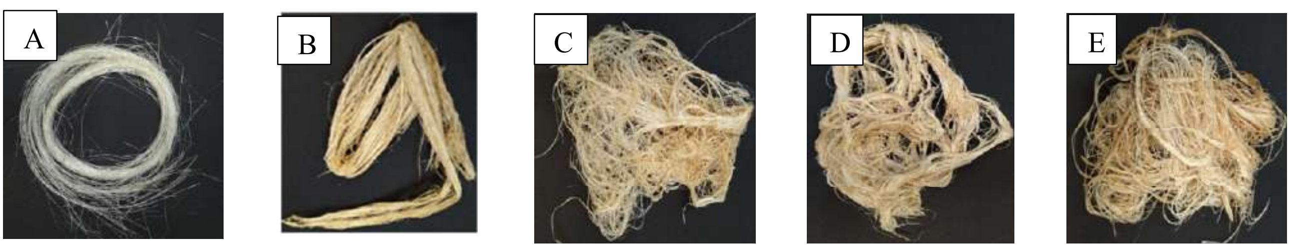

Figure 2 - Digital Photographs of Banana Pseudostem Fibres A) WRF, B) DF, C) ETF 0.5%, D) ETF 0.7%, E) ETF 1%

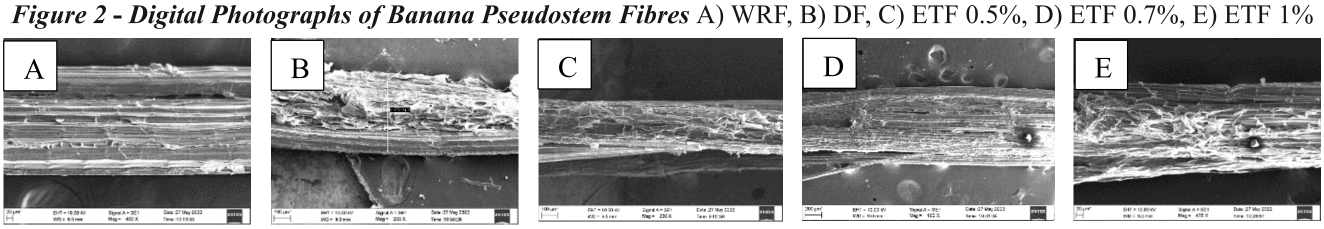

Figure 3 - SEM image of banana pseudostem fibre samples A) WRF, B) DF, C) ETF 0.5%, D) ETF 0.7%, E) ETF 1%

ETF 0.7% and ETF 1% extracted fibres. Fig. 3A reveals that the binder material was removed and shows that the fibres were cleaner, while Fig. 3C, 3D, 3E show cleaner and more rough fibres compared to those of the Fig.3A. Among the enzyme-treated fibres, ERF 0.5% exhibited good results, followed by ERF0.7% and ERF1%. Fig. 3B displays the SEM image of DF, which shows a cloudy, scaly fibre surface due to the presence of the binder (waxy substance, lignin, hemicellulose, and cellulose). However, the presence of binder content occupying the spaces in the fibre can contribute to the strength and greater diameter [20]. The presence of adhering tissue and a rough surface was observed in the DF sample, while it was not prominent in the fibres extracted using other methods.

4. Conclusion

In conclusion, this study provides key insights into banana pseudostem fibre behaviour, particularly under enzyme treatment compared to water retting. This research demonstrated that enzymatic processing significantly enhances the physical and subjective qualities of decorticated fibres, surpassing the effectiveness of water retting. Notably, the study identified 0.5% pectinase as the optimal concentration for minimizing tissue content, highlighting the potential advantages of enzyme-retted applications. Scanning electron microscopy analysis further validated the efficacy of enzyme treatment by revealing damaged fibres in mechanically extracted samples, emphasizing the removal of binder materials in both water-retted and enzyme-retted fibres. These findings underscore the promising prospects of enzyme treatment for obtaining high-quality fibres, with implications for textile and apparel production.

The present study advocates for continued exploration and focused research in the realm of banana fibre extraction to harness its full potential for sustainable and superior-quality textiles.

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References:

[1] T. D. Tavares, J. C. Antunes, F. Ferreira, and H. P. Felgueiras, "Biofunctionalization of Natural Fiber-Reinforced Biocomposites for Biomedical Applications", *Biomolecules*, **10/1** (1–44), (Jan. **2020**), DOI: https://doi.org/10.3390/biom10010148

[2] N. Poonia, N. Arya, and Pooja, "Banana fiber: A review", *International Journal of Education & Management Studies*, **10/2** (144–146), (**2020**)

[3] V. A *et al.*, "Extraction and Characterization of Natural Fiber from Stem of Cardiospermum Halicababum", *Journal of Natural Fibers*, **18/6** (898–908), (**2019**), DOI: https://doi.org/10.1080/15440478.2019.1669514

[4] S. Balda, A. Sharma, N. Capalash, and P. Sharma, "Banana fibre: a natural and sustainable bioresource for eco-friendly applications", *Clean Technologies and Environmental Policy,* **23** (1389–1401), (Jul'**2021**), DOI: https://doi.org/10.1007/s10098-021-02041-y

[5] K. Delate, B. Heller, and J. Shade, "Organic cotton production may alleviate the environmental impacts of intensive conventional cotton production", *Renewable Agriculture and Food Systems,* **36/4** (405-412), (**2020**), DOI: https://doi.org/10.1017/S1742170520000356

[6] N. Venkateshwaran and A. Elayaperumal, "Banana fiber reinforced polymer composites - A review", *Journal of Reinforced Plastics and Composites*, **29/15** (2387–2396), (Aug. **2010**), DOI: https://doi.org/10.1177/0731684409360578

[7] Statista [Internet]. Bananas: production volume worldwide 2020 | Statista, [Cited 2022 Nov 15], Available: https://www.statista.com/statistics/716037/global-banana-market-volume/

[8] Statista [Internet]. Global leading producers of bananas 2020 | Statista, [Cited 2022 Nov 15]. Available: https://www.statista.com/statistics/811243/leading-banana-producing-countries/

[9] A. Shroff, A. Karolia, and J. Shah, "Bio-softening of Banana Fiber for Nonwoven Application", *Int J Sci Res*, **4/4** (524–527), (**2015**)

[10] B. A. Akinyemi and C. Dai, "Development of banana fibers and wood bottom ash modified cement mortars", *Construction and Building Materials*, **241**, (Apr **2020**), DOI: https://doi.org/10.1016/j.conbuildmat.2020.118041

[11] S. K., Tripathi, N. K., Bhardwaj, S., Chechi, and R. Varadhan, "Suitability of banana stem pulp as replacement of softwood pulp for making superior grade unbleached paper from agro residue pulp", *Appita Journal*, **72/3** (163–178), (**2019**)

[12] M. Shah Kamal, M. Arshad Ali, and M. Ferdous Alam, "Socio-economic status and problems of banana growers in Bangladesh", *International Journal of Natural and Social Sciences*, **1/2** (91–99), (**2014**)

[13] L. Sisti, G. Totaro, M. Vannini, and A. Celli, "Retting Process as a Pretreatment of Natural Fibers for the Development of Polymer Composites", *Lignocellulosic composite materials*, (97–135), (**2018**), DOI: https://doi.org/10.1007/978-3-319-68696-7_2

[14] A. Ribeiro et al., "Microbial diversity observed during hemp retting", *Appl. Microbiol Biotechnol*, **99/10** (4471–4484), (**2015**), DOI: 10.1007/s00253-014-6356-5

[15] P. Badanayak, S. Jose, and G. Bose, "Banana pseudostem fiber: A critical review on fiber extraction, characterization, and surface modification", *Journal of Natural Fibers*, **20/1, (2023**), DOI: https://doi.org/10.1080/15440478.2023.2168821

[16] M. R. Sanjay, et al., "A comprehensive review of techniques for natural fibers as reinforcement in composites: Preparation, processing and characterization", *Carbohydr Polym*, **207** (108–121), (Mar. **2019**), DOI: https://doi.org/10.1016/j.carbpol.2018.11.083

[17] A. R. Rozyanty, et al., "Effect of water and mechanical retting process on mechanical and physical properties of kenaf bast fiber reinforced unsaturated polyester composites", *Composite Structures*, **257** (1–20), (Feb. **2021**), DOI: https://doi.org/10.1016/j.compstruct.2020.113384

[18] A. Subagyo and A. Chafidz, "Banana Pseudo-Stem Fiber: Preparation, Characteristics, and Applications", *Banana Nutrition - Function and Processing Kinetics*, (2018), DOI: 10.5772/INTECHOPEN.82204

[19] S. Xu, C. Xiong, W. Tan, and Y. Zhang, "Microstructural, Thermal, and Tensile Characterization of Banana Pseudo-stem Fibers Obtained with Mechanical, Chemical, and Enzyme Extraction", *Bioresources*, **10/2** (3724–3735), (**2015**), DOI: 10.15376/biores.10.2.3724-3735

[20] A. C. S. I. Mumthas, G. L. D. Wickramasinghe, and U. S. W. Gunasekera, "Effect of physical, chemical and biological extraction methods on the physical behaviour of banana pseudo-stem fibres: Based on fibres extracted from five common Sri Lankan cultivars", *Journal of Engineered Fibers and Fabrics*, **14** (1–15), (Jul **2019**), DOI: https://doi.org/10.1177/1558925019865697

[21] M. Vellaichamy and P. V. Gaonkar, "Biological Treatment of Banana Pseudostem Fibre: Effect on Softening and Mechanical Properties", *Int J Curr Microbiol Appl Sci*, **6/5** (1268–1274), (May **2017**), DOI: https://doi.org/10.20546/ijcmas.2017.605.137

[22] S. Balakrishnan, G. L. D. Wickramasinghe, and U. G. S. Wijayapala, "Eco-Friendly softening for banana Fibers from Sri Lankan banana cultivar: Influence on physical and chemical Properties on banana Fibers", *Journal of Natural Fibers*, **19/14** (9177–9189), (**2022**), DOI: https://doi.org/10.1080/15440478.2021.1982811

[23] V. Sadrmanesh and Y. Chen, "Bast fibres: structure, processing, properties, and applications", *International Materials Reviews*, **64/7** (381–406), (Oct. **2019**), DOI: https://doi.org/10.1080/09506608.2018.1501171

[24] A. Doshi and A. Karolia, "OPTIMIZATION OF ENZYME TREATMENT FOR BANANA FIBER", *International Journal of Textile and Fashion Technology (IJTFT),* **6/2** (1–8), (**2016**)

[25] S. Chauhan and A. Sharma, "Utilization of Pectinases for Fiber Extraction from Banana Plant's Waste", *Int J Waste Resour*, **4/4** (1–6), (**2014**), DOI: 10.4172/2252-5211.1000162

[26] Tholkappiyan E, "A Preliminary Study for Improving the Banana Fibre Fineness using Various Chemical Treatments", *Global Journal of Researchers in Engineering*, **XVI/III** (17–22), (**2016**)

[27] F. Islam, S. Joannès, and L. Laiarinandrasana, "Evaluation of Critical Parameters in Tensile Strength Measurement of Single Fibres", *Journal of Composites Science*, **3/3,** (**2019**), DOI: https://doi.org/10.3390/jcs3030069

[28] B. P. Saville, 'Fibre dimensions', Physical Testing of Textiles, **1999**: pp. 44-76, DOI: https://doi.org/10.1533/9781845690151.44

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Comprehensive Study on Manufacturing, Quality Assurance, Properties, and Applications of Geosynthetic Geomembranes

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Abstract:

This extensive investigation provides a comprehensive analysis of geosynthetic geomembranes, elucidating their pivotal role as impermeable membrane liners in various engineering and environmental applications. The review explores the properties, construction, and applications of prominent geomembranes, including HDPE, LLDPE, PVC, EPDM, RPE, RPP, and GCL, showcasing their versatility and adaptability. The manufacturing process, from raw material preparation to final product formation, is detailed, emphasizing the intricate procedures involved in producing geomembranes with diverse dimensions. The paper underscores the critical significance of quality assurance and control in geomembrane manufacturing, outlining essential tests for uniformity, strength, puncture resistance, and impermeability. In addition, key manufacturers and suppliers in the field are highlighted, offering practical insights for professionals and researchers involved in diverse engineering projects. As the demand for effective fluid containment, environmental protection, and sustainable infrastructure continues to grow, this review serves as a valuable reference, providing a nuanced understanding of geomembranes and their applications in contemporary engineering practices.

Keywords: *Fluid Containment, Geomembrane, Geosynthetic, Impermeable Barrier, Synthetic Membrane, Technical Textile.*

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1. Introduction

Geotextile geomembranes, commonly referred to as geomembranes, have emerged as pivotal components in contemporary civil engineering and geotechnical practices. These specialized synthetic membranes serve the essential purpose of meticulously controlling the movement of fluids, rendering them indispensable in a diverse range of construction and environmental protection applications [1]. Over the years, the nomenclature surrounding geomembranes has evolved, encompassing terms such as synthetic membranes, polymeric membranes, plastic liners, flexible membrane liners, impermeable membranes, and impervious sheets. In this comprehensive examination, we employ the term "geomembrane" as the standardized reference for these impermeable membrane liners, primarily composed of polymeric materials. They are available in nonreinforced or reinforced composite variants, offering remarkable versatility in their applications. Their chemical composition endows them with remarkable impermeability, enabling compatibility with various materials, including rocks, earth, and soils. Furthermore, geomembranes can be effectively integrated into capping systems, where they serve as impermeable layers, enhancing security in diverse construction scenarios [2]. Geomembranes display multifaceted functionality, acting as reinforcements, filters, and separators, catering to the specific demands of each project. The impermeable nature of geomembranes makes them an ideal solution for the containment and management of fluids in various construction contexts. They have found extensive application in mining operations, playing crucial roles in lining solution and evaporation ponds, tailings impoundments, waste management, and water resource management [3]. Furthermore, geomembranes play a pivotal role in landfill barrier systems, where they emerge as cost-effective solutions for the containment of municipal solid waste, effectively addressing environmental concerns.

This review paper aims to delve into the extensive body of research and applications surrounding geomembranes, shedding light on their diverse uses, material properties, and the pivotal role they play in civil engineering, geotechnical engineering, and environmental protection.

2. Construction, Properties, and Applications of Various Geomembranes

The selection and specification of a geomembrane for a specific application necessitate a deep understanding of the properties of the various geomembranes specially the polymer used in its manufacture. These properties, such as flexibility, UV resistance, and thickness, greatly influence ease of installation and expected service life. The types of geomembranes with their construction, properties and applications are explain below.

2.1 High-density Polyethylene (HDPE) Geomembranes

2.1.1 Construction:

HDPE geomembranes are engineered from high-density polyethylene, a thermoplastic crystalline polymer known for its robust construction and dense molecular structure [4].

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Typically, these geomembranes contain a small percentage of carbon black, usually ranging from 2 to 3 percent, which enhances their resistance to ultraviolet (UV) radiation. The manufacturing process involves the extrusion of HDPE material into large sheets or rolls, which can be customized to various dimensions, thicknesses, and collars, which facilitates easier installation [5].

2.1.2 Properties:

HDPE geomembranes are distinguished within the polyethylene family for their superior chemical resistance, a characteristic derived from their dense molecular structure. They feature factory-quality welds created through hot wedge and extrusion welding methods, which are often stronger than the geomembrane sheet itself [1]. The marketplace benefits from rigorous quality control and quality assurance testing, ensuring their reliability. Furthermore, their inherent UV stability eliminates the necessity for additional liner coverage, making them a cost-effective choice. HDPE geomembranes are available in roll stock, with thickness options spanning from 20 to 120 mil, catering to diverse project specifications.

2.1.3 Applications:

HDPE geomembranes offer versatile solutions with applications in a wide array of settings. They are prominently utilized in critical water management infrastructure, including irrigation ponds, canals, ditches, and water reservoirs, where their impermeable properties are crucial [5]. In the mining industry, HDPE geomembranes play a vital role in heap leach and slag tailing ponds, ensuring the safe containment of mining byproducts and preventing environmental contamination. Beyond their utilitarian applications, HDPE geomembranes contribute to aesthetically focused projects, enhancing landscapes with their use in golf course and decorative ponds [6].

2.2 Linear Low-density Polyethylene (LLDPE) Geomembranes

2.2.1 Construction:

LLDPE geomembranes are manufactured from a thermoplastic polymer with a lower density than High-Density Polyethylene (HDPE). These geomembranes are produced through an extrusion process, involving the melting of the polymer and shaping it into large sheets or rolls. Notably, LLDPE geomembranes are recognized for their flexibility, rendering them more manageable and easier to install compared to their high-density counterparts. Furthermore, they are available in various sizes, textures, and thickness options, offering flexibility to cater to diverse construction and environmental needs [7].

2.2.2 Properties:

LLDPE geomembranes exhibit exceptional flexibility, allowing them to conform to uneven surfaces and adapt to changes in ground contours. This inherent characteristic makes them particularly well-suited for applications where differential settlements or rough subgrade conditions are anticipated. Additionally, LLDPE geomembranes offer impressive puncture resistance, ensuring the integrity of containment systems even in challenging environmental conditions. While LLDPE geomembranes are more flexible, it's worth noting that they have slightly lower tensile strength when compared to HDPE geomembranes [1]. Notably, LLDPE geomembrane seams can be thermally welded, creating strong and secure connections between sheets, thereby ensuring the overall integrity of containment systems.

2.2.3 Applications:

LLDPE geomembranes find extensive application in a diverse range of industries, showcasing their remarkable versatility. They are crucial components in animal waste containment systems, where they serve as impermeable liners, effectively preventing the migration of contaminants into the surrounding soil and groundwater. In the mining sector, LLDPE geomembranes are pivotal in the construction and management of heap leach and slag tailings ponds, providing essential containment solutions for waste materials and process fluids. Furthermore, LLDPE geomembranes contribute to the aesthetic appeal of golf courses and landscaping projects by serving as liners for decorative ponds and water features. These geomembranes also ensure the secure storage of various liquids, including industrial and agricultural chemicals, in liquid storage tanks. Moreover, LLDPE geomembranes are deployed in applications involving brine solutions, industrial process waters, and diverse liquid containment scenarios, serving as reliable and impermeable barriers. In the realm of environmental protection, LLDPE geomembranes play a pivotal role in containment projects focused on isolating and controlling contaminants, thereby facilitating soil and groundwater remediation efforts aimed at mitigating environmental impacts [5].

2.3 Polyvinyl Chloride (PVC) Geomembrane

2.3.1 Construction:

PVC geomembranes are synthetic membranes made from a combination of high-quality polyvinyl chloride (PVC) resin, plasticizers, and additives. They are manufactured through extrusion or calendaring processes, resulting in a continuous, flat sheet of the desired thickness and width. PVC geomembranes are characterized by their flexibility, durability, and chemical resistance, making them ideal for a wide range of construction and environmental applications [8].

2.3.2 Properties:

PVC geomembranes exhibit a range of desirable properties that make them highly effective in various applications. Their exceptional flexibility allows them to conform to irregular terrain contours and adapt to diverse construction needs, making them advantageous in situations anticipating differential settlements or rough subgrade conditions. The durability of PVC geomembranes is noteworthy, as they can withstand extreme temperatures, UV exposure, and chemical attack, ensuring prolonged performance in demanding environmental conditions. The chemical resistance of PVC geomembranes is also significant, as they are compatible with a broad range of liquids and gases, including chemicals, acids, and hydrocarbons, making them suitable for applications involving exposure to corrosive or hazardous substances. Additionally, PVC geomembranes possess other beneficial properties such as strong mechanical strength, abrasion resistance, and ease of welding, making them versatile for a wide array of containment and environmental protection applications. In essence, the combination of flexibility, durability, chemical resistance, and other commendable attributes positions PVC geomembranes as versatile and reliable materials for a multitude of construction and environmental protection purposes [8].

2.3.3 Applications:

PVC geomembranes are versatile materials with a wide range of applications across diverse industries. In environmental containment systems, such as landfill liners, covers, and caps, PVC geomembranes play a crucial role in preventing the migration of contaminants into the surrounding soil and groundwater. This application is vital for environmental protection. Additionally, these geomembranes are employed to line potable water reservoirs, ensuring the safe storage of drinking water due to their chemical resistance and durability. Furthermore, PVC geomembranes are effective linings for tanks used to store various liquids, including industrial and agricultural chemicals, wastewater, and potable water. Their use extends to secondary containment systems, where they play a crucial role in safeguarding against leaks and spills of hazardous substances [8].

2.4 Ethylene Propylene-diene Monomers (EPDM)

2.4.1 Construction:

Ethylene Propylene-diene Monomers (EPDM) geomembranes are synthetic rubber membranes that offer exceptional weather resistance and durability. They are manufactured through a blending and compounding process that vulcanizes ethylene, propylene, and diene monomers to create a thermoset rubber. This process imparts the geomembrane with its unique properties, including flexibility across a wide temperature range and outstanding resistance to UV exposure [9].

2.4.2 Properties:

EPDM geomembranes possess several advantageous characteristics that make them well-suited for a variety of construction and environmental applications. Notably, their exceptional flexibility, even at low temperatures, makes them ideal for scenarios where they need to conform to irregular terrain contours or undergo repeated bending and folding. The UV resistance of EPDM geomembranes ensures their suitability for outdoor applications, providing durability in the face of prolonged sun exposure. In terms of durability, EPDM geomembranes exhibit resilience to various environmental conditions, including extreme temperatures, chemical attack, and mechanical stress. This durability factor contributes to their long-term performance in demanding applications. Additionally, the chemical resistance of EPDM geomembranes, compatible with a wide range of liquids and gases, including chemicals, acids, and hydrocarbons, positions them as an ideal choice for applications involving exposure to corrosive or hazardous substances. In summary, the flexibility, UV resistance, durability, and chemical resistance of EPDM geomembranes collectively make them a reliable and versatile material for various construction and environmental protection needs.

2.4.3 Applications:

EPDM geomembranes find diverse applications in construction and environmental engineering, showcasing their versatility and reliability. Widely utilized in water containment systems, these geomembranes serve as liners for irrigation ponds, canals, reservoirs, and ditches. Additionally, they play a crucial role in lining potable water reservoirs and drinking water storage tanks. In agricultural settings, EPDM geomembranes are employed to line and cover agricultural ponds and containment structures, including fish ponds and tanks. Beyond water-related applications, EPDM geomembranes contribute to landscaping endeavours by serving as liners for golf courses and decorative ponds. In environmental remediation projects, these geomembranes are utilized as protective barriers to address soil remediation needs. Moreover, EPDM geomembranes find application in various other contexts, such as secondary containment systems, mining applications, and landfill closures, as highlighted by. This broad range of applications underscores the adaptability and effectiveness of EPDM geomembranes in meeting the diverse needs of construction and environmental engineering projects [9].

2.5 Reinforced Polyethylene (RPE) Geomembrane

2.5.1 Construction:

Reinforced Polyethylene (RPE) geomembranes are a versatile and durable type of geomembrane that is widely used in construction projects. They are constructed with meticulous attention to detail, featuring a robust polyethylene fabric with either an HDPE or LDPE coating. This unique combination of materials creates an impermeable barrier capable of securely containing liquids, solids, or sludge in various construction and environmental applications. RPE geomembranes are crafted to provide resilience in challenging conditions, ensuring durability and long-term performance [10].

2.5.2 Properties:

RPE geomembranes possess a unique combination of properties that make them particularly well-suited for a diverse range of containment and environmental protection applications. These geomembranes are characterized by their exceptional flexibility and adaptability to varying terrain contours, ensuring a secure and impermeable barrier. They offer outstanding resistance to UV radiation, chemicals, and even oils, which contributes to their longevity and effectiveness in harsh conditions. RPE geomembranes remain durable even when exposed to challenging environmental factors, such as extreme temperatures, fluctuating water levels, and mechanical stress. Their ability to be prefabricated into large panels, which reduces the number of seams required during installation, enhances their efficiency and reliability. Furthermore, their adaptability to varying thicknesses, ranging from 12 to 36 mil, ensures they can cater to specific project requirements. The convenience of on-site repairs and their fast installation capabilities make them well-suited for emergency applications [10].

2.5.3 Applications:

RPE geomembranes, featuring a sturdy polyethylene fabric with HDPE or LDPE coating, exhibit exceptional versatility for diverse construction and environmental settings. These geomembranes securely contain substances like contaminated soils, liquids, and sludge. Specifically, RPE geomembranes excel in lining temporary retaining ponds for water storage in construction or environmental projects, boasting durability and UV resistance for prolonged exposure. In soil remediation, they play a crucial role in constructing pads to treat contaminated soils, effectively containing contaminants and preventing leaching into the environment. In summary, the robust qualities of RPE geomembranes make them indispensable for secure containment and management of various substances in different construction and environmental contexts [10, 11].

2.6 Geosynthetic Clay Liners (GCL)

2.6.1 Construction:

Geosynthetic Clay Liners (GCLs) are a type of geomembrane that is constructed by sandwiching a layer of processed sodium bentonite between two geotextile layers. When exposed to moisture, the bentonite swells and forms a low-permeability clay liner, effectively preventing the seepage of liquids and contaminants. GCLs are widely used in construction applications where impermeable containment and environmental protection are essential [12].

2.6.2 Properties:

Geosynthetic Clay Liners (GCLs) exhibit a unique set of properties that render them highly suitable for a diverse range of containment and environmental protection applications. Their inherent impermeability, even in the presence of hydraulic gradients, makes them ideal for preventing liquid and contaminant seepage. Notably, GCLs are characterized by durability, showcasing resistance to physical and chemical degradation, ensuring their long-term effectiveness in harsh environmental conditions. The flexibility of GCLs is another notable attribute, allowing them to easily adapt to uneven surfaces and facilitating straightforward installation. Additionally, GCLs offer a cost-effective alternative to traditional clay liners while delivering comparable performance, further enhancing their appeal in various applications. In essence, the impermeability, durability, flexibility, and cost-effectiveness of GCLs collectively contribute to their effectiveness in meeting the stringent requirements of containment and environmental protection initiatives [12].

2.6.3 Applications:

Geosynthetic Clay Liners (GCLs) are widely employed in diverse construction applications, showcasing their versatility and effectiveness. In landfill management, GCLs serve as impermeable liners and covers, preventing leachate seepage into the environment. For dams and reservoirs, GCLs offer a reliable solution to prevent seepage and protect water quality. Similarly, they are utilized in canals and ponds to maintain water levels and prevent seepage. In agriculture, GCLs find use in lining ponds and manure storage facilities. In mining and industrial settings, GCLs play a crucial role in lining pits and waste containment facilities, preventing the infiltration of hazardous materials into the soil and groundwater. The applications extend to diverse contexts, including golf courses, decorative ponds, and slag tailings, highlighting the broad utility of GCLs in meeting impermeability and containment requirements across various construction and environmental scenarios [13].

3. Manufacturing Process of Geomembranes

The manufacturing process of polymeric geomembranes involves a series of sequential operations to create these essential materials used in waste containment, environmental protection, and civil engineering projects.

3.1 Raw material preparation:

The process begins with the preparation of raw materials, including polymer resin and various additives such as antioxidants, plasticizers, fillers, carbon black, and lubricants. These additives are carefully selected to impart specific properties to the geomembranes, such as UV resistance, flexibility, and chemical stability.

3.2 Formulation:

The combination of polymer resin and additives forms the "formulation" for the geomembrane, defining its characteristics and performance attributes.

3.3 Extrusion:

For certain geomembranes, particularly HDPE, LLDPE, and polypropylene, the extrusion method is employed. In this step, a molten polymeric compound is extruded through a die to create a continuous sheet of polymeric material. Blown film extrusion, cast extrusion, and extrusion coating are sub-methods within this stage, each offering unique advantages. Blown film extrusion, for instance, provides biaxial orientation for improved tear resistance.

3.4 Texturing:

Texturing is a critical step in enhancing the frictional properties and sliding resistance of geomembranes. Various methods, such as coextrusion, impingement, lamination, and structuring, are employed during or after extrusion to achieve the desired surface texture.

3.5 Calendaring:

Another manufacturing method, especially applicable to PVC, CSPE, and reinforced geomembranes, is calendaring. In this step, the polymeric compound is passed through a series of heated rollers, forming a polymeric sheet. Calendaring can produce multi-ply geomembranes with complementary properties, and textured surfaces can be achieved using patterned rollers.

3.6 Final product formation:

The extruded or calendared sheets serve as the foundation for the final geomembrane product. Depending on the application and specific requirements, the sheets may undergo additional processes or be combined to create multi-ply geomembranes [4].

4. Quality Assurance and Control in Geomembrane Manufacturing

Quality assurance and control are integral components of geomembrane manufacturing, ensuring the reliability and performance of these crucial products [14]. Geomembranes play a pivotal role in various applications, including environmental protection, waste containment, and liquid storage, where their impermeability is essential. By implementing rigorous quality assurance and control processes, manufacturers can verify that their geomembranes meet stringent standards and regulations. This is of utmost importance, as it safeguards safety, prevents environmental contamination, and reduces the risk of costly failures. In geomembrane manufacturing range of essential tests involves to ensure the reliability and performance of these critical products. These tests include [14, 15]:

- Thickness measurements: To verify the uniformity of the geomembrane.
- Seam strength tests: To assess the quality of welded or bonded seams.
- Tensile strength tests: To determine the geomembrane's ability to withstand mechanical stress.
- Puncture resistance tests: To gauge its ability to resist damage.
- Permeability tests: To assess the impermeability of the geomembrane, ensuring that it effectively prevents liquid or gas seepage.
- Tests for UV resistance and environmental stress cracking: To evaluate the geomembrane's durability in various conditions.

5. Manufacturers and Suppliers of Geomembrane

5.1 Manufacturers

- GSE Environmental, Website: http://gseinc.com
  GSE Environmental is a global manufacturer known for producing geomembranes, geonets, and geosynthetic clay liners. They offer a wide range of geosynthetic solutions for environmental and civil engineering applications.
- Solmax: Website: https://www.solmax.com
  Solmax is a prominent manufacturer specializing in high-quality geomembranes and related geosynthetic products. They provide innovative solutions for a variety of applications in the geosynthetics industry.
- Raven Industries: Website: https://ravenefd.com
  Raven Industries is involved in the production of various geomembranes, including high-density polyethylene (HDPE) geomembranes. Their products are used in a wide range of applications, from agriculture to environmental protection.
- NAUE Geosynthetics: Website: https://www.naue.com
  NAUE Geosynthetics is a company that specializes in geosynthetic solutions, offering geomembranes, geotextiles, geogrids, and other products for soil stabilization, environmental protection, and civil engineering projects.
- Agru America: Website: https://www.agruamerica.com
  Agru America is a manufacturer that produces various geomembranes, including HDPE and LLDPE geomembranes. Their geomembranes find application in sectors such as environmental protection, waste containment, and industrial applications.

5.2 Suppliers and Distributors:

- Geosynthetics Limited: Website: https://www.geosyn.co.uk
  Geosynthetics Limited is a UK-based company that supplies and distributes a wide range of geosynthetic materials, including geomembranes. They serve various industries with geosynthetic solutions.
- HUESKER: Website: https://www.huesker.com
  HUESKER is a global geosynthetic engineering company offering a range of geosynthetic products, including geomembranes. Their products are used in applications related to geotechnical engineering and environmental protection.
- Titan Environmental Containment: Website: https://www.titanenviro.com
  Titan Environmental Containment is a North American supplier specializing in geosynthetics, including geomembranes. They cater to various projects in the fields of environmental and civil engineering.
- Geosynthetics, Inc.: Website: https://www.geosynthetics.net
  Geosynthetics, Inc. is a U.S.-based company that supplies geosynthetic products, including geomembranes, to a wide range of industries. Their products are used in applications such as waste containment and soil reinforcement.

6. Conclusions

This comprehensive investigation provides a thorough exploration of the crucial role played by geosynthetic geomembranes in contemporary engineering and environmental practices. Geomembranes, as impermeable membrane liners, serve as indispensable components in a myriad of applications, including waste management, mining, water containment, and construction. The review delves into the properties, construction, and applications of various types of geomembranes, such as HDPE, LLDPE, PVC, EPDM, RPE, RPP, and GCL, highlighting their versatility and adaptability. The manufacturing process, from raw material preparation to final product formation, is elucidated, emphasizing the intricacies involved in producing geomembranes of varying dimensions and specifications.

Furthermore, the paper underscores the paramount importance of quality assurance and control in geomembrane manufacturing, elucidating the battery of tests conducted to ensure uniformity, strength, puncture resistance, and impermeability. The inclusion of key manufacturers and suppliers in the field enhances the practical utility of the review, providing valuable information for professionals and researchers engaged in the design and implementation of diverse engineering projects.

As we look to the future, with increasing demands for fluid containment, environmental protection, and sustainable infrastructure, geomembranes stand out as critical components within the realm of geosynthetic materials. This review serves as a comprehensive reference, offering insights into the multifaceted functionalities and applications of geomembranes, as well as the meticulous processes involved in their creation. By illuminating the diverse landscape of geomembranes, this paper contributes to the collective knowledge base, empowering practitioners to make informed decisions in their pursuit of effective and sustainable engineering solutions.

References

[1] D. Smith, "Quality assurance for geosynthetics" Geosynthetics in Civil Engineering, 2006, 233-243, https://doi.org/10.1533/9781845692490.2.233

[2] S. Manan, J. Pitroda, and J. J. Bhavsar, "HDPE geomembranes: A liner material for reservoirs," International Conference on: Engineering: Issues, opportunities and Challenges for Development, April, 2015, 1-12

[3] L. Zhou, Z. Zhu, Z. Yu, and C. Zhang, "Shear testing of the interfacial friction between an HDPE geomembrane and solid waste," Materials, Vol. 13, Issue 7, April 2020, doi: 10.3390/ma13071672

[4] J. Scheirs, "HDPE Geomembranes", A Guide to Polymeric Geomembranes, 2009, 21-51. doi: 10.1002/9780470748213.fmatter

[5] K. H. Lou, A. Tay, and C. S. Lim, "New developments in polyethylene materials for geomembrane applications," 11th International Conference on Geosynthetics, September 2018, 16-21

[6] H. B. Ng and C. Qi, "HDPE geomembrane applications in high altitude region," 5th Asian Regional Conference on Geosynthetics: Geosynthetics for Sustainable Adaptation to Climate Change, December 2012, 843-850

[7] C. West, "Structured geomembrane liners in mining base and closure systems," SME Annual Meeting and Exhibit and CMA 113th National Western Mining Conference, May 2011, 9-12

[8] A. Luciani, C. Todaro, D. Martinelli, and D. Peila, "Long-term durability assessment of PVC-P waterproofing geomembranes through laboratory tests," Tunnelling and Underground Space Technology, vol. 103, September 2020, 1-11, doi: 10.1016/j.tust.2020.103499

[9] A. Kumar, R. Choudhary, and A. Kumar, "Characterisation of asphalt binder modified with ethylene–propylene–diene–monomer (EPDM) rubber waste from automobile industry," Road Materials and Pavement Design, Vol. 22, Issue 9, March 2021), 1-25, doi: 10.1080/14680629.2020.1740772

[10] I. D. Peggs, "Factors influencing the durability of polypropylene geomembranes: The goal Being an Effective Specification," Geosynthetics Research and Development in Progress, May 2012, 1-12. doi: 10.1061/40782(161)59

[11] M. Sadlier and R. Frobel, "Current developments and trends for water reservoir renovation with geosynthetics," 11th International Conference on Geosynthetics, 2018, 1-7

[12] G. Heerten, "Geosynthetic clay liner performance in geotechnical applications", Clay Geosynthetic Barriers, 2022, 70-87, doi: 10.1201/9781003078777-1

[13] R. K. Rowe, "Geosynthetic clay liners: Perceptions and misconceptions," Geotextiles and Geomembranes, Vol. 48, Issue 2, April 2020, 137-156, doi: 10.1016/j.geotexmem.2019.11.012

[14] D. Smith, "Quality assurance for geosynthetics", Geosynthetics in civil engineering, 2007, 233-242, doi: 10.1201/9781439824290.ch11

[15] H. Zanzinger, "Quality assurance in the manufacture and installation of GCLs", Geosynthetic Clay Liners, 2020, 335-345. doi: 10.1201/9781003077848-24

Factors affecting Handloom Output in India: Results from a Panel Based Study across the States

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Abstract:

Background

The Indian handloom sector is vital for providing employment and contributing to the economy, particularly in agricultural regions. The Fourth All-India Handloom Census shows 31.44 lakh households engaged in handloom work, with most earning less than Rs. 5,000 monthly. The industry is diverse in terms of income, education, and other factors, with a focus on women's empowerment. Additional research is needed to understand the economic conditions of weaver households across India.

Methods

The panel data used in this study comes from census reports titled "The National Handloom Census of Weavers and Allied Workers." The dynamics are modeled using panel data regression.

Results

The findings highlight the important contribution that membership in cooperatives, SHGs, and businesses makes to total productivity. For instance, access to critical supplies, raw materials, and member buy-back schemes. To ensure that the handloom industry continues to expand, proactive governmental interventions are required to place unorganized homes under the auspices of these organizations.

Conclusion

The Indian economy benefits greatly from the handloom sector. The key factors influencing the productivity of the handloom sector are examined in the current study. Two main factors impacting production are the number of families weaving and their participation in cooperative groups. To improve efficiency, the report recommends changes to government policies that would move disorganized units into organized structures.

Keywords: *Cooperative Memberships, Empowerment of Handloom, Handloom Productivity, Panel data Regression, Policy Interventions*

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1. Introduction

The Indian handloom sector is an age-old industry that has played a crucial role in providing employment opportunities and contributing to the economy. The sector holds significant importance in terms of its magnitude and potential for generating jobs. Because of its close ties to other vital industries like agriculture, the handloom sector is very crucial to the agricultural economy. It generates a steady demand for agricultural production by using agricultural items as inputs. Handloom is therefore highly valued in an economy such as India, where the majority of people still rely on the agricultural sector for their livelihood.

The "Fourth All-India Handloom Census" states, there are 31.44 lakh households in India engaged in handloom work, representing 13% growth compared to the previous census. Four Indian states (Assam, West Bengal, Manipur, and Tamil Nadu) collectively represent 1.8 million weaver households, which accounts for the total number in the country. Most weaver households (66.3%) make less than Rs. 5,000 a month and only three states (Goa, Uttarakhand, and Maharashtra) have 60% or more of weaver households earning more than this amount per month. However, many of these households rely on extra sources of income. Only 17.5 percent of families rely exclusively on weaving and earn more than Rs 5,000 per month. This also implies that for a significant portion of households engaged in weaving are critically relying on the handloom sector for their means of subsistence.

Apart from the poor economic conditions faced by the average weaver households, the information from the survey clearly shows the diversity of weaving households across the states in terms of the level of income generated, education, the average number of days engaged in weaving, type of cloth produced, input material used, location of the household, and social and financial inclusion, etc. However,

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only very few studies tried to explore these complex economic and social dynamics well. In this background, this study tries to explore the presence of any systematic factors behind the existing economic conditions of the weaver households across the states in India.

The field of the study has great importance as it specifically focuses on promoting women's empowerment. According to the last census, the sector employs more than 2.3 million female weavers and related workers. The handloom sector primarily operates within households, relying on labor provided by the whole family. Hence, the active participation of a significant proportion of women in any role within this industry has resulted in direct financial benefits for them, so granting them economic autonomy and enhancing their sense of self-value both within their households and in society at large.

The structure of this document is as follows. A quick summary of research in the handloom industry is given in the next section. The section that follows will provide details on the data and methods. The results and discussion will come next, with the paper's conclusion coming last.

2. Literature Review

Research was conducted to determine and evaluate the influence of a few key variables on the improved living conditions of weavers in the state of Andra Pradesh's Srikakulam district. Several key variables that significantly impact the living conditions of weavers have been identified, including disorganized operations, diversification of products, loan requirements, availability of raw materials, low returns, and marketing challenges. The weavers' level of satisfaction has decreased because of a range of concerns. Ultimately, the degree of satisfaction felt by handloom weavers is influenced by a multifaceted interplay of economic, cultural, and individual factors. [1].

To ascertain the factors impacting the handloom weaving practices of women weavers in the Lakhimpur District of Assam, another research study was conducted. It was also found that the income of weavers affects their level of participation. The performance and output of handloom goods were impacted by the rise in health-related issues among weavers. Weavers described excruciating levels of physical discomfort. Therefore, enhancing the working conditions and the compatibility of the weaver with the loom would aid in reducing the pain and suffering experienced by weavers. This would increase the income, performance, and output of the weavers [2].

With over 65% of all looms in the nation, the Northeastern states of India are home to the greatest concentration of handlooms. The study investigates the role of motivation in the entrepreneurship process within the cluster by analyzing entrepreneurial motivations, including ambitions, reasons for entering the industry, factors that facilitate entry into entrepreneurship, and the desire for their children to become entrepreneurs in the same industry. The cluster has undoubtedly developed into a hub for entrepreneurship with the primary objectives of generating income, being independent, and making a life [3].

The research study conducted by Ramswamy and Hmangaihzual intends to examine the strategies employed for promoting and distributing micro handloom firms throughout the rural region of North East India. The data used in this study is derived from primary sources, specifically from a structured questionnaire administered to 175 out of 325 entrepreneurs operating within the Thenzawl cluster. According to the survey, weavers encounter many challenges when trying to market their goods. It has also been discovered that the cluster is not experiencing the implementation of the federal government's ambitions to sell handloom items. To support tribal communities in this isolated region of northeastern India in realizing their Made in India goals, increased efforts in product distribution and promotion are needed [4].

An investigation is carried out to look at the sociological and demographic aspects that affect the handloom weavers' decision to become members of an Odisha cooperative society. The main determinants of handloom weavers' willingness to work under a WCS (Weavers' Cooperative Society) are their skill level and marital status, according to the results of the binary logistic regression study. With proper training, government policies should work to strengthen cooperative societies. [5].

The Manipuri handloom industry, which is Bangladesh's main ethnic handcrafted garment sector, has a troubled past, a hazy present, and an uncertain future. A research study is conducted to discuss the issues and future potential of this sector. This piece uses geographic information systems to pinpoint the locations of handloom product outlets based on visitor traffic, commercial prospects, and the accessibility of unprocessed materials. The outcome demonstrates the main causes for the fall in handloom weaving endeavors are the competitive market, capital scarcity, and low-profit margin [6].

A study is being carried out to investigate the factors that affect workers' occupational choices in the Assamese handloom sector and to concentrate on the factors that influence workers' occupational choices. The tested empirical model's findings indicate that family size, access to modern technology, annual income, and education are the primary elements that influence the transition from being reelers to being owners. Similarly, the crucial factors that facilitate the transformation of reelers into weavers include annual earnings, level of education, and availability of formal financial resources. The widespread availability of modern technology primarily drives the transition from weavers to handloom proprietors [7].

Kumar and Sulaiman investigated to identify the primary issues and obstacles related to the production and marketing of handloom manufacturing facilities in South India. The examination of the issues faced by the handloom units aids in determining the particular requirements of this industry and helps to focus policy and research efforts. The study's primary data were acquired from the sample handloom manufacturing facilities in South India. The investigation found that while handloom goods are becoming more and more popular both domestically and internationally, the handloom units are dealing with several issues related to manufacturing and marketing [8].

This study examines the difficulties faced by Himachal Pradesh's handloom weavers by providing a thorough overview of the handloom industry's value chain and the role that cooperative societies and tourism play in sustaining the demand for handloom products, particularly in areas that see a high volume of both domestic and foreign travel. The findings show that a more organized and enlarged handloom weavers market is necessary for the handloom sector to remain sustainable. The handloom industry is significant to the state economy [9].

A study has revealed that occupational health issues are present in all handloom weavers. Weavers' output has decreased significantly as a result of occupational health issues. The handloom weavers were in extremely vulnerable and impoverished socially, medically, and economically [10].

To improve the socioeconomic profile of weavers, a study was conducted to examine the socioeconomic conditions and issues facing the handloom weaving industry in East Godavari District. The research also sought to augment measures already in place for the industry's growth as well as those of APCO, handloom weaver cooperative societies, and weavers themselves [11].

3. Data and Methodology

The present study uses secondary data published by the Government of India. Most of the information we used for the analysis was about “The National Handloom Census of Weavers and Allied Workers” conducted by the “National Council of Applied Economic Research, New Delhi”. As we use data from multiple census reports, we use a panel data framework for the analysis. We use both panel data regressions for modeling the dynamics.

3.1 Panel Data Regression Model

Following standard notions, we briefly describe the panel data models here. Below, we represent the common linear panel models.

$$y_{it} = \alpha_{it} + \beta_{it}^T x_{it} + u_{it} \qquad (1)$$

Where the indices “i" and "t" represent the districts and year, and residual uit is the random error term.

We make certain assumptions regarding the parameters, errors, and homogeneity of the regressors. These assumptions allow us to construct a range of possible models for analyzing panel data. The parameter's homogeneity is one of the common assumptions. We assume that the error term consists of two distinct components, one of which is unique to each individual and remains constant throughout time.

Here is the estimated fixed effect model for the variables considered in this study.

$$(Production)it = \beta_0 + \beta_1(HHs)_{it} + \beta_2(HHsize)_{it} + \beta_3(Debt)_{it} + \beta_4(WorkingDays)_{it} + \beta_5(Membership)_{it} + \varepsilon_{it}$$

4. Results and Discussion

Table 1: Descriptive Statistics

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Production	58	11	1371097	85352.81	232351.94
HHs	58	568	1269506	101727.03	241114.12
HH size	58	2.58	6.04	4.4359	0.87
Debt	58	0	27964	1621.93	4570.46
Working Days	58	82	295	215.71	58.50
Membership	58	1	253076	16270.10	36972.45
Valid N (list wise)	58				

Table 2: Correlation Matrix

Variables	Production	HHs	HH size	Debt	Working Days	Membership
Production	1.0000	0.9763**	-0.0862	0.1014	-0.1984	0.7820**
HHs		1.0000	-0.1062	0.2124	0.1759	0.7554**
HH size			1.0000	-0.2973*	-0.2941*	-0.3049*
Debt				1.0000	0.1948	0.2876*
Working Days					1.0000	0.0344
Membership						1.0000

***, * indicates that the estimated coefficient is significant at 1 and 5 percent level*

Table 3: Fixed Effects Model Estimation Results

Variables	Coefficient	Std. Error	t-ratio	p-value
Constant	19546.0	52322.3	0.3736	0.7120
Number of Households	0.771986	0.220811	3.496	0.0019***
Household size	-4627.16	5799.10	-0.7979	0.4327
Debt	-1.81853	1.26926	-1.433	0.1648
Working Days	-32.8739	202.270	-0.1625	0.8723
Membership	1.09656	0.176229	6.222	<0.0001***

LSDV R-squared: 0.994793

Within R-squared: 0.789028

LSDV F (33, 24) (p=8.50e-21)

Durbin-Watson: 1.914724

Test for differing group intercepts = P (F (28, 24) > 3.44644) = 0.00148264

Breusch-Pagan test - test statistic: = 4.06 (p-value = 0.043)

Hausman test - test statistic= 15.23 (p-value = 0.009)

Table 1 contains descriptive statistics, Table 2 provides the correlation coefficients of all of the variables used in the regression analysis. We have selected five independent variables for the panel regression, which include the number of handloom households (HHs), household size (HH size), total debt of the handloom households (Debt), average number of working days (Working Days), and membership in a cooperative society, SHG, or production company (Membership), about the dependent variable Total Household Handloom Production (Production). The tests for different group intercepts ($P < 0.05$), the Breusch-Pagan test ($P < 0.05$), and the Hausman test ($P < 0.05$) show that the fixed effect model is better than the pooled OLS and random effect models. States are defined as cross-section units. i = 1, 2,... 29.

The parameter estimates in Table 3 indicate the variable HHs are statistically significant ($t = 3.496$, $p < .001$). As HHs increase by one unit, production increases by 0.772 units by holding all other variables constant. The variable membership is statistically significant ($t = 6.222$, $p < .001$). As membership increases by one unit, production increases by 1.097 units. The variable HHsize is not statistically significant ($t = -0.798$, $p > 0.05$). Similarly, the variables debt ($t = -1.433$, $p > 0.05$) and number of working days ($t = -0.163$, $p > 0.05$) are insignificant for having an impact on production. Essentially, this estimate shows that India's handloom production will increase with the increase in the number of handloom households and their membership in cooperative societies, SHGs, and production companies. The presented empirical evidence indicates that variables like the number of handloom households and membership in cooperative societies, SHGs, and production companies influence handloom production. Specifically, the estimated model, which includes five independent variables, accounted for 79 percent of the variance in total household handloom production in India.

The results demonstrate the significant role that membership in cooperatives, SHGs, and companies plays in contributing to overall production. It also indicates that these associations can reduce household uncertainties in their production engagement. This could be because these organizations facilitate the easy acquisition of raw materials and other necessary supplies for their members, and they may also offer buy-back programs. This significant contribution suggests active policy interventions to bring unorganized houses under the umbrella of these organizations, thereby fostering further growth in the sector.

5. Conclusion

The handloom industry contributes significantly to the Indian economy in several ways, such as creating jobs, empowering women, and fostering strong ties with the agricultural sector. The current study looks into the important variables that affect the output generation performance of the handloom industry. The results from the analysis show that the number of households engaged in weaving and their membership in cooperative societies have a significant effect on the total output from the handloom sector. It explains how collectives can contribute to output generation and suggests considering government interventions to bring the unorganized units under the umbrella of cooperatives and similar organizations for better sector performance.

References

[1] Venugopal, K., Pranaya, D., Das, S., & Jena, S. K. (2023/12//). Handloom weaving: Critical factors influencing the satisfaction- the socio & economic context. Economic Affairs, 68(4), 1979-1988. doi:https://doi.org/10.46852/0424-2513.4.2023.9

[2] Bori, G., & Bhattacharyya, N. (2021/12//). Factors affecting handloom weaving practices among women weavers of Assam. Economic Affairs, 66(4), 623-628. doi:https://doi.org/10.46852/0424-2513.4.2021.15

[3] Ramaswamy, R., & Kumar, N. V. R. J. (2012/12//). Motivational factors of tribal entrepreneurs in handloom clusters: A case study of thenzawl, Mizoram. IUP Journal of Entrepreneurship Development, 9(4), 56-68. Retrieved from https://www.proquest.com/scholarly-journals/motivational-factors-tribal-entrepreneurs/docview/1288625634/se-2

[4] Ramswamy, R., & Hmangaihzuali, J. B. (2016/03//). Promotion and distribution of handloom products in tribal clusters in northeast India. IUP Journal of Entrepreneurship Development, 13(1), 47-58. Retrieved from https://www.proquest.com/scholarly-journals/promotion-distribution-handloom-products-tribal/docview/1781343156/se-2

[5] Meher, A. K., Venkatachalapathy, T. K., & Panda, P. K. (2023/12//). Does the weavers' cooperative society yield higher income to the handloom weavers? Evidence from Odisha. Parikalpana: K I I T Journal of Management, 19(2), 204-216. doi:https://doi.org/10.23862/kiit-parikalpana/2023/vl9/i2/223466

[6] Ahmed, Z., Hussain, A. H. M. B., Alam, R., & Singha, A. K. (2022/06//). Perils and prospects of Manipuri handloom industries in Bangladesh: An ethnic community development perspective. GeoJournal, 87(3), 2125-2140. doi:https://doi.org/10.1007/s10708-020-10365-3

[7] Alin, B. B., Goswami, K., & Hazarika, B. (2013). Determinants of occupational choice of workers in the handloom industry in Assam. International Journal of Social Economics, 40(12), 1041-1057. doi:https://doi.org/10.1108/IJSE-03-2012-0042

[8] Kumar, S.,IV, & Sulaiman, E. (2017). Crisis of handloom units in Kerala and Tamil Nadu: An empirical study on the problems and challenges. Journal of Rural and Industrial Development, 5(1), 22-34. Retrieved from https://www.proquest.com/scholarly-journals/crisis-handloom-units-kerala-tamil-nadu-empirical/docview/2024123596/se-2

[9] Sharma, S., Jena, B. B., & Chandra, R. (2021). Socioeconomic conditions of handloom weavers – A study of Himachal Pradesh. Turkish Journal of Computer and Mathematics Education, 12(10), 4023-4038. Retrieved from https://www.proquest.com/scholarly-journals/socio-economic-conditions-handloom-weavers-study/docview/2628339860/se-2

[10] Bagale, G., & Mahajan, S. (2022). Measuring economic, health, and social conditions of poor rural weaving community. Academy of Marketing Studies Journal, 26 Retrieved from https://www.proquest.com/scholarly-journals/measuring-economic-health-social-conditions-poor/docview/2719452210/se-2

[11] Teki, S., Bhaskar, N. U., & Devi, P. U. (2020///Jul-Dec). Management strategies of handloom weaver's co-operative societies in Andhra pradesh. AAYAM: AKGIM Journal of Management, 10(2), 21-33. Retrieved from https://www.proquest.com/scholarly-journals/management-strategies-handloom-weavers-co/docview/2493870782/se-2

[12] NCAER (2010) the Handloom Census of India 2009-10, the National Council of Applied Economic Research, New Delhi.

[13] NCAER (2019) Fourth All India Handloom Census2019-20, the National Council of Applied Economic Research, New Delhi.

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Improvements to Eco-Friendly Sanitary Napkins Made from Natural fibres: Development and Characterization

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Abstract:

Three sanitary napkin types produced from natural fibers were put through a rigorous evaluation process to determine their performance attributes in this study. In order to give a thorough understanding of their absorbency, retention, rewet resistance, and leakage prevention capabilities, these napkins had different core compositions and top layers. The outcomes showed that although all the variations had different advantages and disadvantages, Sample S3, which had a bamboo-flax-hemp core, was the best performer. It had remarkable absorbency and retention, even though it slightly rewet under load. Sample S1 excelled in absorbency and dryness, while Sample S2 showed balanced performance. These results highlight the significance of customizing the composition of sanitary napkins to individual user preferences while maintaining an environmentally and biodegradably sound framework. Textiles play an essential role in assisting women in their struggle against numerous barriers. Women's health and hygiene are supported by absorbent hygiene, an essential type of medical textiles, particularly during the menstrual cycle, which presents several challenges for women. In order to make sanitary napkins more affordable, this research focuses on changing natural fibres to make them appropriate for use in them. This aids in breaking into the rural women's market, assisting the women in adapting to the physiological changes occurring during these vulnerable days, allowing them to make their vitalizing contributions to society with greater flair.

Keywords: *bamboo, eco-friendly, flax, hemp, hygienic, sanitary napkins, super absorbent polymer*

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1. Introduction

The demand for disposable items to maintain a healthy atmosphere and the growing consumer awareness of environmental friendliness have been the motivating factors for the start of this research on enhancing the eco-friendliness of this disposable sanitary product. The prepared sanitary napkins are made up of an absorbent core, a super absorbent polymer, and a leak-proof substance, all of which are enclosed in cover stock [1].

People now expect more from textiles in terms of providing this sanitary functionality as consumer awareness of hygienic lifestyles grows. Research in the textile and garment industries has been heavily focused on developing novel fibres, textiles, finishes, and apparel items that will provide the wearer with this level of comfort. There are several synthetic commercial items on the market. But in order to meet the requirements of sustainability and eco-friendliness on a worldwide scale, the market is now being flooded with safer raw materials that can give our fabrics numerous uses [2-4]. The revival of interest in products made from renewable resources is a result of ecological concerns. Natural fibres, agro-waste fibers and biodegradable polymers might be thought of as an environmentally safe option because of this [5]. All natural fibres and agro-waste fibers are low density, less harmful to technology used for processing them, economically viable, and biodegradable [6].

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Sanitary napkins are a distinctive feature of female growth that occurs throughout the menstrual cycle, when a woman's body is at its weakest and needs appropriate precautions to protect herself. A wear study conducted to assess the comfort of sanitary napkins revealed that a highly humid microclimate developed in the area between the napkin and the skin, which led to subjective pain. Inconvenience related to sultriness was reported by more than 60% of the individuals [7]. This discomfort is brought on by the increase in temperature inside the napkins, and adults who use diapers have also reported feeling it [8].

Due to the fact that vaginal bacteria like Candida albicans thrive in warm, moist environments and cause infections, women become more vulnerable to vulvo-vaginal infections as a result. A free flow of water vapor could lessen the pain caused by napkins [9]. The vulva region, which is made up of epithelial tissues, surrounds the vaginal opening. This tissue's structure, occlusion, moisture, and susceptibility to friction set it apart from other bodily parts. The vulva, like other epithelial tissues, defends the vagina from hazardous bacteria through the use of defense cells. However, inadequate ventilation, heated settings, and minor wounds brought on by friction between clothing and skin encourage the growth of microorganisms. This worsens if the user wears underwear, pantyliners, or sanitary napkins made of synthetic materials, which raise the temperature and pH of the vulva region and lead to a variety of skin infections that manifest as itchiness, soreness, redness, and swelling in the vaginal area [10]. The polypropylene (PP) spunbond nonwoven is used as the outer cover material for the majority of sanitary napkins, which are the absorbent pads worn externally by women during menstruation to absorb the menstrual flow [11]. This outer cover stock is better suited for sanitary napkins because it is in close contact with the skin of the vulva region [12]. This article discusses the various styles of sanitary napkins that have been produced from a variety of raw materials that have been improved and developed through earlier research.

2. Materials and Methods

2.1 Methods for Preparation of Sanitary Napkins from Natural Fibres

2.1.1 Assembly of sanitary napkins with prepared absorbent core layer

- Absorbent core - length-25 cm and width-7.5 cm
- Leak proof polyethylene sheet - length-25 cm and width-7.5 cm + (2 * Thickness of prepared absorbent core)
- Cover stock polypropylene sheet - length-27 cm and width-18 cm

Polypropylene sheet was used to cover the absorbent core and leak-proof polyethylene sheet at the bottom. They are joined by a seal. The sanitary napkin is subsequently manufactured and sealed.

2.1.2 Top Layer

The top layer is made entirely of spun bamboo, which is hypoallergenic, soft, and biodegradable, by nature. A non-woven fabric with a web-like structure is produced by the spun lacing process, offering a soft and smooth surface.

2.1.3 Middle Layer

Super Absorbent Polymer (SAP) is a highly absorbent material that can hold many times its weight in liquid in the middle layer (B). Menstrual fluids can be quickly absorbed and retained with the help of sanitary napkins.

2.1.4 Core Layer

- Bamboo Fiber: Gives the inner layer comfort and softness.
- Flax Fiber: Provides the core with extra strength and absorbency.
- Hemp Fiber: Boosts the absorbency of the core and adds to its environmental friendliness.

2.2. Testing methods for sanitary napkins

The tests conducted to measure the performance of sanitary napkins are given in the Table 1.

Table 1 - Tests conducted for measuring the performance characteristics of sanitary napkins

S. No.	Performance Properties To Be Tested	Testing Standards	Remarks
1	Absorbency%	IS:5405-1980 A-1.2	These tests were done in 2 ways: 1. In-house method 2. performance tester method
2	Retention%	IS: 5405-1980 5.1	
3	Rewet under load	Modified IS: 5405-1980 5.1	
4	Leak Factor	Modified IS: 5405-1980 5.1	
5	Fibre Absorbency	MA001-1-diapers-worldwide.com	

2.2.1 Absorbency test for sanitary napkins

This test was carried out using a burette, a glass plate, a stand to hold the sample, a weighing machine, a stopwatch, goat blood with anticoagulant, or test fluid, either of which simulated menstrual blood. The napkin's dry weight (IN) was recorded and it was placed on a glass plate that was flat and level so that the underside of the napkin could be seen. From a height of about 1-2 mm away from the burette, liquid was dripped at a rate of 15 ml per minute onto the centre of a sanitary napkin. The sanitary napkin's ability to absorb liquid was tested until it reached its maximum capacity and began to leak (which could be seen by the pad on the sides leaking), at which point it ceased to be absorbent. Based on the burette readings, the amount of liquid absorbed up until the end point was measured in ml, and the values were tabulated.

The sanitary napkin's ability to absorb blood up until the point of leakage was measured as its absorbency percent.

The absorbency% was calculated using the formula:

Absorbency% = ((FA-IN)/ (IN))*100

IN - Initial weight of the whole napkin

FA - Final weight of napkin

2.2.2 Retention%, leak factor and rewet under load

For this test, a burette, a glass plate, a stand to hold the sample, one kilogram of weight, blotting paper, a weighing machine, a stopwatch, goat blood with an anticoagulant, or test fluid, either of which simulated menstrual blood. After determining the leak location and weighing the sanitary napkin, blotting papers with known initial weights were placed on top and bottom of the pad, respectively. Over this area, where the fluid was absorbed, a standard weight of 1 kg was applied for 1 minute. To determine the final weight of the napkin and blotting papers, the top and bottom of the pad are removed at the completion of the loading period.

The retention percentage measured how much blood the sanitary napkin could hold after absorbing it when 1 kg of weight was applied.

The retention% was calculated using the formula:

Retention% = ((FR-IN)/ (IN))*100

Where, IN- Initial weight of the whole napkin
FR- Final weight of napkin

The leak factor is the ability of the sanitary napkin to resist leaking of the absorbed blood from the sides and bottom of the sanitary napkin on application of 1 Kg weight.

The leak factor was calculated using the formula:

Leak factor% = ((FTB-ITB)/ (ITB))*100

Where, ITB- Initial weight of the top blotting paper

FTB- Final weight of the top blotting paper

The rewet under load is the ability of the sanitary napkin to resist leaking of the absorbed blood from the top of the sanitary napkin on application of 1 Kg weight.

The Rewet under load was calculated using the formula:

Rewet under load% = ((FBB-IBB)/ (ITB))*100

Where, IBB- Initial weight of the bottom blotting paper

FBB- Final weight of the bottom blotting paper

2.2.3 Methods for testing the sanitary napkin performances in the fabricated performance tester

The tests were carried out using a stop clock, performance tester, and test fluid. The steps mentioned above were taken in order to use the made-up performance tester. Compared to the above-described internal method, the procedure was simpler and more accurate because the integrated load cell eliminated the need to remove sanitary napkins from the apparatus each time the apparatus' weight needed to be measured.

To ensure the correct reading, the load cell controller is initially nullified. The burette's precise centering was verified. The sample sanitary napkin was set on top of the glass plate. The burette was adjusted so that it would release the liquid at a rate of 15 drops per minute and between 1 and 2 millimeters away from the sanitary napkin. Additionally, a reservoir is available to supply the liquid to the burette throughout the testing process, eliminating the need to unload the burette and refill it with liquid. The sample's weight will be displayed by the electronic weighing balance. Every time the time component needed to be measured and recorded, the stop clock was set to run. In order to measure the fluid retention capacity, the liquid reservoir holder was tilted sideways and the weighing lever was skewed inside over to the top of the napkin's center. By putting blotting paper over and below the sanitary napkin before applying weight, it was possible to measure the napkin's rewet under load and leak factor. Blotting papers and sanitary napkins were individually weighed before being placed on the base plate to determine weight. The performances of the sanitary napkin were calculated.

2.3 Performance tests for sanitary napkins developed from the natural fibres

The performance of sanitary napkins made from natural fibers was evaluated using the fabricated performance tester and tested according to the tests listed in Table 2.

Table 2 - Dimensional and performance characteristics done for the developed sanitary napkins

Experiment	Standard
Strike through rate	STN2: 138/90
Absorbency%	IS:5405-1980 A-1.2
Retention%	IS: 5405-1980 5.1
Rewet under load	Modified IS: 5405-1980 5.1
Leak Factor	Modified IS: 5405-1980 5.1

3. Results and Discussion

3.1 Varieties of Sanitary Napkins made from the natural fibres

Table 3 - Varieties of Sanitary Napkins

Samples	Top layer	Middle layer	Core layer (%)	Weight of absorbency (g/m^2)	Dimension of pad(cms)
S1	100% bamboo spunlaced	Super absorbent polymer	bamboo 40 : flax 60	7.5	25 X 7.5
S2	100% bamboo spunlaced	Super absorbent polymer	bamboo 40 : hemp 60	7.5	25 X 7.5
S3	100% bamboo spunlaced	Super absorbent polymer	bamboo 40 : flax 30 + hemp 30	7.5	25 X 7.5

Table 4 - Performance analysis of prepared sanitary napkin

Samples	Absorbency %	Retention%	Rewet under load	Leak Factor	Strike through rate (sec)	extent spread of goat blood (mm)
S1	142.48	138.65	0	2	12	L=55,B=40
S2	138.87	128.87	0.71	0	5.99	L=35,B=30
S3	184.68	183.81	6.9	0.65	8.78	L=50,B=45

Tables 3 and 4, respectively, provide information on the different sanitary napkins manufactured with different natural fibers as well as the results of their performance analysis. The information supplied shows the extent of spread of goat blood for three distinct samples (S1, S2, and S3), each of which represents distinct properties of absorbent materials, as well as the absorbency, retention, rewet under load, strike-through rate, and leak factor. Sample S3 is the best of all the napkin samples because of its good absorbency, retention, and leak factor—even though it rewets under load more than the other samples.

With an absorbency percentage of 142.48%, Sample S1 exhibits good absorbency and can hold a significant volume of fluid. In addition, it has a high retention percentage of 138.65%, which indicates that the majority of the liquid that is absorbed is retained. Interestingly, S1 does not rewet under load, indicating that it keeps its dryness under pressure. Its relatively high leak factor of 2 could, however, suggest that it is less successful in keeping liquid from passing through. The 14 second strike-through rate suggests that it absorbs quickly. Goat blood has spread quite a bit, measuring 55 mm in length and 40 mm in width, which suggests good coverage.

In spite having lower retention and absorbency percentages than sample S1, sample S2 still performs well. It shows some wetness under pressure with a minor rewet under load of 0.71. Effective liquid containment is suggested by the low leak factor of 0. The comparatively quick absorption is indicated by the strike-through rate of 5.99 seconds. Goat blood has spread less widely than S1, measuring 35 mm in length and 30 mm in width.

Sample S3 exhibits superior fluid absorption and retention capacity, as evidenced by its highest absorbency and retention percentages. Its notable rewet under 6.9 load, however, could compromise its dryness under pressure. At 0.65, the leak factor is comparatively low. An acceptable absorption speed is indicated by the strike-through rate of 8.78 seconds. With measurements of 50 mm in length and 45 mm in width, the goat blood spread is likewise significant, indicating good coverage.

As a result of their various strengths and weaknesses, these samples are suitable for a variety of applications depending on the particular requirements of absorbency, retention, rewet resistance, and leakage prevention.

4. Conclusion

Three different types of sanitary napkins made of natural fibers, each with specific performance characteristics, were thoroughly analyzed in the study. A number of standards, such as absorbency, retention, rewet under load, leak factor, strike-through rate, and the degree of goat blood spread, were carefully examined in order to evaluate these sanitary napkins. Important information about the effectiveness of these environmentally friendly and biodegradable menstrual products was provided by the results. With an absorbency percentage of 142.48%, Sample S1, which was made up of a core layer made of a blend of bamboo and flax and a top layer spunlaced entirely of bamboo, showed excellent absorbency, with a retention percentage of 138.65%, it effectively held onto liquid, and when under load, it showed no signs of rewetting, demonstrating its resilience to pressure. S1, which comparatively high leak factor of 2, indicating that there is still potential for improvement in stopping liquid seepage. At 14 seconds, the strike-through rate was rapid and the spread of goat blood was wide.

In comparison to Sample S1, Sample S2, which had a core layer made of a bamboo-hemp blend, showed slightly less absorbency and retention. It performed well with a leak factor of 0, ensuring efficient liquid containment, but it also displayed a low rewet under load of 0.71, indicating some wetness under pressure. The rate of strike-through was 5.99 seconds, and the spread of goat blood was marginally smaller than S1. With the highest absorbency and retention rates out of the three samples, Sample S3 remained out as the top performer. It was exceptional at absorbing and holding onto fluids. Its notable rewet under 6.9 load, however, may have an impact on its dryness under pressure. With a leak factor of 0.65, it was evident that liquid eakage was effectively prevented. Goat blood was widely dispersed, and the strike-through rate was 8.78 seconds.

The study's conclusions imply that sanitary napkins' performance can be greatly impacted by the type of natural fibers used in their development. The bamboo-flax-hemp core of Sample S3 showed excellent absorbency and retention, but it also had a minor rewet resistance issue. Sample S2, which combined hemp and bamboo, showed balanced performance traits. With a bamboo-flax core, Sample S1 was the most absorbent and driest, but its ability to prevent leaks could be strengthened. Because of these differences in performance, these sanitary napkins can be used for a variety of purposes. Women can select products that meet their unique needs, whether they are for absorbency, dryness, or leak prevention, and they are also biodegradable and environmentally friendly. This research opens the door for environmentally friendly sanitary napkin alternatives that put performance and sustainability.

Reference :

[1] J. Saranya, C. Prakash & S. Kubera Sampath Kumar, "Menstrual Hygiene Practices among Adolescent Girls", International Journal of Innovative Technology and Exploring Engineering, 8/12 (2019) 364-366, https://doi.org/10.35940/ijitee.L3270.1081219

[2] M.P. Sathianarayanan, N.V. Bhat, S.S. Kokate & V.E. Walunj, "Antibacterial finish for cotton fabric from herbal products", Indian Journal of Fibre and Textile Research, 35/1 (2010) 50-58

[3] Choi TM, Cheng TE. 'Sustainable Fashion Supply Chain Management', New York; Springer: 2015: pp. 15-25

[4] Y. Song, Q. Zheng & C. Liu, "Green biocomposites from wheat gluten and hydroxyethyl cellulose: processing and properties", Industrial Crops and Products, 28/1 (2008) 56-62, https://doi.org/10.1016/j.indcrop.2008.01.004

[5] H.D. Rozman, K.R. Ahmadhilmi & A. Abubakar, "Polyurethane (PU)-oil palm empty fruit bunch (EFB) composites: the effect of EFBG reinforcement in mat form and isocyanate treatment on the mechanical properties", Polymer Testing, 23/5 (2004) 559-565, https://doi.org/10.1016/j.polymertesting.2003.11.004

[6] Y. Habibi, W.K. El-Zawawy, M.M. Ibrahim & A. Dufresne, "Processing and characterization of reinforced polyethylene composites made with lignocellulosic fibres from Egyptian agro-industrial residues", Composites Science and Technology, 68/7 (2008) 1877-1885, https://doi.org/10.1016/j.compscitech.2008.01.008

[7] A.M.Z. Jukic, C.R. Weinberg, D.D. Baird, P.P. Hornsby & A.J. Wilcox, "Measuring menstrual discomfort: a comparison of interview and diary data", Epidemiology, 19/6 (2008) 846-850, https://doi.org/10.1097/EDE.0b013e318187ac9e

[8] W. Audra & A. Frank, "Comfort Perception of Breathable and Nonbreathable Diapers", International Nonwovens Journal, 14/3 (2005) 19-22, https://doi.org/10.1177/1558925005os-1400303

[9] I. Parkova & A. Vilumsone., "Microclimate of Smart Garment", Material Science, 6 (2011) 99-103

[10] G.B. Marcela, G.G. Paulo & L.B.P. Cristina, "Association of sanitary pads and clothing with Vulvo vaginitis", Jornal Brasileiro De Doenças Sexualmente Transmissiveis, 25/3 (2013) 123-127

[11] H.S. Mohapatra, A. Chatterjee & P. Kumar, "New Generation Application of Polypropylene", International Journal of Advanced Engineering and Nano Technology, 1/1 (2013) 1-9

[12] Ingo, G.M., and S. Scarlet. 1987. Copper-Modified Carboxyalkyl-cellulose Fiber. US Patent US4637820A, filed March 4, 1987, and issued March 4, 2005

Quality Aspects of Ring Spun Tencel/Polyester and Tencel/Cotton Ply-Twisted Yarns

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Abstract:

The paper presents the results of an experimental study on the quality aspects of tencel-polyester and tencel-cotton ply-twisted yarns. Three distinct fibre-mixes of tencel-polyester and tencel-cotton blended ring-spun ply-twisted yarns with varying single and ply - twists were analyzed for their physical properties. It was found that tencel- polyester ply - twisted yarn exhibits superior strength and extensibility compared to tencel-cotton ply-twisted yarn. Achieving higher strength and extensibility necessitates a low singles' yarn twist factor and a high doubling-ratio. Comparable to tencel-cotton ply - twisted yarns, tencel-polyester yarns exhibit greater uniformity; however, the degree of uniformity diminishes as the singles' yarn twist factor increases. The results also showed that tencel- polyester ply -twisted yarn have less hairiness and lower rigidity, the latter increases with an increasing doubling- ratio.

Keywords: *Ring-spun yarn, Tencel blended yarn, Tencel-cotton yarn, Tencel-polyester yarn, Tex twist factor*

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1. Introduction

With the continuous surge in demand for technical textiles, the need to expand production capacities for plied and folded yarns has escalated significantly. Plied yarns, formed by twisting two or more single yarns, play a crucial role in improving yarn properties and producing higher value products, Ply-twisted yarns exhibit greater regularity, balanced longitudinal variations in individual ends, and compensation for spot defects [1-2]. The twisting process determines the yarn structure, strength, and the handle properties of the resultant product, including bulk, quality, and yarn hairiness.

The development of yarn structural becomes even more complex when the yarn is spun from blends of fiber with dissimilar properties and type [3, 4]. The blending of different fibers is a common practice in the spinning industry to achieve a desirable range of properties that meet end-use requirements and economic considerations. The introduction of new cellulosic fibers like Tencel, along with the availability of fibers with diverse types and properties, has opened a rich variety of materials for blending. Tencel fiber, known for its luxury and practicality, blends seamlessly with other nature and synthetic fibres such as cotton, polyester, lycra or wool, enhancing comfort and performance.

While some researchers have explored the properties of ring-spun tencel, polyester, and cotton single yarns, along with their blends, more information is required for the better practical application of ply -twisted tencel-blended yarns. This paper aims to identify the quality aspects of ply-twisted tencel-polyester and tencel- cotton yarns, focusing on quantifying the physical characteristics of these structures.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Yarns of 29.5 Tex were spun from tencel and its blend with polyester and cotton fibres using three different blend ratios (25:75, 50:50, 75:25,) and Tex twist factor ranging from 28.71 to 47.85. The fibre specifications of tencel, polyester and cotton fibres are given in Table 1. For blending tencel and polyester fibres, each of the two components was hand opened and sandwiched well to produce a homogeneous blend. However, for tencel-cotton blended yarns, the combed cotton sliver was blended with tencel fibre in the opening room. The conversion to drawn sliver was carried out by using a MMC carding machine and Lakshmi Rieters' drawframe DO/2S. Two drawing passages were given to the card sliver, the linear density of finisher sliver being adjusted to 3.69 ktex. The finisher sliver, converted into 492 Tex roving on an OKK flyframe, was used to produce 29.5 Tex yarn on Lakshmi Rieters' G5/1 ring frame using a spindle speed of 12,000 rpm. For plying, two single yarns of 29.5 Tex were first parallel wound on a parrel winder for a suitable package and were later S- twisted on Texmaco ring doubler running at 8500 rpm. All plied yarns were twisted at three different doubling ratios (doubling to single twist ratio, D/S ratio) of 0.35, 0.53 and 0.71 for preparing final plied yarns of tencel – polyester and tencel-cotton blends.

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Table 1– Specifications of Tencel, Polyester and Cotton fibers

Fibre	Length, mm	Linear density, dtex	Tenacity, cN/tex	Breaking elongation %	Modulus, cN/tex
Tencel	38	1.40	31.3	7.2	731.3
Polyester	38	1.33	56.2	10.8	698.9
Cotton	33.1[a]	1.18	24.9	6.5	525.5

[a] Span length, 2.5%

2.2 Tests

All the yarns were tested for single strand strength and breaking extension on an Instron (Model 4411) using 500 mm test specimen and 200 mm/min cross- head speed. The tensile parameters were averaged from 50 observations for each yarn sample. Yarn irregularity was determined using the Uster Evenness Tester (UT-III). The flexural rigidity was measured on weighted ring yarn stiffness tester by ring loop method [5]. Zweigle hairiness meter (Model G565) was used to record yarn hairiness. The hairiness was tested at speed of 50 m/min for 4 minutes and an average of ten readings is taken.

3. Results and Discussion

The influence of three experimental factors, namely blend ratio, single yarn Tex twist factor, and doubling- ratio (D/S ratio) on the yarn characteristics, was assessed for significance using ANOVA analysis (Table 2). The confidence level used was 99%. The main factors significantly influenced most properties for both tencel-polyester and tencel-cotton blended ply-twisted yarns, except imperfection.

Table 2 - ANOVA results for Tencel-polyester and Tencel-cotton blended ring spun plied yarns

Fibre type	Process variables	Properties										
		Tenacity	Breaking elongation	Unevenness	Imperfection				Flexural rigidity	Hairiness		
					Thin	Thick	Neps	Total		N1	N2	S3
Tencel-Polyester	B	s	s	s	ns	ns	ns	ns	s	ns	ns	s
	C	s	s	ns	ns	ns	ns	ns	s	s	s	s
	D	s	ns	s	ns	ns	ns	ns	s	s	s	s
Tencel-Cotton	B	s	s	s	ns	s	s	s	s	ns	ns	ns
	C	s	s	ns	ns	s	s	s	ns	s	s	s
	D	s	ns	s	ns	s	s	s	s	s	s	s

s- Significant at 99% significance level; ns- Not significant at 99% significance level
B- Tencel %; C-Single yarn tex twist factor; D- Double to single yarn twist ratio

3.1 Tenacity

As expected, the tenacity of both tencel-polyester and tencel-cotton yarns tends to increase after plying (Table 3). During plying, the twist is applied in the opposite direction to that of single yarns, resulting in the parallelization of fibers. Consequently, more fibers share the load during tensile loading, leading to increased yarn tenacity [6-7]. Regardless of single yarn twist, tenacity continues to increase due to ply twist for both tencel-polyester and tencel-cotton yarns. This phenomenon persists across the entire set of yarns under investigation; however, the level of increase in tenacity differs between tencel-polyester and tencel-cotton yarns. In the case of tencel-polyester yarns, the tenacity of ply - twisted yarns majorly decrease with an increase in single yarn twist. Conversely, tencel-cotton ply-twisted yarns spun with higher cotton content display an increase in tenacity with an increase in singles' as well as ply twist. These results reaffirm that doubling-ratio is the most influential parameter determining yarn tenacity. Simultaneously, the composition of the fibre-mix in the blended yarns also affects the tenacity of the ply-twisted yarns. As seen in Table 3, increasing tencel content in the fibre- mix increases the tenacity of tencel-cotton ply-twisted yarns but adversely affects the tenacity of tencel-polyester yarns. This behavior is quite understandable and arises due to the higher tenacity and breaking extension of tencel fibre than cotton and lower tensile properties than polyester fibre.

3.2 Breaking extension

Table 3 shows the breaking extension values of tencel blended ply - twisted yarns. Generally, tencel-polyester ply-twisted yarns exhibit higher breaking extension than their tencel-cotton counterparts. A positive correlation exists between doubling-ratio and yarn extension, indicating an increase in breaking extension. As observed in Table 3, a higher plied yarn extension can be achieved with a low single yarn twist factor in combination with a high doubling- ratio. Conversely, ply-twisted yarns produced with high single yarn twist display lower breaking extension, which increases with an increasing doubling -ratio. Regarding the fibre mix composition, the breaking extension of ply - twisted yarns follows the same trend as tenacity. In the case of tencel-polyester ply-twisted yarns, the breaking extension increases with an increase in proportion of polyester fibre in the mix.

Similarly, the breaking extension of tencel-cotton ply-twisted yarns decreases with an increase in cotton content in the mix. These trends are expected consequences of the significant differences in the breaking extension of polyester and cotton fibres. Additionally, all the ply - twisted yarns show higher breaking extension when plied with a high twist factor. This can be attributed to the fact that a higher twist in the yarn provides better packing and obliquity of fibres, making the yarn more extensible [8].

Table 3 - Influence of single twist factor and doubling ratio on tenacity, breaking extension and flexural rigidity of ring spun tencel-polyester and tencel-cotton blended plied yarns at different blend ratios.

Fiber type	Blend ratio	Single yarn tex twist factor	Tenacity, g/tex				Breaking elongation, %				Flexural Rigidity, dyne-cm^2 * 10^{-1}			
			Single yarn	Ply-twisted yarn			Single yarn	Ply-twisted yarn			Single yarn	Ply-twisted yarn		
				0.35[a]	0.53[a]	0.71[a]		0.35[a]	0.53[a]	0.71[a]		0.35[a]	0.53[a]	0.71[a]
Tencel: polyester	25:75	28.71	25.95	28.04	30.39	30.41	10.65	10.89	11.06	12.62	3.03	4.14	4.35	4.92
		38.28	25.29	28.96	29.71	31.68	11.16	11.49	11.69	11.88	3.33	4.59	4.95	5.17
		47.85	24.12	25.15	26.36	26.79	12.48	9.02	8.84	9.46	3.71	5.17	5.51	5.71
	50:50	28.71	24.54	26.72	27.01	28.16	9.09	9.66	9.9	8.96	3.09	4.68	4.92	5.44
		38.28	22.95	25.22	26.58	27.06	9.61	10.59	10.24	10.42	3.71	5.17	5.62	5.84
		47.85	20.28	22.53	22.81	22.91	9.82	8.91	8.75	9.18	4.84	5.44	5.64	6.87
	75:25	28.71	23.27	23.73	25.05	26.48	7.96	8.05	8.12	8.17	4.55	5.17	5.44	5.92
		38.28	22.7	23.77	24.83	25.48	8.19	9.01	9.2	9.75	4.67	5.87	6.29	6.73
		47.85	20.02	21.63	21.77	21.9	8.69	8.87	8.44	9.04	5.66	6.28	6.73	7.04
Tencel: cotton	25:75	28.71	17.49	16.97	18.45	20.45	5.62	6.48	7.04	7.19	2.94	3.94	4.92	4.92
		38.28	19.52	16.57	18.11	20.13	6.66	6.69	6.72	6.8	3.88	4.35	4.68	5.17
		47.85	18.03	16.62	16.89	18.89	7.06	5.38	5.67	6.03	2.89	4.17	4.35	4.97
	50:50	28.71	18.59	19.54	19.79	20.95	5.89	6.73	7.13	7.37	4.22	5.35	5.44	5.9
		38.28	20.54	22.47	22.85	23.15	6.21	6.64	6.75	6.85	4.57	5.25	5.77	5.85
		47.85	19.31	20.17	20.26	20.44	6.36	6.43	6.08	6.53	3.72	5.26	5.35	5.44
	75:25	28.71	20.83	21.38	21.7	23.73	5.93	7.59	8.29	9.13	4.73	5.92	5.92	6.16
		38.28	20.15	21.06	21.21	21.79	6.51	6.72	6.85	6.89	5.44	5.94	6.04	7.11
		47.85	18.37	19.51	20.18	20.75	6.75	6.87	6.19	7.11	4.83	6.3	7.68	7.87

[a] Double to single yarn twist ratio

3.3 Flexural rigidity

Table 3 shows the flexural rigidity values of different yarns. The presence of tencel fibre in the fibre mix increases the flexural rigidity of both types of blended yarns. This can be attributed to the higher modulus and lower bulk of tencel fibre compared to polyester and cotton fibre, which aids in increasing the packing of fibres and impedes the freedom of fibre movement [9]. Furthermore, the flexural rigidity values of both tencel-polyester and tencel-cotton ply-twisted yarns are significantly higher than the corresponding single yarns and further increase with an increasing doubling-ratio. This is due to the wrapping of single twisted yarns around each other in a plied yarn, which always reduces the freedom of fibre movement as compared to that in single yarn structure, resulting in higher flexural rigidity of the ply- twisted yarns [10].

3.4 Unevenness and Imperfections

The unevenness of singles and ply – twisted yarns depend on various factors. The single yarn twist plays an important role, but other factors such as the composition of the fibre-mix and doubling-ratio also have significant influence. As can be seen from Table 4, unevenness of all the single yarns increases with an increasing single twist factor. The reason for the increased unevenness is the higher crimp added to the yarn, which gives a wavy effect to the structure due to mechanical hinderance [11].

For all yarns, the unevenness reduces significantly after plying. However, the unevenness of ply-twisted yarns slightly increases with an increase in single yarn twist factor, most likely due to obstruction in fibre movement at the nip of the front roller [12]. Interestingly, tencel- cotton ply-twisted yarns exhibit more reduction in unevenness than those of tencel-polyester yarns, irrespective of single yarn twist. Furthermore, the unevenness of all ply – twisted yarns increases with an increase in doubling- ratio; tencel- cotton ply-twisted yarns display more unevenness compared to their tencel-polyester counterparts.

Imperfection figures of tencel- cotton and tencel-polyester single and ply-twisted yarns, as shown in Table 4, reduce considerably on plying. Tencel- cotton ply-twisted yarns show more thick places, thin places and neps compared to tencel-polyester ply-twisted yarns. However, there is no specific trend for reduction in imperfections with San increase in doubling-ratio.

Table 4 - Influence of single twist factor and doubling ratio on unevenness and imperfections/km of ring spun tencel-polyester and tencel-cotton blended plied yarns at different blend ratios.

Fiber type	Blend ratio	Single yarn tex twist factor	Unevenness, U%				Imperfections/km			
			Single yarn	Ply-twisted yarn			Single yarn	Ply-twisted yarn		
				0.35[a]	0.53[a]	0.35[a]		0.35[a]	0.53[a]	0.35[a]
Tencel: polyester	25:75	28.71	8.95	6.39	6.42	7.33	2	0	4	0
		38.28	9.26	6.12	6.37	6.38	0	0	0	0
		47.85	9.46	6.44	6.49	6.75	0	0	0	0
	50:50	28.71	9.27	6.31	6.61	6.72	0	0	0	0
		38.28	9.54	6.27	6.33	6.43	2	0	4	4
		47.85	9.64	6.59	6.70	7.07	3	0	0	0
	75:25	28.71	9.59	6.76	7.10	7.16	1	0	0	0
		38.28	10.22	6.53	6.99	7.39	2	2	4	0
		47.85	10.51	6.20	6.80	7.05	6	2	0	0
Tencel: cotton	25:75	28.71	12.29	8.07	8.53	9.44	16	0	4	0
		38.28	11.81	8.32	8.53	8.69	24	0	0	4
		47.85	13.2	8.61	8.63	9.14	16	0	10	0
	50:50	28.71	11.59	7.89	8.05	8.53	18	4	2	0
		38.28	11.7	7.83	7.88	8.86	13	0	0	4
		47.85	12.36	7.70	7.87	8.23	12	6	0	0
	75:25	28.71	11.35	7.51	7.66	8.23	28	0	0	0
		38.28	11.56	8.21	8.76	9.28	12	4	1	0
		47.85	11.68	7.72	7.95	8.95	9	3	0	0

[a] Double to single yarn twist ratio

3.5 Hairiness

Table 5 shows the yarn hairiness value in class N1 (<1mm long), N2 (<2mm long) and S3 (>3mm long) for ring-spun tencel blended single and ply-twisted yarns. As expected, the hairiness of both types of yarns is greatly affected by the change in single yarn twist factor. An increase in the single yarn twist factor leads to a decrease in both short and long hairs irrespective of the composition of the fibre mix. However, the effect of single yarn twist factor on hairiness is more pronounced in tencel- cotton yarns. This reduction in hairiness occurs because high twist enables the fibres to traverse towards the yarn axis owing to a high rate of migration, resulting in firm embedment of fibres in the main body of the yarns [13]. Table 5 also shows that both tencel-polyester and tencel-cotton ply-twisted yarns display a drastic decline in hairiness compared to their singles counterparts, and the number of hairs in all three length classes decreases with an increase in doubling-ratio. At a high doubling- ratio, the high compression force on the strands and the low twist in the strands make the strands flatten at the point of contact between the strands. Hence, an increase in ply twist reduces hairiness [14]. An increase in ply twist also decreases the number of hairs in all three length classes in statistically meaningful terms. This is because ply twist causes the hairs of single strands to be trapped between the strands or wrapped on the surface of the yarn, resulting in a decrease in hairiness.

4. Conclusión

a. The properties of ply-twisted yarns depend solely on the doubling ratio and the composition of fibe-mix. Generally, tencel-polyester ply-twisted yarns are stronger, more extensible, more even, and have fewer imperfections compared to their tencel-cotton counterparts. Increasing the doubling ratio enhances the tenacity, breaking extension, and evenness of ply-twisted yarns, regardless of the composition of the fibre mix.

b. The doubling ratio is also a crucial factor for the hairiness and flexural rigidity of ply-twisted yarns. Increasing the doubling ratio reduces hairiness in both types of yarns but adversely affects flexural rigidity. Under all experimental conditions, tencel-polyester yarns exhibit less hairiness and more flexural rigidity, even after plying.

Table 5 - Influence of single twist factor and doubling ratio on hairiness of ring spun tencel-polyester and tencel-cotton blended plied yarns at different blend ratios

Fiber type	Blend ratio	Single yarn tex twist factor	Hairiness/10m											
			Single yarn			Ply-twisted yarn								
						0.35[a]			0.53[a]			0.71[a]		
			N1	N2	S3	N1	N2	S3	N1	N2	S3	N1	N2	S3
Tencel: polyester	25:75	28.71	1015	117	12	2483	286	51	1940	219	43	1748	186	23
		38.28	905	83	12	1731	175	25	1413	133	12	1358	118	10
		47.85	870	79	11	1357	132	10	1175	39	8	1146	16	7
	50:50	28.71	853	72	20	2368	267	48	2221	215	39	1659	155	24
		38.28	801	56	15	1754	157	30	1449	121	19	1335	112	18
		47.85	54	7	8	1328	19	7	1155	16	6	754	10	5
	75:25	28.71	755	51	31	2587	293	56	2369	237	46	1654	152	32
		38.28	702	44	27	1536	123	37	1268	91	23	1204	85	21
		47.85	654	40	25	963	72	23	911	60	12	831	53	6
Tencel: cotton	25:75	28.71	1402	161	33	3086	398	77	2989	364	52	1974	210	29
		38.28	1019	106	23	1922	186	39	1659	152	35	1580	127	22
		47.85	996	99	20	1427	141	25	1394	141	23	1179	22	19
	50:50	28.71	1240	123	29	3430	429	96	3170	374	73	1926	193	40
		38.28	1017	84	25	2008	172	31	1559	137	26	1513	132	22
		47.85	933	85	22	1371	163	16	979	87	15	673	59	13
	75:25	28.71	1309	117	39	3456	371	83	2985	282	82	1921	173	39
		38.28	1112	96	37	2246	201	41	2117	189	31	1599	136	27
		47.85	1101	80	34	1664	134	25	1403	129	24	1337	113	15

[a] Double to single yarn twist ratio

References

[1] Tyagi G K, Quality aspects of two-for-one and ring-twisted OE rotor-spun plied yarns, *Indian J. Fibre Text. Res*, Vol.31, June 2006, pp.293-297

[2] O Ozdemir, S Sardag & F Kalaoglu, Effect of twisting methods on plied yarn properties, *Indian J. Fibre Text. Res.*, Vol.31, Sept 2006, pp. 394-400

[3] Kaushik RCD, Salhotra KR & Tyagi G K, influence of doubling on characteristics of acrylic-viscose rayon rotor-spun yarns, *Indian J. Fibre Text. Res*, Vol.-12, sept.1987, pp.142-145

[4] Tyagi G K & Chatterjee KN, Contribution of doubling to the characteristics of polyester/cotton ring and rotor spun yarns, *Indian J. Fibre Text. Res*., Vol.-17, Mar 1992, pp. 9-14

[5] Owen J D and Riding G, The weighted ring stiffness test, *J Text Inst*, 55(1964) T414

[6] Tyagi G k, R. Chattopadhyay, Physical characteristic of tencel-polyester and tencel-cotton yarns produced on ring, rotor and air-jet spinning machines. *Indian J Fibre Text Res*, vol.-38, sept. 2013, pp, 230-236

[7] Basu Arindam and Gotipamul L Rajanna, Quality characteristics of polyester/viscose and polyester/cotton two ply yarns, *Indian J Fibre Text Res*, 31(2006), 279-285

[8] Louis A. Fiori, John J. Brown, and Jack E. Sands, Effect of single and ply twists on the properties of a 31/2 carded cotton yarn. *Text Res J*, March 1954, pp 267-272

[9] Wooding C, Regenerated Cellulosic Fibres, Woodhead publishing Limited, Cambridge, 2001, Vol.12, No.6, 290-304

[10] Chattopadhyay R, Strategic responses by Hong Kong textile and clothing firms towards MFA, *J Text Inst*, 88(1997) 76-78

[11] Tyagi G K, Ajay R, Gupta S & Kapoor V, Influence of fiber linear density, twist and direct dye on physical and dye-uptake characteristics of viscose rayon yarns, *Indian J Fibre Text Res*, 11 (1986) 150

[12] Tyagi G K, Bhowmick M, Bhattacharyya S and Kumar R, Effect of spinning conditions on mechanical and performance characteristics of cotton ring and compact spun yarns, *Indian J Fibre Text Res*, 35(2010) 21-30

[13] Tyagi G K, Sharma K R, Goyal A & Singh M, Variation in polyester-viscose and polyester-cotton ring and rotor yarn characteristics as a consequence of fibre cross-section, *Indian J Fibre Text Res,* 29 (2004) 184

[14] Palaniswamy k, Mohamed Peer A, Effect of the single yarn twist and ply to single yarn twist ratio on the hairiness and abrasion resistance of cotton two-ply yarn, *Autex research journal*, Vol.6, No.2, June 2006

Studies on Tensile Behaviour and Uniformity of Jute Plied Yarn

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Abstract:

Jute plied yarns are primarily used as sewing twine for sacks, apart from their other uses in carpet, geotextiles, etc. Though tensile behaviour and uniformity are the two most important properties of jute-plied yarns, studies on the factors that influence these properties are not available. In the present work, the authors studied the influence of the number of plies, single yarn twist factor and ply to single yarn twist ratio on tenacity and breaking extension of jute plied yarn. It is observed that with increase in the number of plies, the optimum tenacity of jute plied yarn is achieved at comparatively lower ply to single twist ratio. They also noticed that breaking extension of jute ply yarn increases with increase in the number of plies as well as ply to single twist ratio. While studying the irregularity of jute plied yarn, they observed that plying improves jute yarn regularity and maximum improvement is observed in 4-ply yarn followed by 3-ply and 2-ply.

Keywords: *irregularity, jute, plied yarn, tenacity, twist factor, twist ratio*

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1. Introduction

Although single yarns are used in most textile applications, this type of yarn possesses comparatively higher hairiness, lower abrasion resistance, higher unevenness and most importantly, lower specific strength and elongation [1,2]. These factors not only contribute to the aesthetic appearance but also influence the functional performance of the yarns and fabrics made thereof.

A plied or folded yarn is produced by twisting two or more single yarns together. Despite of the fact that twisting adds cost to the yarn, plying is sometimes inevitable where single yarn properties cannot fulfil the end-use requirement of the product. Although further processing like sizing to improve weavability of warps, waxing to increase abrasion resistance of knitted yarns, singeing to remove unwanted surface hairiness etc. are practiced to overcome some of the deficiencies of single yarns [3], plying is exclusively done to achieve special properties of yarn and/or fabric which have no alternative method to achieve.

Studies show that while multiple strands of single yarns are twisted together the longitudinal variations in the individual yarns are balanced and spot defects are compensated [2]. Studies also show that plying two or more single yarns improves vital yarn properties like strength, elongation, evenness, hairiness, abrasion resistance, bulkiness, etc. [4-6].

Extensive studies have been conducted to understand properties of plied yarn made out of cotton and other major types of textile fibres [1-7]. Omerglu [7] observed that hairiness values of plied yarn, made out of ring spun cotton single yarns, decreased as twist levels increased with evidence of greater influence of ply twist than single twist. Sett, Mukherjee and Kundu [4] observed that the tenacity of Z on Z plied yarn is higher than S on Z plied yarn. The authors also obsereved that tenacity of S on Z plied yarn decreases with increase in single yarn twist level but in case of Z on Z plied yarn it gradually increases to maximum level and then decreases with further increase in single yarn twist. Coulson & Dakin [8] opined that for all values of singles twist there is a best doubling twist at which maximum strength can be obtained. In general, the maximum strength obtainable from the doubled yarn decreases as the singles twist increases. The strongest doubled yarn of any count can be obtained by using single yarns of low twist level with high doubling twist.

Like cotton and other textiles, jute yarns are also plied, particularly for its end-use as sewing threads, carpets, fancy yarns, etc. Although it is reported that the performance of jute sewing thread plays great role on the serviceability of jute sacks, studies on structure-property relations of jute plied yarns are limited. Moreover, considering the fact that jute fibres are distinctive and its processing technology are different from conventional textiles process, this necessitates a comprehensive study to understand the physical and mechanical characteristics of jute plied yarn in order to optimize parameters to achieve a quality plied yarn. Effort in this work has been made to understand effects of various ply yarn parameters on its properties.

2. Materials and Methods

To study the effect of single yarn as well as plied yarns' structural parameters on properties of plied yarn, 27 different types of plied yarns of 930 tex resultant count were produced by varying single yarn count in three levels (233 tex, 310 tex and 465 tex), single yarn twist factor (TF) in three levels (24, 26 and 28 in tpc-tex unit) and plied to single twist ratio in three levels (0.5, 0.7 and 0.9). All the yarn samples were prepared from TD4 quality raw jute (as per Indian Standard No. IS 271: 2003) in pilot machines following norm-based machine parameters. The detailed set parameters for singles and plied yarn are given in Table 1.

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Table 1: Single and Ply yarn parameters

Plied yarn count (tex)	930			930			930		
No. of ply x single yarn count (tex)	4 x 233			3 x 310			2 x 465		
Single yarn twist factor (in tpc - tex unit)	24	26	28	24	26	28	24	26	28
Ply to single twist ratio (D:S)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

In order to independently study the dependancy of plied yarn tenancity on number of plies as well as to understand the optimum ply to single twist ratio (D:S) which yields maximum plied yarn tenacity, plied yarn samples were prepared varying combinations of number of plies from two to four and five levels D:S from 0.5 to 0.9 with increment of 0.1. To rule out effect of single yarn twist in this case, only singles prepared using twist factor of 24 were considered.

For experimentation and analysis purposes, 3-factors and 3-levels Box–Behnken experimental design was used to plot response surfaces using Minitab statistical software. The factors and levels used for experimentation purpose are given in Table 2.

Table 2: Box–Behnken Design of Experiments

Factors	Levels		
	- 1	0	1
No. of Ply	2	3	4
Single yarn twist factor (in tpc - tex unit)	24	26	28
Ply to single twist ratio (D:S)	0.5	0.7	0.9

The tensile properties of single as well as plied yarns were tested as per ASTM D2256 in Instron UTM in a testing laboratory accredited as per ISO/IEC 17025. Average of ten observations for a particular quality of yarn was considered for analysis purpose. Uniformity of the yarns was tested in Premier Uniformity Tester as per ASTM D1425. Three observations were made for each quality of yarn.

3. Results and Discussion

Test results obtained from the experimental yarns were assessed for determining influence of the parameters on tensile and uniformity of plied yarn, two most important property requirements. Such effects are described below:

i. Influence of number of ply and ply to single twist ratio on plied yarn tenacity:

In order to understand the dependency of number of ply and ply to single twist ratio (D:S) on the tenacity of plied yarn, tenacity of multi-ply yarns are plotted against five levels of D:S which is given in Fig. 1. From the plot it can be observed that irrespective of number of plies in the folded yarn, ply yarn tenacity increases with initial increase in D:S and then starts falling, keeping an intermediate optimum level of D:S. The initial rise in tenacity may be attributed from better binding of single yarns within the ply as a result of increased twist level. Such binding may enable the constituent single yarns to share stress equally, rather than distinctive stress sharing by single yarns in case of loosely twisted plied yarn. The fall in tenacity after the optimum D:S may be due to prominent obliquity effect, as the phenomenon observed in multifilament yarns.

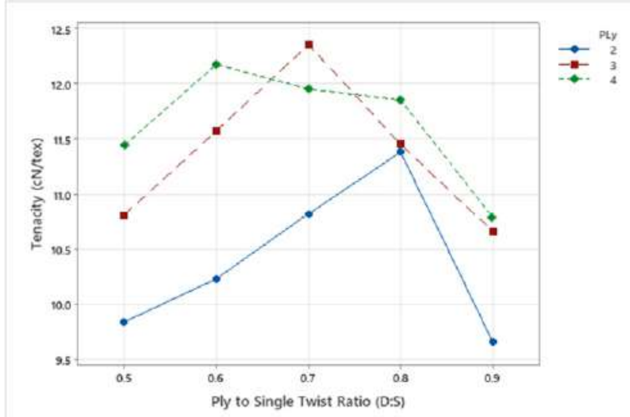

Figure 1: Ply tenacity (cN/tex) vs. no. of ply and ply to single twist ratio

It can also be seen from the plot that with increase in the number of plies, the optimum tenacity of the folded yarn can be obtained at lower D:S. The same behaviour may be explained by the findings of Huang et. al. [9] who narrated that interaction forces are generated between the single yarns during the axial-tensile process of a ply yarn. The authors derived following relation to define the frictional resistance (f_y) by the single yarns which contribute to the plied yarn strength

$$f_y = \mu N + \alpha S$$

Where, μ is the friction coefficient, N is the radial pressure, α is the cohesion coefficient, S is the contact area.

Considering the above relation, since each single yarn touches the neighbouring yarns, contact area between the single yarns' thereby increases with increase in the number of plies. As a result, 4-ply yarns having four contact lines/areas among single yarns as a whole may lead to higher frictional resistance and thereby higher tenacity. In contrary, with 2-ply yarn there exist only one contact line/area, and thus, less contribution to yarn strength.

ii. Influence of single yarn twist factor and number of ply on plied yarn tenacity:

Contour plot of plied yarn tenacity with respect to no. of plies and single yarn TF at a fixed D:S is given in Fig. 2. From the plot it is evident that out of these two parameters, no. of plies is the most dominating factor for plied yarn tenacity, as with increase in number of plies for any level of singles' TF, the tenacity increases significantly. In contrary, single yarn TF influences ply tenacity only when number of ply is less (2 or 3 in this case), but has minimal effect for higher number of plies. In this instant case, a 4-ply yarn showed highest tenacity (>11.5 cN/tex) for all three levels of single yarn TF, whereas, tenacity of 2-ply yarn was least (~10 cN/tex) when single yarns' TF was 24 and increased up to 11 cN/tex sequentially with increase in singles' TF to 28.

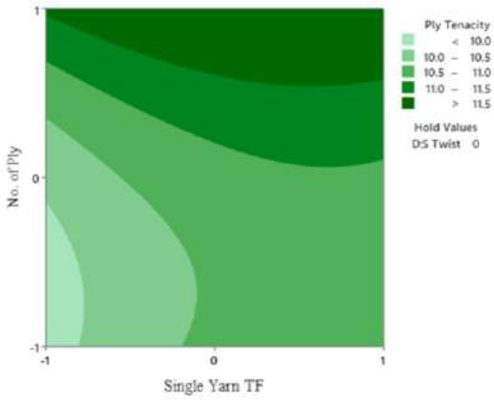

Figure 2: Ply tenacity (cN/tex) vs. single yarn TF and no. of ply

iii. Influence of single yarn twist factor and ply to single twist ratio on plied yarn tenacity:

Fig. 3 below shows the tenacity contour plot of a 3-ply yarn with respect to single yarn TF and ply to single (D:S) twist ratio. The plot shows that when the other parameters are kept fixed, both singles' and ply twist effect ply yarn tenacity. While an increase in singles' TF, the ply tenacity steadily increases, the later however increases first with increase in D:S and starts falling in case of further increase in D:S. The optimum value of ply tenacity is achieved somewhere with higher singles' TF but with low to medium D:S. To analyze the behaviour, dependency of single yarn's strength with respect to the above three levels of TF was studied and it was observed that single yarn strength of jute yarn was increased with increase in TF level. This trend of rise in singles' strength with TF may have influenced ply tenacity increment.

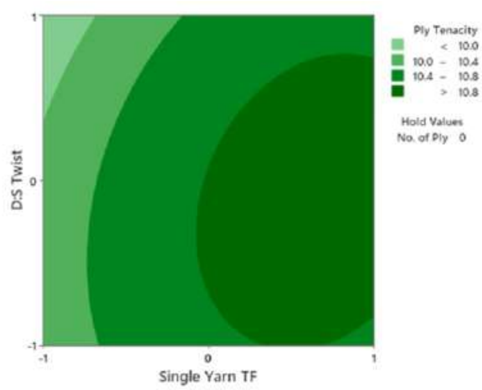

Figure 3: Ply tenacity (cN/tex) vs. single yarn TF and D:S

i. Jute plied yarn breaking extension:

Jute fibre possesses high modulus and low breaking extension [10] and consequently jute yarns are less extensive. Behaviour of plied yarn breaking extension has been studied in this work and plots with respect to the considered parameters are given in Fig. 4.

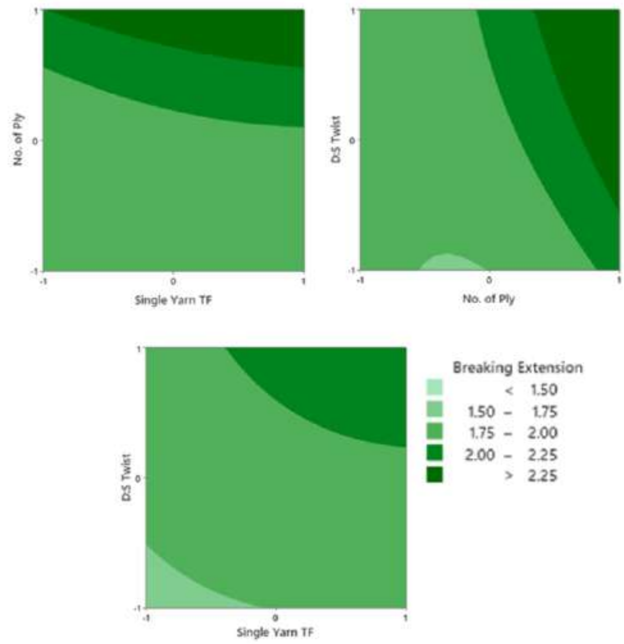

Figure 4: Jute plied yarn breaking extension with respect to no. of ply, single yarn TF and D:S

Graphs show that plied yarn breaking extension is mostly dependent on number of ply and ply to single twist ratio, and it increases with increase in the number of plies as well as D:S. Increase of ply extension due to increase in D:S may be attributed from higher obliquity of single yarns in ply structure.

v. Uniformity of jute plied yarn:

With high variability of jute fibre length, jute yarns produced in the conventional system possess high irregularity. Fig. 5 below shows the mass irregularity (U%) of single jute yarns prepared at 26 twist factor and plied yarns tested in capacitance type yarn evenness tester and Table 3 shows corresponding thick (+50%) and thin places (-50%) per km in the single as well as plied yarns.

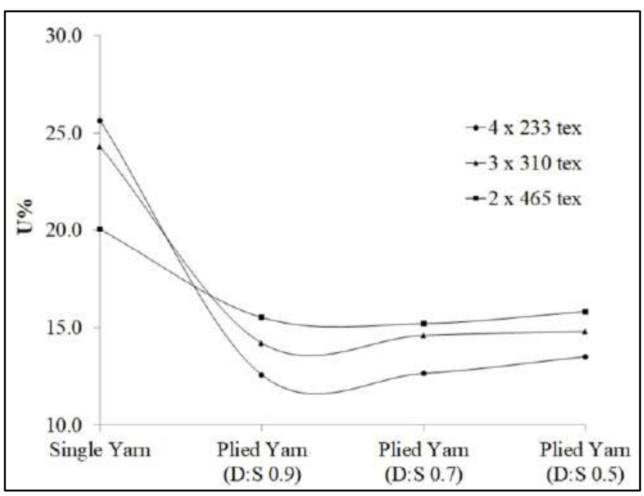

Figure 5: Mass irregularity of single and ply yarn

Table 3: Thick and Thin places in yarns

Ply type	Thick places (+50%) / km		Thin places (-50%) / km	
	In single yarn before plying	In plied yarn	In single yarn before plying	In plied yarn
4-ply	1360	210	1970	40
3-ply	1440	180	1560	130
2-ply	830	510	600	160

The general principle of improvement in yarn evenness due to folding also holds good for jute yarn as it can be seen from the Fig. 5. Irrespective of number of plies, jute ply yarn shows significant improvement in yarn regularity, which may be due to doubling effect and thereby compensation of thick and thin places. Table 4 also justifies that plying compensates thick and thin places present in single yarns. Although single yarn of 233 tex shows highest U% as compared to other single yarns, while these yarns are folded to get a desired count of ply yarn, the improvement is also highest as compared to other yarns. This is due to effect of 4 plies as compared to 3 ply and 2 ply for 310 tex and 465 tex single yarns respectively. Ply to single twist ratio, however, plays insignificant role as far as ply yarn evenness is concerned.

4. Conclusion

Efforts in this work have been made to understand effects of various parameters of tensile and uniformity of jute plied yarn. Based on the study, the following conclusions are made –

- Irrespective of number of plies in the folded yarn, jute ply yarn tenacity increases with initial increase in ply to single twist ratio and then starts falling. However, with increase in the number of plies, the optimum tenacity of the folded yarn can be achieved at comparative lower ply to single twist ratio.
- Tenacity of jute plied yarn increases with increase in the number of plies. Moreover, tenacity of 2 and 3 ply jute yarns can be enhanced by using single yarns of comparatively high twist factor.
- Jute ply yarn breaking extension increases with increase in the number of plies as well as ply to single twist ratio.
- Irrespective of number of plies, jute ply yarn shows general tendency of improvement in yarn regularity. The improvement is maximum for 4-ply yarn followed by 3-ply and 2-ply
- Thick and thin places present in single jute yarns are also compensated after plying. This may also be one of the reasons for increase in jute yarn tenacity after plying.

References

[1] K. Palaniswamy and P. Mohamed, "Effect of the single-yarn twist and ply to single-yarn twist ratio on the hairiness and abrasion resistance of cotton two-ply yarn," AUTEX Research Journal, vol. 6, no. 2, pp. 59 - 71, 2006.

[2] O. Ozdemir, S. Sardag and F. Kalaouglu, "Effects of twisting methods on plied yarn properties," Indian Journal of Fibre and Textile Research, vol. 31, pp. 394 - 400, 2006

[3] D. E. A. Plate and J. Lappage, "An alternate approach to two-fold weaving yarn – Part I – Control of surface fibres," Journal of the Textile Institute, vol. 3, no. 99-106, 1982

[4] S. K. Sett, A. Mukherjee and N. Kundu, "Influence of twist on tensile and abrasion properties of DREF-II friction spun plied yarns," American International Journal of Research in Science, Technology, Engineering & Mathematics, vol. 6, no. 1, pp. 52 - 56, 2014.

[5] P. H. Brorens, J. Lappage, J. Bedford and S. L. Ranford, "Studies on the Abrasion Resistance of Weaving Yarns," The Journal of The Textile Institute, vol. 812, pp. 126 - 134, 1990.

[6] S. Dhamija, A. Chowdhury and R. Chattopadhyay, "Effect of Ply Twist Factor on Hairiness and Unevenness of Two Plied Cotton Yarns Made of Different Spinning Technologies," Journal of the Institute of Engineers (India), vol. June, 2016.

[7] S. Omeroglu, "An investigation on the effects of ply and single twists on strength, hairiness and abrasion resistance properties of two-ply cotton ring-spun yarns," Tekstil ve Konfeksiyon, vol. 23, no. 2, pp. 204 - 212, 2013

[8] A. F. W. Coulson and G. Dakin, "Doubled Yarns. Part I. the influence of twist on the strength and certain other properties of two-fold yarns," The Journal of The Textile Institute, vol. 48, no. 7-8, pp. T207 - T232, 1957

[9] Huang, W., Fu, T., Zhang, Y. and Wang, J., 2017. An approach to predict the tensile strength of a two-ply yarn from single filament yarn. The Journal of the Textile Institute, 108(3), pp.412-417

[10] Virk, A.S., Hall, W. and Summerscales, J., 2009. Tensile properties of jute fibres. Materials Science and Technology, 25(10), pp.1289-1295

Effect of Sewing Process and Enzyme Treatment on the Sewing Thread of Denim Garments

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Abstract:

The Denim market has been able to clinch the pinnacle of demand and commendation as the most popular dress material in the past three decades for all ages. From special wear to regular wear, denim has barged into the acceptance of kids, women, and men. But today's fashion era prefers denim jeans based on their attractive shades & styles, designs, and various types of wash appeals, rather than only their robustness. Today's fashion-conscious consumer requires diversified wash-down treatments such as de-sizing, enzymatic washings with or without stones, decolorization, neutralization, brightening, and finishing as per the market and trend requirements. Being unaware of the impact of all the down treatments on denim, consumer acceptance is based only on the aesthetically pleasing outlook of the denim. Thus, this research paper deals with in-depth insight into the effect of sewing and enzyme treatments on the sewing threads present as an integral part of denim wear for the evaluation of the residual properties with the use of lockstitch and chain stitches. The work has been able to elucidate that chain stitches and acid enzymes are detrimental to the tensile properties of the unraveled sewing threads.

Keywords: *Acid enzymes, Chain stitch, Enzyme treatment, Fashion-conscious consumer, Wash-down treatments.*

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1. Introduction

The invention of denim in the late 1800s by Levi Strauss for miners revolutionized the apparel and fashion industry in a variety of forms and style lines [1]. Jeans is a more popular name for denim pants that has evolved into a product that caters to almost every age. The denim industry is growing rapidly every year [2]. Denim is flourishing due to innovative finishes, patterns, and easy care [3]. The denim production capacity is spread over the world, the largest producer being Asia when striping down to the country level, the USA is the biggest single supplier, followed by Indonesia and India occupies 5th place [4]. Most jeans are denim based made from 100% cotton or a blend of 50% cotton and 50% polyester [5].

Usually, denim fabric is used for lower garments, and the wash-down effect is applied in a usually haphazard manner. In making patterning effects on denim, the existing methods are often detrimental to the fiber and are not cost-effective [6]. But today's fashion consumers prefer denim due to the attractive shades, designs, styles, and various types of wash appeals, rather than for its robustness. Denim garments in the past were worn in a raw, rigid, and starch-finished form. But today's fashion requires various types of value-added treatments such as de-sizing, enzymatic washing (with or without stones), decolonization, neutralization, brightening, and finishing [7].

Normally, denim washing is carried out in sewn form of denim garments. The denim garments are subjected to different washing techniques such as rinse wash, bleach, enzyme wash, acid wash, stonewash, sand wash, over-dyed/tinted look, whiskering, damaged and used look [8]. In denim washing, enzymes play an important role in getting a clean, smooth, fuzz-free fabric surface with reduced tendency of pill formation and improved fabric handle [9]. The quality of denim apparel depends mainly upon the fabric quality, sewing thread type and selection of seams play a major role in garment durability, especially for fashionable denim garments, even though their contribution may not be reflected in terms of cost and quantity [10]. Seam strength is dependent on the sewing thread strength; a reduction in thread strength during sewing will lead to lower seam strength than expected [11]. Therefore, in order to minimize the sewing thread strength reduction, it is important to understand the contribution of different machine elements or operations during sewing.

Studies on the strength reduction of sewing threads have been an important aspect of assessing their performance during high-speed sewing. The effects of the thread properties, machine parameters, and the number of fabric plies have been investigated. It has been postulated that the reduction in fiber strength and the damage inflicted on fibers during high-speed sewing in an industrial lockstitch sewing machine [12]. Synthetic fibers are being increasingly used to manufacture sewing threads to meet the diverse demands of the sewing process and those of the various end-uses to which the threads are put. Any new developments and modification in synthetic fibers, to achieve better sewing and seam performance requires extensive knowledge of the changes in the mechanical and other properties of the fibers caused by the various stresses imposed on them during high-speed sewing [13].

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The sewing thread is subjected to impact, tensile, bending, compressive, shear, and surface stresses during stitch formation. Most of these stresses are cyclic in nature and therefore expected to fatigue the thread and hence the constituent fibers [14]. This may cause some critical flaws and damage to the fibers, which would ultimately affect the subsequent seam performance of the sewing thread. Further, this may also generate a potential weak spot in the thread to result in its breakage at high sewing speeds [15, 16].

The stresses created within the sewing thread harm the processing and functional characteristics of the thread. In an early research work, it was reported that there is up to 60 percent reduction in sewing thread strength after sewing and various reasons are responsible for the reduction including the structural damage, along with dynamic and thermal loading [17]. The change (%) in tensile properties at different stages is calculated according to Equation 1[18].

$$\%\ \text{Change in tensile properties} = \frac{T\ \text{Thread after sewing} - T\ \text{Parent thread}}{T\ \text{Parent thread}} \quad \text{-----} \quad \text{(Equation 1)}$$

(Where, T – Tensile strength of sewing threads)

In addition to the thread strength, the strength of the fabric is an important property that decides and influences the performance of the fabric. Enzymatic treatment of fabrics such as denim is known as one of the finishing treatments with many uses because it creates a special appearance and updates apparel. It is estimated that 80% of denim washing is carried out by cellulase enzyme [19]. Cellulases are added to desized denim fabric in a washing machine, and the combination of enzyme action and fabric friction, as well as mechanical abrasion, produces desired fading and softening effect of the garment [20]. When the fabric is washed and treated with enzymes (neutral and acid), the surface fibers are aggressively removed from the fabric surface [21]. The denim fabric is more damaged by the acid enzyme washing than the neutral enzyme washing [22]. It has been observed that not much work has been conducted on the effect of enzyme-based denim washing on the sewing threads used in denim garments.

This research work aims the study the effect of sewing thread fineness, stitch type, and enzyme type on the mechanical properties of sewing threads unraveled from denim fabrics. The mechanical properties (breaking load, initial modulus, and breaking energy) of the sewing threads unraveled from the seams of denim fabrics are compared with the parent sewing thread properties. Along with it, the effect of enzyme treatment on the sewing thread during the wash-down treatments of denim is also studied.

Therefore, the main objectives of this research work was to study the changes in the tensile properties of unravelled sewing threads of Lapped seams of classical denim jeans prepared with the use of Lockstitches and Chain stitches configurations post sewing processes and also, after the enzyme wash-down treatments in acid and neutral conditions. This was carried out to adjudge the combined impact of both the industrial processes on the severance of sewing threads.

2. Materials and Methods

2.1 Materials

Commercially viable PC core spun sewing threads were sourced from Vardhman Yarns & Threads Ltd., Hoshiarpur, Punjab (India) with three different ticket numbers to be compatible with the chosen denim fabric. The physical and structural details of the sewing threads are reported in Table 1. The 100% twill woven cotton denim fabric with 10.50 oz/yd2 (GSM), fabric set of 72 EPI & 40 PPI, and Linear density of warp and weft 7.5 Ne & 9 Ne was sourced for the work. The lapped seamed denim was prepared with lockstitch configurations (LS) on JUKI-DDL-8300N (31234) SNLS machine and Chainstitch configurations (CS) on Feed off the arm (MS-191) as per ASTM D1683/D1683M-22. The machine speed was set at consistent 1500 SPM. To maintain the constant machine speed, a DC shunt motor with an AC to DC conversion Panel was used on both (Lock Stitch and Feed of the arm) sewing machines. The tachometer was also used for the measurement of the speed of the main shaft at every change of machine speed. The DC motor with 220 armature voltage, 2.4 A, 0.37 KW, and 3000 rpm was used as shown in Fig 1. The stitch density was kept at 8 SPI and Groz-Beckert (UY 128 GAS) sewing needles with needle numbers 21 & 22 were selected. Cellulase enzyme was chosen in both acid and neutral conditions according to the aesthetic look of the final effect required on denim. The active enzyme specifications are listed in Table 2 [23].

R & B Thickness Tester, Innolab Tensile Tester, Instron tensile tester 4411, Twist Tester, CTT (Constant Tension Transport) Lawson Hemphill tester, CSI abrasion tester and Optical microscope were used for the property evaluation of the sewing threads and fabric.

Table 1 - Properties of sewing threads

Sewing thread type	Code	Thread linear density (tex)	Number of Ply	Twist per inch (TPI)	Tenacity (g/tex)	Modulus (gm/tex)	Breaking Energy (J)	Friction co-efficient against Metal Surface	Yarn to Yarn Abrasion, (Cycles to break)	Shri-nkage (%)
P-C Corespun	**PC90**	90	2	14.37	34.34	211.8	1.13	0.08	1890	0.6
P-C Corespun	**PC105**	105	3	11.78	43.39	217.4	3.48	0.12	2340	0.8
P-C Corespun	**PC120**	120	3	11.52	47.14	251	4.56	0.17	1962	0.46

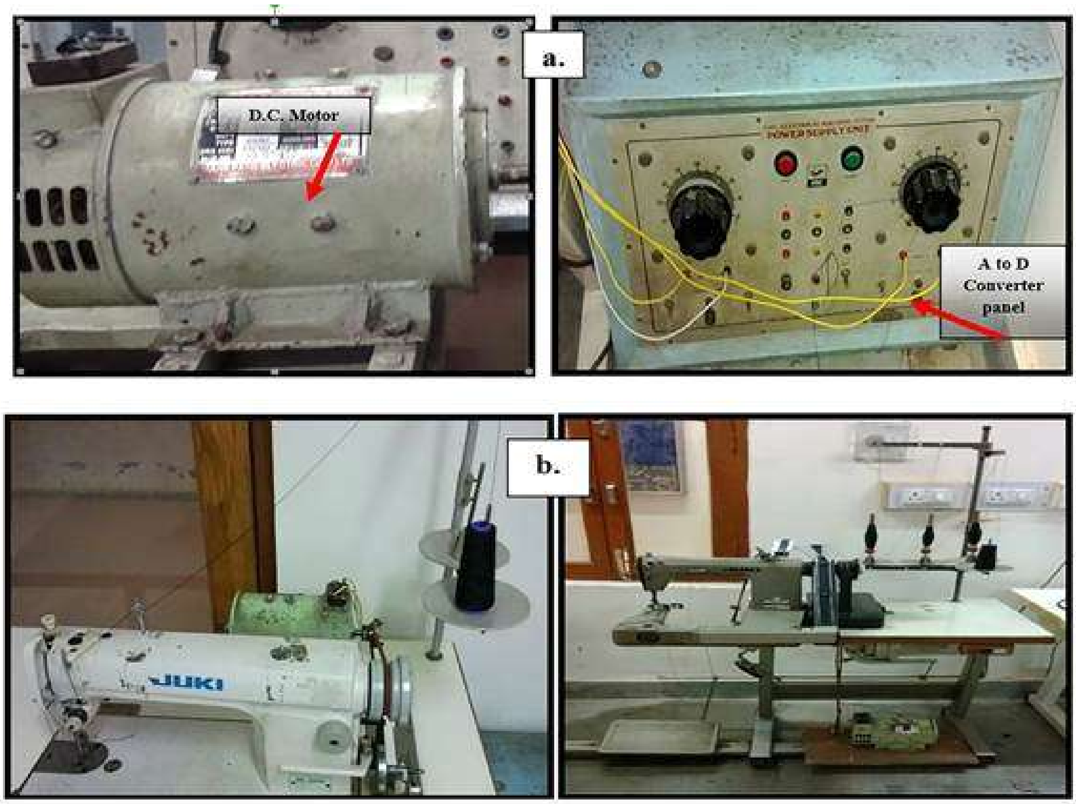

Figure 1 - a. D.C. Motor with conversion panel, b. Arrangement of DC shunt motor for lock stitch and feed-off the arm sewing machines.

Table 2 - Enzyme specifications

Specification	Acid cellulose enzyme	Neutral cellulose enzyme
Declared Activity	1500 EGU/gm	2450 ECU/gm
Physical form	Liquid	Liquid
pH at 40-55ºC	4 - 5.5	6-8

2.2 Seam Sample Preparation

The modified JUKI-DDL-8300 N (31234) SNLS (stitch class 301) and Feed-off-the-arm DNCS MS-191 (stitch class 401) were used to produce the seams at the stipulated sewing conditions (reported in section 2.1). The fabric samples were cut to convenient sizes of 24×2.5 inches and weft-way seams (Lapped seams) were produced. Identical settings of foot pressure and needle thread tension were maintained at the same level for all the desired seam samples produced. The same combinations of needle and bobbin/looper threads were used for the sampling.

2.3 Enzyme treatment of denim

The denim fabrics were seamed as discussed in section 2.2 and exactly half the number of samples were taken out for the enzymatic treatment using cellulase enzyme (in both acidic and neutral conditions) as per enzyme specification (Table 2).

2.4 Seam unraveling

Stitched samples were unraveled with caution for the needle thread which was further tested for the tensile properties in a similar way as the parent threads. The unraveled needle threads were taken out immediately after the sewing process (S1) and from the enzymatic treated seams of denims (S2), from both the stitch structures. Impact of sewing process and enzyme action on the overall change in the tensile properties was observed from the unraveled sewing threads. Thus, two sets of data were investigated- % change in tensile properties after sewing process alone (S1) & % change in tensile properties after sewing process followed by enzyme treatment (S2).

2.5 Sewing thread and fabric evaluation

The denim fabric was evaluated for Fabric thickness (ASTM D- 1777), Fabric weight (ASTM D-3776) and Fabric strength (ASTM D-5035). The parent sewing threads and unravelled sewing threads were tested for Tenacity (ASTM D-2256), Elongation (ASTM D-2256), Frictional properties (ASTM D-3108), TPI- (ASTM D-1422), Initial modulus (ASTM D-2256), Breaking energy (ASTM D-2256), Abrasion resistance (ASTM D-661), Shrinkage (ASTM D-204) and Optical Microscopy. Sewing thread shrinkage was calculated according to boiling water shrinkage method (ASTM D-204). In this method, the specimen was wrapped in cheese–cloth. The wrapped specimen was subjected to immersion in boiling water and allowed to boil for 30 ± 2 mins, cheese cloth along with the specimen was later removed from the bath. The excess water was squeezed out from the cheese cloth and the specimen was, then removed from the cheese cloth & dried in drying oven at 65˚C for 1 hour. The loop length was measured. The shrinkage of each test sample was calculated using the Equation 2:

$$\text{Shrinkage \%} = \frac{L1 - L2}{L1} \times 100 \quad \text{----- (Equation 2)}$$

(Where, L1 = Original length of the loop and L2 = Length of loop after exposure).

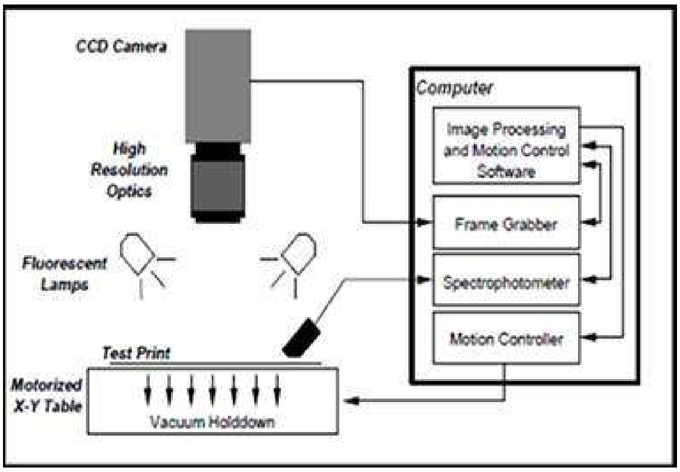

Figure 2 - Optical Microscope with micro- measure software

For checking the microscopic views of sewing threads, optical microscopic method was used. A microscope was used based on micro- measure software having 400% magnification. The thread was illuminated from below and analyzed with a CCD camera positioned above. The results presented below are invaluable for differentiating structural characteristics from the topical or reflective qualities of the threads (set up depicted pictorially in Fig 2).

3. Results & Discussion

3.1 Effect of sewing process on tensile properties of unraveled sewing threads

The impact of sewing process on the performance of PC core spun sewing threads was analyzed and reported in Table 3.

a. Effect on tenacity of sewing threads- The tenacity of chain stitch unraveled thread is even lesser than the residual tenacity of the lockstitch unraveled needle threads. It is due to the reason that the needle threads in the chain stitch must travel the full fabric thickness and moreover, lapped seams are produced with the fabric folding, thereby, multiple fabric layers are encountered by the needle threads during each cycle of stitch formation. The coarser sewing threads show the higher % reduction of tenacity in comparison to finer needle threads. The higher reduction is analyzed after sewing process because surface fibres of thread are pulled out due to abrasion with the needle and fabric assembly. The lockstitch unraveled needle threads must reach up to the fabric bed that lies in the middle of the seam composition thickness. This shows lesser strength loss as compared to the chain stitches. But the tension fluctuations in the interlacing processes for lockstitches might have compensated for energy losses due to the combined effect of interloping and interlacing stitch formation processes in chain stitches.

b. Effect on initial modulus of sewing threads- An increasing trend of loss in modulus was observed for the increasing Tex number from 90 to 120. The main reason can be attributed to the increased abrasive damage that causes displacement of plies, loosening of structure and also, the non-contribution of the higher number of surface fibers in thread tension leading to higher loss in initial modulus for coarser needle threads.

c. Effect on breaking energy of sewing threads- The "energy to break" is a parameter directly related to the thread tenacity. As the needle thread Tex increased, the energy to break point also increased for the parent threads. The needle threads unraveled from the chain stitch configurations show the similar trends as for parent tenacity of threads. The greater loss in energy to break for needle threads of chain stitch owe to the fact that greater fabric thickness along with four fabric layers that the needle threads have to pierce to make its way into the seam configuration. The microscopic view of the threads (shown in Fig. 3-4) to elaborate the effect of abrasion effect of fabric on threads during Interlacement & Interloping processes. It can be observed that in parent thread, fibres on the surface were very less. The number of fibres pull out due to abrasion was found to be more on the surface of thread unraveled from chain stitched denim fabric as compared to the surface of threads unraveled from lock stitched denim. These more surface fibres cause more deterioration in mechanical properties of sewing thread during chain stitch process to prepare denims.

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Table 3 - % Change in the tensile properties of sewing threads

Sewing Threads	90 Tex		105 Tex		120 Tex	
Property	**Lock stitch**	**Chain stitch**	**Lock stitch**	**Chain stitch**	**Lock stitch**	**Chain stitch**
Tenacity (gm/tex)	32.8	29.9	38.8	34.0	42.0	40.3
% Change	**(-4.4)**	**(-12.8)**	**(-10.6)**	**(-21.7)**	**(-10.8)**	**(-14.4)**
Initial modulus (gm/tex)	209.5	208.1	214.1	212	221.2	207
% Change	**(-1.09)**	**(-1.8)**	**(-1.52)**	**(-2.5)**	**(-11.87)**	**(-17.5)**
Breaking energy(J)	1.08	1.02	2.82	2.64	3.79	3.56
% Change	**(-4.4)**	**(-9.73)**	**(-18.96)**	**(-24.13)**	**(-16.88)**	**(-21.92)**

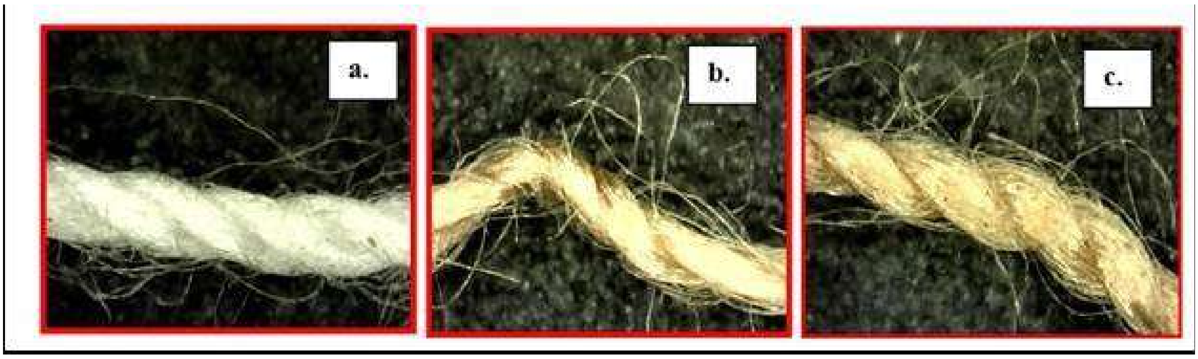

Figure 3 - Microscopic analysis of threads with the impact of sewing process a. Parent b. Lockstitch unraveled c. Chain-stitch unraveled

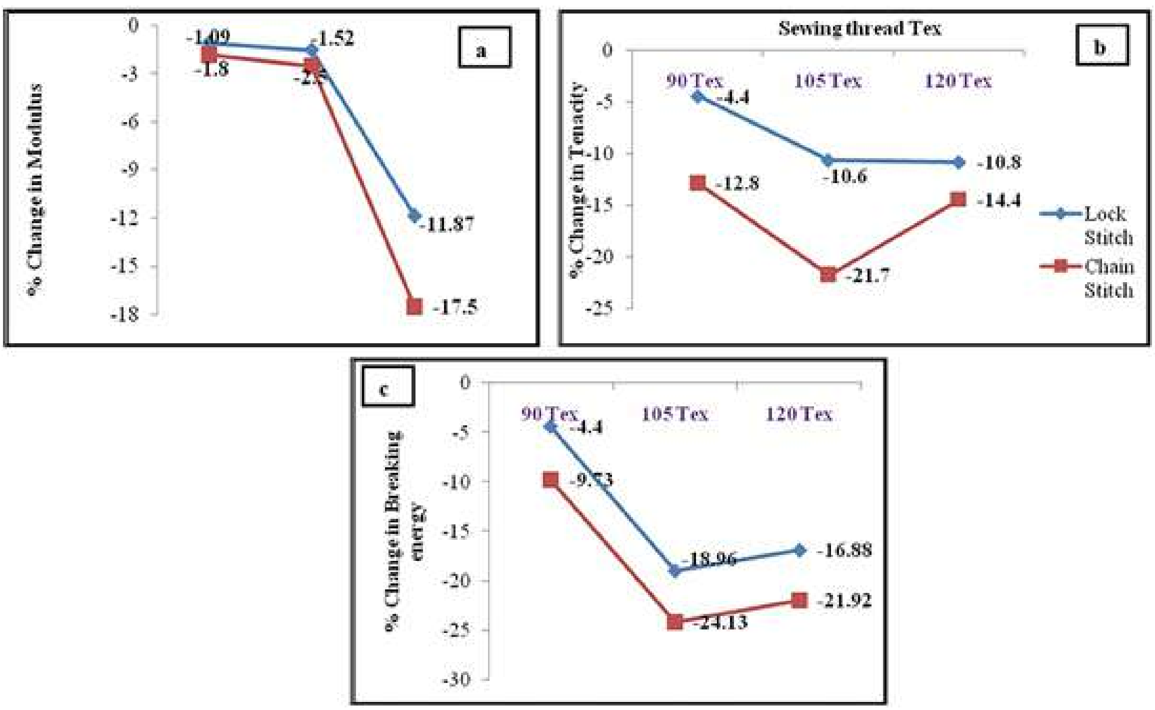

Figure 4 - Effect of sewing process on tensile properties of core spun threads a. % Change in modulus b. % Change in Tenacity c. % Change in breaking energy

3.2 Effect of enzyme wash down treatment on unraveled sewing threads for Neutral and Acid cellulase enzyme

The effect of the enzyme treatment on the unraveled sewing threads is tabulated in Table 4 & Fig. 5-6. The trend of the effected properties has been elaborated as under.

Effect on tenacity of threads- Acid enzyme is showing a major loss for both the stitch types for all the Tex numbers of sewing threads in comparison to the Neutral enzymes. Also, acid enzymes with chain stitches show maximum tensile strength loss for all sewing threads. This is due to the reason that acid cellulase works in the pH 4.5-5.5 and are much more aggressive on fibres than the neutral cellulase enzyme that works best in the pH 6-8. This is true even for short process times used for both the enzymes.

Effect on initial modulus of threads- The modulus for lockstitch unraveled threads treated with neutral cellulase enzyme is exhibiting an increasing trend for 90, 105 and 120 Tex threads; On the other hand, the acid cellulase is showing a detrimental effect on all the thread types both for the lock stitch and chain stitch configurations, except for 120 Tex thread in which the modulus is showing an increasing trend.

Effect on breaking energy of threads- It is showing an increasing trend in a similar manner as for thread tenacity. The breaking energy for unraveled thread is showing the maximum negative change for the sewing threads used for making chain stitches treated with acid cellulase enzyme, i.e., the combination of chain stitches and acid cellulase enzyme is the most detrimental to the breaking energy loss.

Table 4 - Effect of enzyme treatment on sewing thread properties

Sewing thread type	PC Sewing thread											
Property	90 Tex				105 Tex				120 Tex			
	Neutral cellulase enzyme		Acid cellulase enzyme		Neutral cellulase enzyme		Acid cellulase enzyme		Neutral cellulase enzyme		Acid cellulase enzyme	
	L.S.	C.S.	L.S.	C.S.	L.S.	C.S.	L.S.	C.S.	L.S.	C.S.	L.S.	C.S.
% change in Tenacity	-2.0	-3.5	-3.23	-4.1	-2.3	-2.9	-3.6	-4.92	-1.7	-2.1	-2.36	-2.79
% change in Modulus	+0.62	+1.62	-0.46	-1.12	+0.42	+0.81	-1.0	-1.37	+0.65	+3.99	+0.05	+3.59
% change in Breaking energy	-1.8	-5.3	-0.88	-6.04	-0.9	-4.34	-3.16	-11.88	-0.22	-4.61	-2.86	-7.46

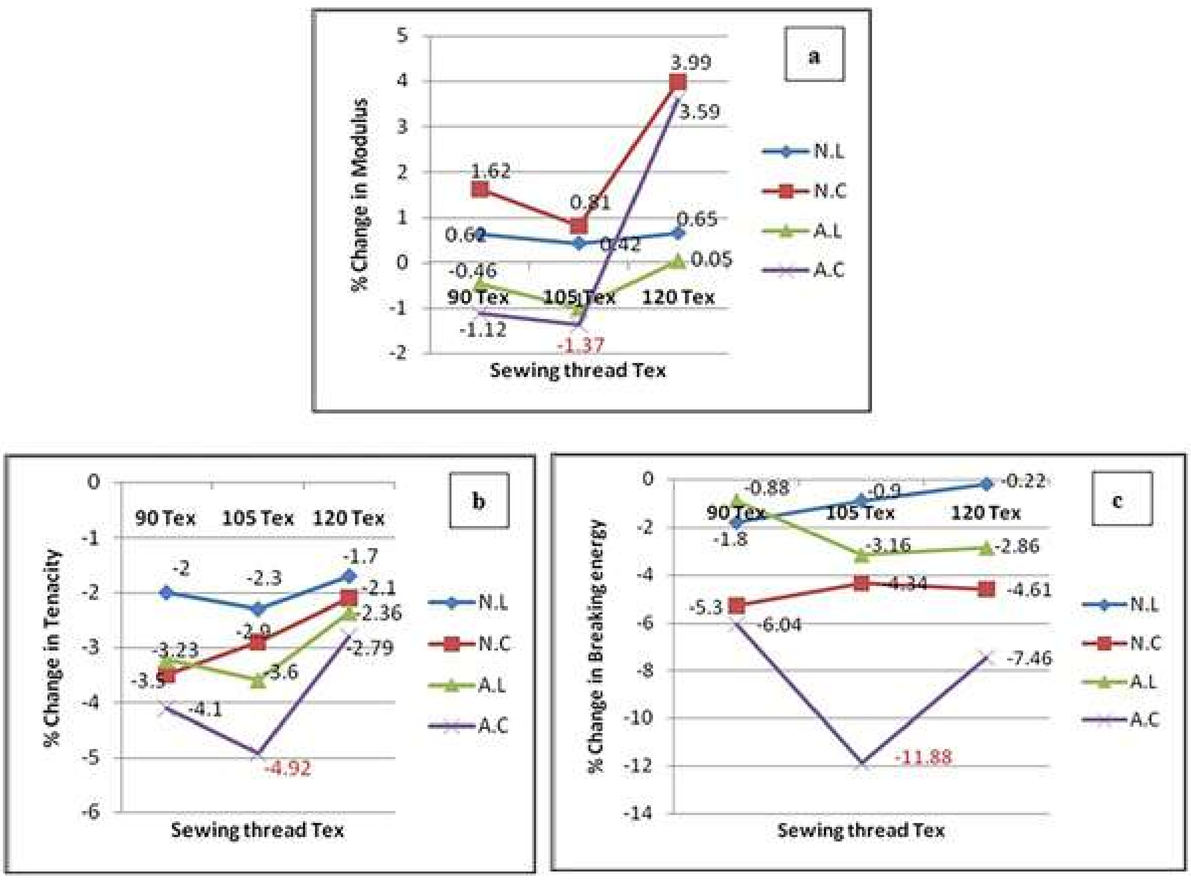

Figure 5 - Effect of enzymatic treatment process on tensile properties of core spun threads a. % Change in modulus b. % Change in Tenacity c. % Change in breaking energy

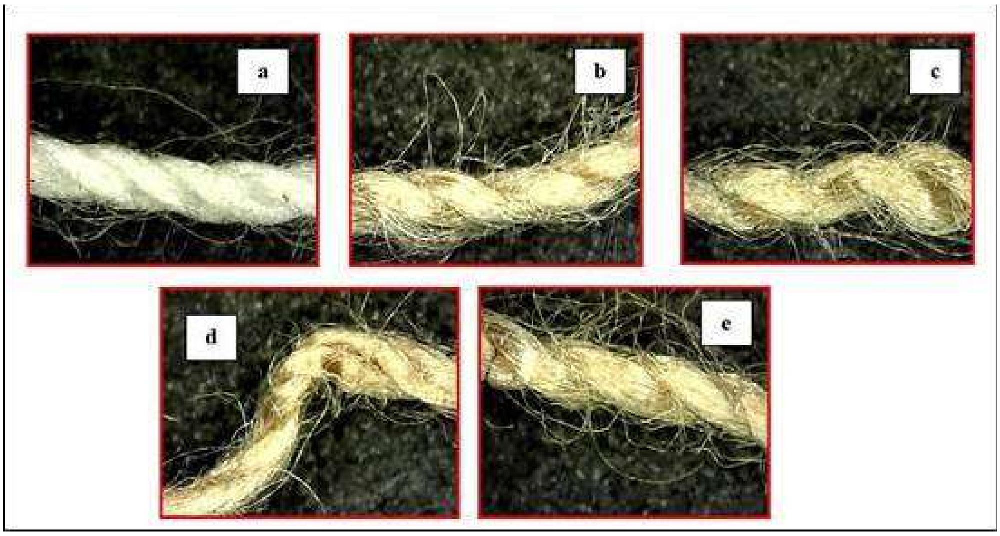

Figure 6 - Microscopic views of sewing threads after Neutral and Acid cellulase enzymatic treatment a. Parent Thread b. Lock stitch- Neutral enzyme c. Chain stitch-Neutral enzyme d. Lock stitch- Acid enzyme e. Chain stitch- Acid enzyme

4. Conclusions

Chain stitch configurations had shown greater tenacity loss in comparison to lock stitches. The reason for this can be adjudged as the chain stitch structure is based upon the two processes of interlacing and interloping that resulted in more bending regions in the unraveled sewing threads, which behaved as the weaker sections during tensile load bearing. Acid enzymes have a more pronounced effect on the tensile properties of sewing threads when compared with the effect of neutral enzymes on the same sewing threads. This is due to the accentuated aggressive action of the acid enzyme in a shorter span of treatments time than the neutral enzyme. In addition to it, 105 Tex sewing threads are showing more change in the tensile properties than 90 and 120 Tex.

References

[1] NEMAILAL, Tarafder. Denim fabric – An overview. Man-made Textile in India, 2008, 387-395

[2] PETER, Obrist. Weaving preparation of denim. Journal of Textile Association, 1998, 58, 5

[3] PATIL, M. Processing of denim. Indian Textile Journal, 1981, 91, 105

[4] KAN, C. W. Recent development in denim processing technologies. Colourage, 2013, 42-43

[5] ADIVAREKAR, R. V, PAUL, R. and PARDESHI, P. D. Denim: Today and tomorrow. Journal of Textile Association, 2001, 63 (4), 139

[6] BARTON, Judi. Denim's empire continuous to expand. International Dyer, 192, 10, 21-24

[7] REKHA, R. and PURNIMA, D. Machineries for garment and denim processing. Man Made Textile in India, 2008, 51 (1), 16-18

[8] SWICE, Good. J. T., TYNDALL, R. M. and THORNE, J. M. Denim garment processing. AATCC garment wet processing, 1994, 6-44

[9] PAUL, R., PARDESHI, P. D. and MANJREKAR, S. G. Denim weaving & dyeing machinery: An overview. Journal of Textile Association, 2001, 62 (3), 115

[10] RAMACHANDRAN, T. and RAMESH, B. V. Analysis of performance of seams and sewing threads in woven fabric. The Textile Magazine, 2007, 49 (2), 34-42

[11] CARR, H. and LANTHAM, B. The Technology Analysis, Textile Book Publishers Inc. New York, 1961, 65

[12] RAMACHANDRAN, T. and RAMESH, Babu V. Analysis of performance of seams and sewing threads in woven fabric. The Textile Magazine, 2007, 34-42

[13] SALHOTRA, K. R., HARI, P. K. and SUNDERSAN, G. Strength reduction in & damage to fibres during high-speed sewing in an industrial lock stitch: Part II. International Journal of clothing science and technology, 1998, 10(1), 64-79

[14] KAUR, R. Seam strength prediction for work wear fabric: M.Tech Thesis, National Institute of Technology, Jalandhar, India, 2007

[15] FERREIRA, F. B. N., HARLOCK, S. C. and GROSBERG, P. A study of thread tension on lockstitch machine: Part I. International Journal of clothing science and technology, 1994, 6(1), 14-19

[16] FERREIRA, F. B. N., HARLOCK, S. C. and GROSBERG, P. A study of thread tension on lockstitch machine: Part II. International Journal of clothing science and technology, 1994, 6(5), 26-29

[17] MAZARI, A. and HAVELKA, Antonin. Tensile properties of sewing thread and sewing needle temperature at different speed of sewing machine. Advance Material Research, 2013, 62(7), 456-460

[18] MAZARI, A. and HAVELKA, Antonin. Influence of needle heat during sewing process on tensile properties of sewing thread. Tekstilec, 2013, 56(4), 345-352

[19] DURAN, N. and MERCELA, D. Enzyme application in the textile industry. Colourage, 2000, 30(1), 41-44

[20] BUCHERT, J. and HEIKINHEIMO, L. Treating denim fabrics with tricoderma reesei cellulases. Textile Research Journal, 2000, 70(11), 969-973

[21] FAOUZI, K., SOUFIEN, D. S. and MSAHLI, F.S. The influence of industrial finishing treatments and their succession on the mechanical properties of denim garment. Autex Research Journal, 2009, 9(3), 94-100

[22] MONTAZER, M. and SADEGHINAM, M. A. Influence of different enzymatic treatment on denim garment. Applied Biochemistry and Biotechnology, 2009, 160 (7), 2114-2128

[23] TRIVEDI, V., SINGH, G.P. and KHANNA, S. Effect of Sewing Process on Tensile Properties of Sewing Threads in Denim Garment. JTA, 2018, 11, 260-265

[24] Apparel Manufacturing Technology by T. KARTHIK, P. GANESAN AND D. GOPALAKRISHNAN, CRC Press, Taylor & Francis Group, 2017

[25] Garment Manufacturing Technology, by RAJKISHORE NAYAK and RAJIV PADHYE, March 2019, Publisher: Elsevier

[26] CARR and LATHAM's Technology of clothing Manufacturer revised by DAVID J. TYLER, 4th edition, (June 23, 2008), Publisher: Wiley-Blackwell

Evaluation on Optical Properties of Textile Fiber

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Abstract:

A textile fiber's optical characteristics are the actions it takes when light strikes them. Birefringence (based upon refraction of light or transmission), dichorism (based on light absorption), and lustre (based on light reflection) are some of a fiber's optical characteristics. When dying, printing, or matching colours on materials, optical characteristics must be taken into account. Because textile fibres were anisotropic, the direction of the fibre affects both their optical and other physical characteristics. As a result, textile fibres were birefringent (optically anisotropic), meaning that their refractive index is polarization-dependent and direction-dependent. We discuss optical properties in this article.

Keywords: *Birefringence, Fibre, Light, Polarization, Refractive index, Textile*

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1. Introduction

The history of textiles is almost as old with the history of human civilization, and it has become more and more enriched over time. The earliest known evidence of the use of fibre dates to the production of flax or wool fabric in an excavations of Swiss lake people in the sixth and seventh centuries BC. While cotton spinning dates back to 3000 BC, the art of silk was originally introduced to India in the year 400 AD. While the skill of spinning linen as well as weaving began to emerge in Egypt about 3400 BC, sericulture and the processes used to spin silk were first discovered in China in 2640 BC [1-3]. The industrialization of the eighteenth and nineteenth centuries had a direct impact on the invention of machineries and their widespread use in processing natural fibres. As more synthetic fibres, like as nylon, were discovered, the demand for textile products grew. This eventually resulted in the development of new and improved natural fibre sources. The growth of transport and communication infrastructure paved the way for international trade in regional expertise and textile art [4-11].

The measurements corresponding to the refractive index and the birefringence offer significant information because it is understood that a lot of the structural aspects of fibres can be seen in their optical properties. A textile fiber's optical characteristics are the actions it takes when light strikes them. Birefringence (based on the refraction of light or transmission), dichorism (based on light absorption), and lustre (based on light reflection) are some of a fiber's optical characteristics [12-15].

A cloth has the ability to reflect, absorb, or transmit visible light. The degree to which light is reflected, absorbed, or transmitted determines the colour of a fabric. Thus, while dying, printing, or matching colours on fabrics, the optical characteristics of the fabric must be taken into account. Because textile fibres is anisotropic, the direction of the fibre affects both their optical and other physical characteristics. As a result, textile fibres become birefringent (optically anisotropic), meaning that their refractive index is polarization-dependent and direction-dependent. Therefore, we must first understand about polaization.

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2. Polarisation

Confusingly, the term "polarisation" (also known as "polarisation") refers to a number of scientific phenomena, the most well-known of which may involve a selective orientation of electromagnetic waves' electric oscillations (visible light), as demonstrated by Polaroid sunglasses that use dichroism to cut down on glare. Magnetic and electric fields the fact that oscillate in phase and at right angles to one another, as well as be perpendicular to the wave's direction of propagation, make up electromagnetic waves [16]. The Electromagnetic spectrum range is shown in figure 1 [17-20].

All possible directions of vibration are equally likely, and polarisation pertains to the exact orientation of the electric field of the wave (which in turn may be orientated in only one direction as well as rotate while the wave travels). In essence, non-polarized light can be made polarised by passing through an optical filter (polarizer or polariser) that lets waves of one polarisation pass but blocks waves of other polarisations.

For instance, the filter confines the electrical vibrations to a single plane, resulting in plane-polarized light, also known as linearly polarised light, where the electric vectors were plane parallel (or plane-polarized) via relation to the direction of propagation.

The term "polarisation" refers to the propensity of a cloud of electrons inside a molecule or atom to be (temporarily) deformed by an externally applied electric field, such as that caused by an adjacent ion and dipole or, in combination of significance here, light (i.e. electromagnetic radiation). This tendency occurs in context with the optical properties of

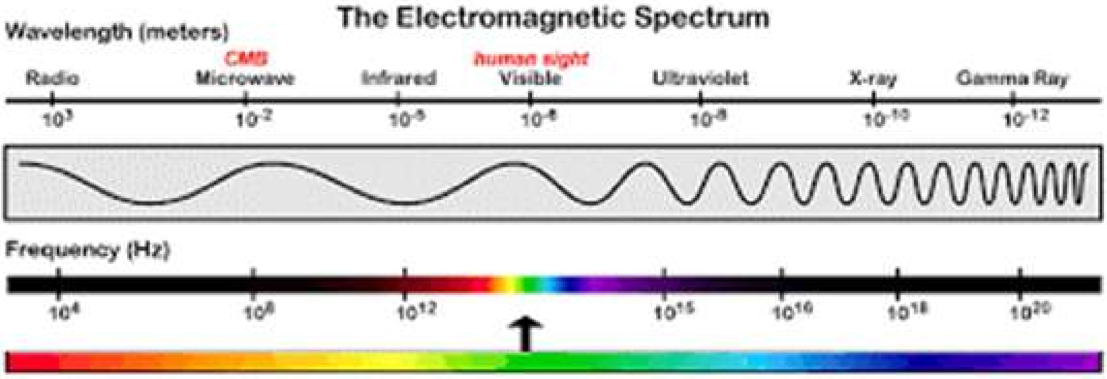

Figure 1: Electromagnetic Spectrum

fibres. The aforementioned indicates that there are various polarisation mechanisms, including ionic polarisation (displacements among positive and negative ions in ionic crystals, such as NaCl), molecular polarisation (polar molecules within a field of electricity can experience torque that causes them to align with the applied field), and electronic polarisation (also known as electric polarisation), which is relevant to the optical properties of textile fibres. Only when light interacts with fibres do electronic operations take place since only the electrons are adequately light to react with the very high frequencies of light waves involved.

The electric field that is being applied polarises the cloud of electrons of the atoms, bonds, and molecules that make up the (transparent and translucent) fibre when light travels through it. A measure of an atom's or molecule's polarisability is the simplicity with which the existence of the electrical fields of nearby molecules can affect the arrangement of electron clouds in a non-polar species. The polarisability of the atom or molecule and the power of the electric field are connected to the induced dipole moment, which is induced by the distorted shape of the electron cloud in the initially non-polar atom or molecule. Polarisability is sometimes stated as polarisability volume, and its values frequently have magnitudes that are comparable to those of molecular volumes. Accordingly, the polarisability of electrons increasing number of electron per unit volume and is proportional to the amount of space occupied by electrons. As electronegativity rises, polarisability falls as a result of the electron clouds (or electron density's) increased confinement. This particular trait is a feature of the idea of soft and hard substances, the former of which are poorly polarisable due to their tightly confined electron clouds and have dispersed electron clouds.

Because surrounding atoms have an impact on a bond's polarisability, polarisability can be divided into three separate directions: one longitudinal direction (i.e., along the molecular and bond axis) & two transverse directions (i.e., perpendicular to a molecular and bond axis). Textile fibres have constituent molecular chains that are arranged parallel or nearly parallel to the fibre axis, yet because of the fiber's axial symmetry, both of its transverse aspects are similar

2.1 Polarization of Light

Unpolarized light is an electromagnetite wave. Light is spread in two different ways as it travels, including magnetic and electric fields are shown in figure 2 given below.

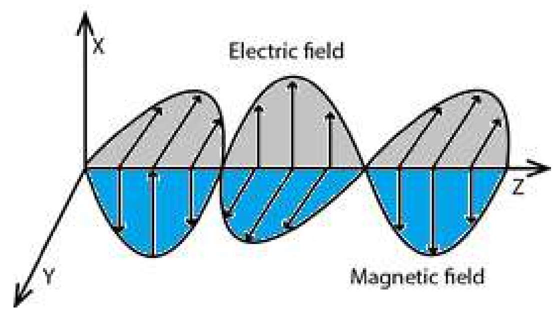

Figure 2: Electric and Magnetic field

Polarisation is the process through which non-polarized light is converted into polarised light. The E field of polarised light is oriented in one direction. Pictorial representation of light is shown in figure 3 [21].

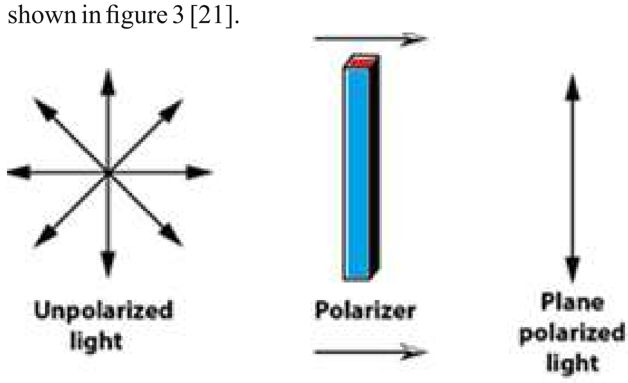

Figure 3: Pictorial Representation of light

2.2 Double refraction

Certain crystals have a phenomenon called double refraction that enables them to divide an unpolarized ray to produce two plane polarised light rays at right angles to one another. The dual refraction is what causes the various colours.

2.3 O-ray & E-ray

One vibrational ray will achieve a higher refractive index during double refraction and refract in accordance with Snell's law. The Ordinary ray, often known as the O-ray, other beam that is vibrating perpendicular to the O-ray will experience a lower refractive index & will bend at a smaller angle. The E-ray, or extraordinary ray, is the name of the ray is shown in figure 4.

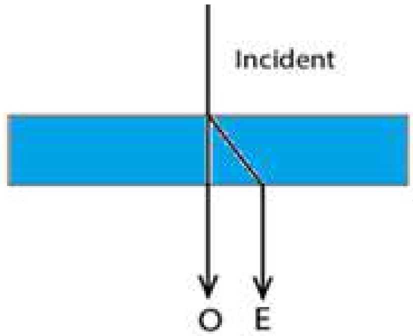

Figure 4: Double refraction. An incident ray splits into an ordinary (O) and extraordinary (E) rays

3. Refractive Index

The refractive index, also known as the index of refraction, is the ratio of the speed of light in a vacuum compared to that in the medium.

3.1 Relation among refractive index, density and swelling

The fibre density has an impact on the refraction index of the fibres. This is due to the fact that when the amount of molecules increases, the refractive index increases as well. Gladstone and Dale's law can be used to express for many fibres the correlation among refractive index and fibre density (r)

$$\frac{n-1}{\eta} = \text{Constant}$$

If the average reflective index is used, the value of constant is 0.3570. A similar relationship can be obtained between refractive index (nm) and volume (vm) of a mixture of different components [22].

3.2 Effect of moisture regain on the refractive index of fiber

Water has a refractive index of 1.33. Since most fibres have refractive index values higher than those of water, they become less transparent as moisture is regained. The influence of moisture on the mean refractive index of fibres is schematically depicted in Figure 5. When low moisture levels are restored to some fibres, a rise in the refractive index is seen, which is likely the result of water filling any holes or flaws in the fibres. [23, 24]

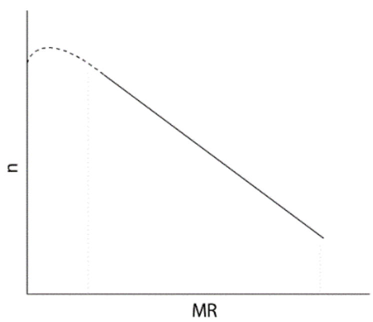

Figure 5: Effect of moisture regains on the refractive index of fibers

3.3 Birefringence

When a light beam strikes a fibre of textile, it divides into a pair of refracted beams, one polarised perpendicular to the fibre axis and the other parallel to the fibre axis. The birefringence value of fibre is the difference between the refractive index for light polarised parallel to the fibre axis and the refractive index for light polarised perpendicular to the fibre axis.

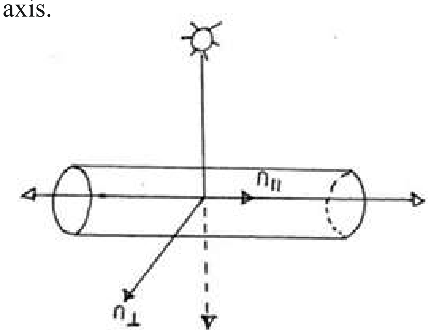

Figure 6: Birefringence

Birefringence can be formalized by assigning two different refractive indices to the fibre for different polarizations is shown in figure 6.

The birefringence magnitude is thus defined by-
$\Delta n = n1 - n2$

Where, for light polarised in parallel and perpendicular directions to the fibre axis, respectively, n1 and n2 are the refractive indices.

The highest possible level of birefringence denotes a higher degree of fibre orientation since the majority of molecules are aligned parallel with the fibre axis.

The ideal value of birefringence varies depending on how the fibres are orientated, and it ranges [25].

3.4 Factors affecting the birefringence of textile fibres:

The birefringence value of textile fibres depend on-
- the degree of orientation and
- the degree of asymmetric of the molecular chain (straight/zigzag/with side groups)

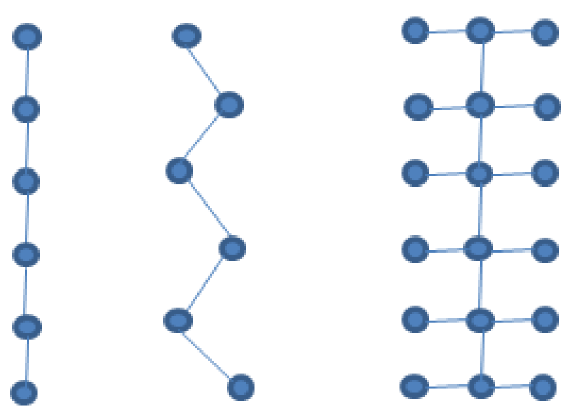

Figure 7: Fig: (a) Straight chain, (b) Zigzag chain & (c) Chain with sidegroup

The bond polarizabilities are highest along the line connecting the atoms when all of the atoms in a molecule are arranged in a straight chain as shown in figure 7 (a), which results in a high birefringence value. Although the real molecules in fibres do not take this structure, there are two reasons why their birefringence will be diminished.

First off, the majority of main chains have a zigzag shape, as seen in figure 7(b), as long as the bonds diverge from the main axis by less than around 55. This will still result in a positive birefringence value. In wool, the keratin molecule's coiling will have a similar result. Second, side groups that are attacked by the primary chain, as seen in figure 7 (c), will produce atomic bonds that are perpendicular to the primary axis. In this instance, n ⊥ value reduces the Birefringence value by being higher than n|| value. In acrylic fibre, side groups have a stronger influence than the main chain, resulting in a negative Birefringence score.

3.5 Dichorism

Dichorism, which can cause differences in shadow depth or even colour itself, is the variation in radiation absorption by a coloured cloth with respect to the direction of polarisation of light.

The magnitude of it is used to gauge the positioning of molecules in dyed fibre that displays dichorism. So, we get-
$\varphi = k1/k2$

Where, φ = Dichric/dichroitic constant

K1 = Absorption co-efficient of light polarized parallel to the fibre axis

K2 = Absorption co-efficient of light polarized perpendicular to the fibre axis.Lustre

A crucial characteristic of textile fibres is lustre. A light beam may reflect across an angle of reflection when it strikes a fibre surface.

The reflection may change depending on the light's colour, polarisation, and incidence angle. As regular light reflection increases, the lustre of textile fibres will consequently rise [26-30].

3.6 Requirements of Dichroism:

1. In order for the dye molecule's radiation absorption to change with the direction of the electric field activating the distinctive vibration, the dye molecule must be asymmetrical.
2. In order for all dye molecules to form the same angle with the axis of the chain molecules (or a small range of angles), the dye molecule must be absorbed onto the fibre molecule in a specific direction.
3. The molecules in the chain must be orientated preferentially.
4. Crossed fibres absorb more light than parallel ones: When light travels through two dichroic fibres, total absorption is higher if the fibres are crossed than if they are parallel. The explanation is rather simple: when fibres are crossed, the first fibre absorbs a significant portion of one component and the second fibre absorbs a significant portion of the opposing component. However, the same component is transmitted through both with minimal absorption if the fibres are arranged in parallel. Dichroic constant for direct dyes on cellulose: Fibre Dichroic constant Ramie 9 Viscose rayon 1.4 – 2.3 Cellophane 1.5

3.7 Reflection & Lusture

An essential aesthetic quality of fabric or textile fibre is lustre. If a light beam strikes a surface, it may reflect brilliantly at the angle of reflection as shown in figure 8 (a), diffusely with variable intensities throughout a hemisphere as shown in figure 8 (b), or in a combination of both as shown in figure 8 (c). The reflection may change depending on the light's hue and polarisation as well as its incidence angle. The lusture of the mtl is determined by the overall visual appearance brought about by these reflections.

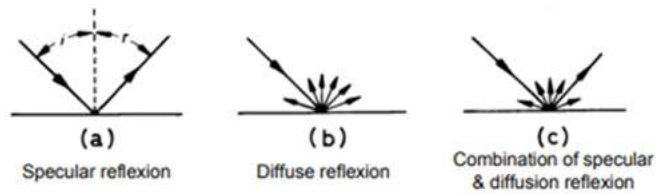

Figure 8: Reflection & Lusture

3.8 Factors affecting the lustre of textile fibres

Different factors affecting the lusture of different textiles are discussed below:

3.8.1. Incident angle of light

Whether the light is incident on the fibre or travels along it. A fibre would reflect light like figure 9 (a) and 9 (b) if it behaved exactly like a circular mirror. It is obvious that if light strikes the fibre, it will reflect at different angles. Instead of falling down the threads, it reflects here with a fixed angle [30, 31].

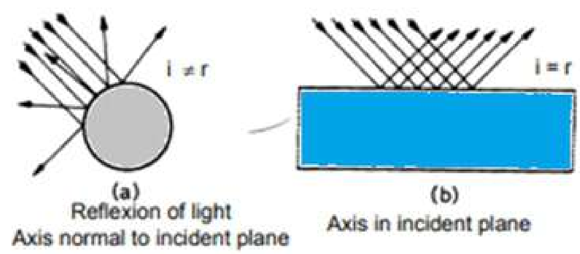

Figure 9: Incident angle of light

3.8.2 Fineness of fibre

The number of unique reflecting surfaces per unit area of a fabric increases with the number of fibres used in the fabric. The same sorts of smoothness and regularity are affected by fibre fineness, therefore the coarser fibres will have more lustre than fibre one.

3.8.3 Irregularity of the fibre surface

Light will reflect in different directions and lose its lustre as a result of irregularities on the fiber's surface and in its cross-sectional structure. It is crucial that fibres be consistent throughout their length. Because of this, the lustre is greatest in regular fibres like silk and M.M.F.

3.8.4 Fibre shape

A key element of lustre is fibre form. Due to (or as a result of) their various circular, serrated, and triangular shapes' influence on the pattern of light reflection, nylon, rayon, and silk must all have different specific forms of lustre is shown in figure 10.

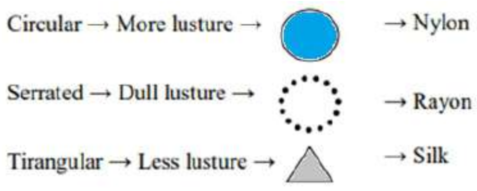

Figure 10: Different fibre shape

3.8.5 Presentation of small particles on fibre like TiO2 or Minimize the lusture of M.M.F

A light beam strikes a fibre and is not only reflected but also transmitted when it does so. The inside surfaces will reflect some of this transmitted light, as shown in figure 11 (a). Small particles, such as TiO2 or cavities as shown in Figure11 (b), can scatter the transmitted light at different angles and result in a highly diffuse reflection if the fibre contains them. TiO2 is used in MMF as a dellustrant to lessen its lustre.

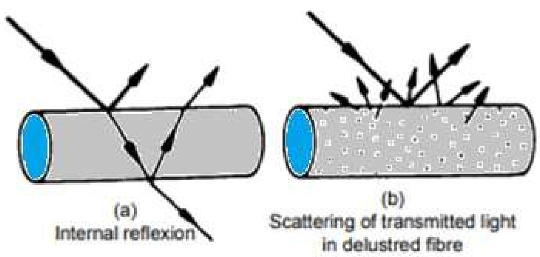

Figure 11: Lusture of M.M.F

3.8.6 Maturity of fibre

A high level of maturity will also result in a high level of reflection, which will also result in a high level of lustre. Reflection Lustre of Maturity is shown in figure 12.

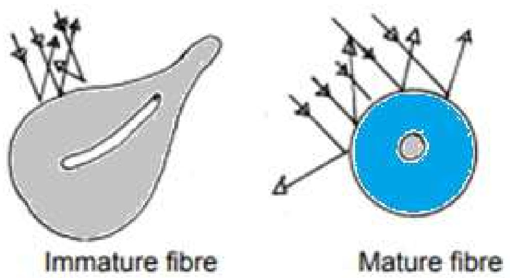

Figure 12: Maturity of fibre

3.8.7 Metamerism

A dye or printed fabric's colour may be noticeably altered when inspected in various lighting situations. The term "metamerism" refers to this occurrence. When viewed under one form of illumination, two fabric materials could appear to have the same colour, but when viewed underneath another type of illumination, they may appear to be an entirely different colour. The fabrics are referred to as a metameric match if this happens. When two fibres with differing chemical compositions, such polyester and cotton, must be dyed in a single colour, the issue of metameric matching may occur. The varying chemical makeup of the fibres makes it impossible to successfully colour them using the same dye in every case.

3.8.8 Delustrants

Man-made and synthetic fibres that have been extruded are frequently translucent and extremely glossy. The use of a delustrant lowers lustre and boosts opacity (and covering power). Powdered TiO2 (particle size range: 0.3-0.4 m in the case of PES fibres) is the most popular delustrant, while other substances like ZnS, Al2O3, and synthetic resins can be used as well. While additional levels of TiO2 are used to secure fibres of different lustre, these are referred to as clear (also known as bright) in the context of fibres that do not contain delustrant, semi-matt (also known as semi-dull), and matt (also known as dull). The latter two variants are created employing additions of 0.5% as well as up to 2% TiO2, respectively, in the case of PA fibres. Because the minute particles of usually TiO2 in delustrant scatter the transmitted light, enhancing the quantity of diffuse reflection, the presence of delustrant throughout the fibre will lower lustre.

4. Conclusion

In this article we have discussed about the optical properties of fibre. So, as we know that the optical properties of a material define how it interact with light. Among the optical properties, refraction, absorption, reflection and scattering of light are the most important. The behavior shown by the textile fibre when light falls on it are called optical properties. A fabric can reflect, absorb or transmit visible light falling on it. The hue of the fabric depends on the extent to which light is reflected, absorbed or transmitted. Thus, optical properties of fabrics need to be taken into consideration when dyeing, printing or colour matching fabrics. Optical properties of textile fibres are birefringent in that refractive index depends on polarization of light. The refractive index of fibres is affected by fibre density. Refractive index will increase when the number of molecules present increases. For many fibres, the relationship between refractive index and fibre density is given by Gladstone and Dale's law. Besides the refractive index other factors affecting the optical properties are polarization, moisture regains, birefringence, dichroism, metamerism, and delustrants etc.

References

[1] Oxford Dictionary of English, 3rd edition (online). Oxford: Oxford University Press; 2012.

[2]Online Etymology Dictionary. Douglas Harper; 2013. http://www.etymonline.com/index.php?allowed_in_frame=0&search= fiber&searchmode=none (accessed 19 March /2013) [database on the Internet].

[3] (1988). Journal of the Society of Dyers and Colourists, 104(12). https://doi.org/10.1111/cote.1988.104.issue-12

[4] Lord, P. R. (2003). Filament yarn production. Handbook of Yarn Production, 88–115. https://doi.org/10.1533/9781855738652.88

[5] Lawrence, C. A. (2003). Fundamentals of Spun Yarn Technology. https://doi.org/10.1201/9780203009581

[6] Wulfhorst, B., Gries, T., & Veit, D. (2006). Principles and Machinery for Yarn Production. Textile Technology, 74–123. https://doi.org/10.3139/9783446433472.003

[7] Lawrence, C. A. (2010). Overview of developments in yarn spinning technology. Advances in Yarn Spinning Technology, 3–41. https://doi.org/10.1533/9780857090218.1.3

[8] Chattopadhyay, R. (2010). Introduction: types of technical textile yarn. Technical Textile Yarns, 3–55. https://doi.org/10.1533/9781845699475.1.3

[9] Alagirusamy, R., & Das, A. (2010). Technical textile yarns. Woodhead Publishing Limited. https://doi.org/10.1533/9781845699475

[10] Woodhead Publishing Series in Textiles. (2014). Advances in Filament Yarn Spinning of Textiles and Polymers, xi–xvi. https://doi.org/10.1016/b978-0-85709-499-5.50015-5

[11] TEXTILE TERMS AND DEFINITIONS. (1962). Journal of the Textile Institute Proceedings, 53(3), P254–P256. https://doi.org/10.1080/19447016208688695

[12] Bahadur, P.S., Singh, S., Bais, P., Jaiswal, S., Laser in textile industry and its application, Asian Textile Journal, 2023, 32(3-4), pp. 50–54.

[13] Bais, Bahadur, P.S., Production and market development of sericulture, Asian Textile Journal, 2023, 32(7), pp. 46–52.

[14] Bahadur, P. S., Srivastava, R., & Srivastava, V. (2023). Review on the Development of Smart Materials, Including Shape Memory Alloys, Characterization, and Recent Applications. Advances in Chemical and Materials Engineering, 107–139. https://doi.org/10.4018/978-1-6684-9224-6.ch005

[15] Singh, P., & Gaur, N. K. (2014). Thermal and Elastic Properties of C60 in Fcc Phase. SOP Transactions on Theoretical Physics, 2014(2), 68–72. https://doi.org/10.15764/tphy.2014.02006

[16] Chekhova, M., & Banzer, P. (2021). Polarization of Light. De Gruyter. https://doi.org/10.1515/9783110668025

[17] Bahadur, P. S. (2018). Investigation of Cohesive, Thermal and Elastic Properties of C60 in Fcc Phase. Journal of Computational and Theoretical Nanoscience, 15(4), 1415–1419. https://doi.org/10.1166/jctn.2018.7300

[18] P. Singh Bahadur, S. Jaiswal and R. Srivastava, "Optical Fiber: Trending Technologies," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), 2021, pp. 166-170, doi: 10.1109/ICIEM51511.2021.9445276.

[19] P. S. Bahadur, S. Jaiswal, R. Srivastava and A. Kumar, "Advanced Application of Nanotechnology in Engineering," 2021 International Conference on Technological Advancements and Innovations (ICTAI), 2021, pp. 92-95, doi: 10.1109/ICTAI53825.2021.9673329.

[20] SINGH, P., and NK GAUR. "Elastic properties of KCNxCl1-x." Optoelectronics and Advanced Materials-Rapid Communications 3.May 2009 (2009): 501-505.

[21] Shahabi, N., & Phirouznia, A. (2020). Normal electric field enhanced light-induced polarizations and magnetic detection of valley polarization in silicene. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-73138-5

[22] On Double Refraction. (2009). Scientific Papers, 111–119. https://doi.org/10.1017/cbo9780511703966.011

[23] Heyn, A. N. J. (1952). Observations of the Birefringence and Refractive Index of Synthetic Fibers with Special Reference to Their Identification. Textile Research Journal, 22(8), 513–522. https://doi.org/10.1177/004051755202200803

[24] Ren, Y. H. (2012). The Relationship among Fiber Fineness, Moisture Regain and Resistance. Advanced Materials Research, 503–504, 1061–1064. https://doi.org/10.4028/www.scientific.net/amr.503-504.1061

[25] Zeidman, M. I. (1980). The Correct Calculation of the Moisture Regain of Fiber Mixtures. Textile Research Journal, 50(6), 393–394. https://doi.org/10.1177/004051758005000614

[26] Schwarz, E. R., & Hotte, G. H. (1935). Micro-Determination of Cotton Fibre Maturity in Polarized Light. Textile Research, 5(8), 370–376. https://doi.org/10.1177/004051753500500802

[27] Fiber Classification: Natural Fibers. (2018). Swatch Reference Guide for Fashion Fabrics, 11–22. https://doi.org/10.5040/9781501328572.ch-002

[28]Fiber Classification: Manufactured Fibers. (2018). Swatch Reference Guide for Fashion Fabrics, 23–30. https://doi.org/10.5040/9781501328572.ch-003

[29]Fiber Classification: Synthetic Fibers. (2018). Swatch Reference Guide for Fashion Fabrics, 31–40. https://doi.org/10.5040/9781501328572.ch-0 Pelton, M. O. (1930). The lustre of textile fibres and a method of measurement. Transactions of the Optical Society, 31(4), 184–200. https://doi.org/10.1088/1475-4878/31/4/30204

[30] The Scope of Textile Fibres. (2015). The Chemistry of Textile Fibres, 1–24. https://doi.org/10.1039/9781782620235-00001

[31] https://textilestudycenter.com/optical-properties-of-textile-fibers/

Extraction of Fibres from Aerial Roots of Giloyi (Tinospora cordifolia) Tree-Finding Sustainable Sources for Bioactive Textiles

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Abstract:

Presently most research initiatives are oriented toward environmentally sustainable solutions. It is vital to address environmental challenges and eliminate non-renewable items as soon as possible. Tinospora cordifolia (Giloyi tree) is widely used in traditional Ayurvedic medicine in India. This study aimed to utilize the aerial roots of Giloyi tree to produce natural cellulosic fibres, the unused section of the tree. It was an exploratory study to discover natural fibre that is completely biodegradable with built-in medicinal characteristics for potential use as raw material for healthcare and sanitation products.

The fibers were extracted from the aerial roots of Giloyi tree using various methods, including biological, chemical, and enzymes;. For fibre extraction, treatments such as water retting, sodium hydroxide, sodium carbonate, urea, and enzymes were used. The concentration, time, and temperature of the treatments were also varied and the process was optimized for each of these treatments. Different extraction methods were used to obtain the results, which were based on the simplicity of fibre separation and the yield from each method.

Keywords: *Aerial roots, Hygiene products, Sustainable fibres, Tinospora Cordifolia (Giloyi Tree), Waste utilization*

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1. Introduction :

Today, global warming and the exhaustion of petroleum reserves have diverted the focus to natural fibres, which are inexpensive and renewable, leading to a rise in their consumption [1]. Biopolymers, like cellulose, are the fundamental building block of natural cellulosic fibres and contribute to their biodegradability and renewability [2]. Due to certain features such as biocompatibility, inexhaustibility, and ampleness in nature, lignocellulosic fibres have seen their usefulness in different domains [3]. Natural gum, which is contained in the plant strands and assists in their adhesion, must be eliminated during the retting process in order to split up the fibre strands from it. Various retting processes include dew/field [4], NaOH [5], and chelating agent EDTA [6].

One of the most economically and ecologically expensive commercial crops to produce is cotton. Cotton production has the second-largest agricultural use of pesticides in the world with five of the most dangerous pesticides used that are known to be cancer-causing apart from being environmentally dangerous. The 60 per cent of the total fibre production in the world accounts for cotton, although during the last three decades man-made fibres have made significant inroads into cotton's share. This situation is aggravated by the rising price of cultivating cotton and other natural cellulosic fibres like jute and linen [7].

Known as Guduchi/Giloyi, Tinospora cordifolia is a large, deciduous climbing shrub in the Menispermaceae family. China and the Indian subcontinent are the main distribution areas. Giloyi is the term that is widely used in Hindi for Tinospora cordifolia. This term has a folkloric expression that has maintained the celestial beings alive and young with the help of this divine medicine. The aerial roots of the Giloyi are long filamentous and extend from the stem's branches [8]. In certain ayurvedic medicines, the use of Giloyi has been acknowledged as one of the significant elements. Anti-spasmodic, antipyretic, anti-allergic, anti-inflammatory, and anti-leprotic are some of the properties that have been discovered in the dry bark of Giloyi [8, 9].

This study attempted to extract natural cellulosic fibres from the aerial roots of the Giloyi, that has inherent antimicrobial and other medicinal properties which are an added advantage for the products made from these fibres. In designing the study, the following research goals were taken into account:

i. Optimization of conditions for fiber extraction from aerial roots of Tinospora cordifolia.

ii. Assessment of the ease of extraction of fibres under optimal conditions.

iii. Comparison of various physical properties of fibres extracted using different methods

iv. Measurement of the percentage yield of fibres extracted.

2. Materials and Methods

Aerial roots of Tinospora cordifolia (Giloyi) were procured from the campus of Lady Irwin College, New Delhi. Chemicals used were Sodium Hydroxide, Sodium Carbonate, Urea, Hydrogen Peroxide, EDTA, Sodium Silicate, and Bactosol CBS Liquid (procured from Archroma). All the chemicals were of laboratory reagent grade.

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2.1 Extraction of Fibres

Table 1 summarises the optimal parameters used for extraction of the fibres

Table 1: Optimized Parameters Used for Extraction of Fibres

Treated with	Concentrations Used	Time Duration (min)	Temperature	MLR
Na_2CO_3	5g/l & 7.5g/l	30, 60, 90 & 120	90ºC	1:40
NaOH	5g/l & 7.5g/l	30, 60 & 90	60ºC (5g/l) & 90ºC (7.5g/l)	1:40
Urea	5%, 7.5% & 10% (owm)	30, 60, 90 & 120	90ºC	1:40
Enzyme	2.5%, 5% & 7.5% (owm)	60, 120, 180 & 240	75ºC (ph-7)	1:40

2.1.1 Bleaching and softener treatment of Extracted Fibres

The bleaching of extracted fibres was done using Hydrogen Peroxide to decolorize them and for their further segregation, a solution of 0.5g/l EDTA, 10g/l Sodium Silicate, 2g/l Sodium Carbonate (to maintain a pH 10-11) and 0.5% of Hydrogen peroxide (MLR 1:30) was used [10]. The fibres were then added in the solution, and bleaching was carried out for 45 minutes at 90°C. Dilute acetic acid was then used for neutralizing the treated fibres. After this polysiloxane commercial softener was used, which further increased the flexibility of fibres.

2.2 Testing of Extracted Fibres

The physical properties that were examined included length, fineness, strength and elongation by using standardized test methods. The test method numbers IS 10014 Part-1, IS 10014 Part-2 and IS 3675 were used to determine the fibre length, fibre denier, elongation and bundle strength of the extracted fibres respectively.

3. Results and Discussion

The study was conducted to examine the possibility of extracting fibres from the aerials roots of Tinosporia cordifolia (Giloyi) using various chemical methods. The different extraction methods that were explored were water retting, alkaline treatment with sodium carbonate and sodium hydroxide, treatment with urea and enzymatic treatment. The extracted fibres were tested for various physical properties, ease of extraction and percentage yield to do a comparative analysis between the different methods. The results obtained have been presented under different heads in the subsequent sections.

3.1 Water Retting

At room temperature, 10 g of dried aerial roots were stored for 15, 30, 45, and 60 days (water was changed after every 7 days). The cork, which consisted of a group of fibres, was visible and swollen by the end of 45 days, making extraction easier. After the period of 45 days, the extraction of fibres was done manually (Fig. 1).

Figure 1: Fibres extracted using water retting

3.2 Treatment with Sodium Carbonate

10 grams of dried aerial roots of Giloyi were treated with different concentrations of Na2CO3 with varying concentration and time.

3.2.1 Effect of concentration and time

The fibres extracted were finer when treated at 7.5g/l concentration of Sodium Carbonate than when treated at 5g/l (Table 2). With increase in time the ease of extracting the fibres also improves. The finest extraction was seen when treated with 5g/l for 60 minutes. Increasing the time to 90 minutes did not further enhance the ease of extraction. Fibre extraction after 30 minutes was easier to extract than those extracted after 60, 90, and 120 minutes of treatment with 7.5g/l Na2CO3. (Table 2). The best Na2CO3 extraction condition was 7.5g/l Na2CO3 at 90°C for 60 minutes with an MLR of 1:40.

3.3 Treatment with Sodium Hydroxide

10 grams of dried aerial roots were treated each with varying concentrations of NaOH at two different temperatures for varying time duration.

3.3.1. Effect of concentration, temperature and time

Aerial roots when treated with 7.5g/l concentration at 60°C the fibres were extractable (Table 2). With time the ease of extraction increases. The best extraction with 5g/l occurred when treated for 90 minutes. Furthermore, no difference was observed. The ease of extracting the fibre improved slightly when the concentration was increased to 7.5 g/l. Individualization of fibre bundles was also achieved in 60 minutes for this concentration (Table 2). The best extraction condition for NaOH treatment was found to be a 60-minute time period with 7.5g/l NaOH at 60°C.

3.4 Treatment with Urea

10 grams of dried aerial roots of Giloyi were treated with varying conditions using urea.

3.4.1 Effect of concentration and time

The outer layer was not fully removed when treated with a 5% owm concentration, making extraction tough (Table 2). The outer layer of the fibres began to collapse using 7.5% owm concentration, making extraction easier. The 10% owm concentration of Urea showed the finest result (Table 2). At 5% owm with the increase in time to 60 minutes, fibres were relatively easily extracted and no difference was seen further. At 7.5% owm with time extraction was made easy. 90 minutes were found to be sufficient to bring about some individualization. No further improvement was seen.

When extracting the fibres with a 10% owm urea concentration, the fibres were extracted more easily than with prior concentrations as time went on. The best urea extraction condition was found to be a concentration of 10% owm with MLR of 1:40 at 90°C for 120 minutes (Table 2).

3.5 Enzyme Treatment

10 grams of dried aerial roots of Giloyi were treated with varying concentrations of Bactosol CBS Liq. (a commercial pectate lyase enzyme).

3.5.1 Effect of concentration and time

At lower concentrations, the outermost layer of the fibre was hard. At 5% owm breakdown starts, making extraction easier (Table 2). Furthermore, no difference was seen. Enzymes are more expensive than the other agents used in fibre extraction. Because raising the concentration did not result in a significant improvement in fibre separation, a lower concentration (5% owm) is preferred.

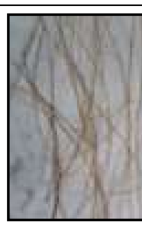
At 2.5% concentration, outer cell was hard to remove before 180 minutes, after that, it started degrading and easily extracted. Therefore, when lower concentration of enzyme is used, it is recommended to carry out the treatment for at least 2 hours before any effect on the outer epidermis layer is seen.

At 5% owm concentration, the mechanism of action of the enzyme was on pectin which has the function of adhesion. As a result of rupturing, fibres adhered inside are released. The outer cell wall of those treated for less than five minutes was difficult to dissolve because the enzyme required more time to dissolve it. After 180 minutes of treatment, the extraction process was simpler since pectin had probably disintegrated. In the case of 7.5% owm concentration, the extraction process becomes easier with time [10].

Table 2 shows that the best fibres were extracted when enzymes were used at 5% owm with 1:40 MLR at 90oC and pH 7 for 180 minutes.

Table 2: Fibres Extracted after Treatment with Various Condition and Methods

	30 minutes	60 minutes	90 minutes	120 minutes
Na_2CO_3 5g/l				
7.5g/l				
NaOH 5g/l				
7.5g/l				

	30 minutes	60 minutes	90 minutes	120 minutes
Urea 5%owm				
7.5%owm				
10%owm				
Enzyme	**60 minutes**	**120 minutes**	**180 minutes**	**240 minutes**
2.5% owm				
5% owm				
7.5% owm				

3.3 Yield of Fibres after Extraction

Fig. 2 depicts the yield percentage of fibres obtained from the aerial roots of Giloyi after treatment with different conditions.

Figure 2: Yield Percentage of Extracted Fibres

3.7 Bleaching using Hydrogen Peroxide

Hydrogen peroxide was used for the bleaching method. Fibre separation occurred easily and the color of the fibres also became light after bleaching treatment (Fig.3).

Figure 3: Extracted fibres after Bleaching treatment

3.8 Softening Treatment

The fibres treated using NaOH were stiff and had a harsh feel. The improvement in the luster and pliability of fibres were seen after a polysiloxane commercial softener treatment (Fig. 4).

Figure 4: Fibres extracted using NaOH bleached and given softener treatment

3.9 Analysis of Physical Properties of Extracted Fibres

Table 4 depicts the values of the different parameters of physical properties tested for the fibres extracted using various extraction methods.

From the results obtained for the physical properties, it was seen that fibres extracted from treatment with NaOH before bleaching yielded the longest fibre with length of 432.23mm and the shortest were the fibres extracted from the water retting with length of 193.77mm. Fibres treated with NaOH before bleaching yielded the finest fibre of all with 75.08 denier and the coarser fibre was extracted when treated using enzyme with 96.30 denier. In terms of bundle strength fibres extracted using NaOH before bleaching shows good strength of 16.95g/Tex and the lowest was seen in the fibres extracted using water retting of 7.55g/tex. Maximum amount of stretch (elongation) was obtained by NaOH after bleaching as 7.80% and the lowest stretch resulted by water retting method of 3.77%. The effect of alkali and bleaching agent seems to change the polymer orientation and makes the fibres more amorphous which helps the fibres in further elongation.

4. Conclusion

The final evaluation of the effectiveness of the extraction method was done in terms of quality of fibres extracted, ease of extraction and the overall yield from each method. In comparison, it was observed that those treated with enzyme (5% owm) concentration for 180 minutes were easiest to extract than other fibres. The fibres which were extracted from the enzyme treatment were also good in yield percentage. The fibres extracted using NaOH were the finest and longest with good bundle strength. The highest percentage of elongation was observed in fibres treated with NaOH followed by bleaching.

This being done from an unused part of the plant can be a sustainable alternative source for cellulosic fibres. With a documented list of medicinal value and properties of this plant, it can find good use in various textile applications and especially as bioactive textiles in health and hygiene products. The aerial roots of Giloyi used for the study were also not pulled or cut from the tree but were used when they fell from the trees on their own. This is a very effective way to conserve the environment and a good method of utilizing plant waste.

Table 4: Physical properties of the fibres extracted from aerial roots of Giloyi tree

S. No.	Test Parameter	A Water Retting	B Treatment with Na_2CO_3, bleached	C Treatment with NaOH	D Treatment with NaOH, bleached	E Treatment with urea, bleached	F Treatment with enzyme, bleached
1.	Fibre length (mm)	193.77	207.97	**432.23 (Longest)**	274.8	254.33	293.1
2.	Fibre denier	85.01	93.45	**75.08 (Finest)**	91.72	89.44	96.30
3.	Bundle strength (g/tex)	7.55	13.47	**16.95 (Good Strength)**	13.56	13.67	13.63
4.	Elongation (%)	3.77	5.71	6.99	**7.80 (Maximum)**	6.22	6.12

References

[1] Dunne R, Desai D, Sadiku R, Jayaramudu J. A review of natural fibres, their sustainability and automotive applications. Journal of Reinforced Plastics and Composites. 2016 Jul; 35(13):1041-50

[2] Wolela AD. Extraction and characterization of natural cellulose fibers from Sanseveria trifasciata plant. Trends in Textile Engineering & Fashion Technology. 2019 Jul: 21; 5(2):630-4

[3] Derrouiche I, Ben Marzoug I, Sakli F, Roudesli S. Study of extraction and characterization of ultimate date palm fibers. Adv. Mater. 2015 Jun; 4:7-14

[4] Ramesh M. Hemp, jute, banana, kenaf, ramie, sisal fibers. InHandbook of properties of textile and technical fibres 2018 Jan 1 (pp. 301-325). Woodhead Publishing

[5] Majumdar S, Kundu AB, Dey S, Ghosh BL. Enzymatic retting of jute ribbons. International biodeterioration. 1991 Jan 1; 27(3):223-35

[6] SHARMA HS. Chemical retting of flax using chelating compounds. Annals of applied biology. 1988 Aug; 113(1):159-65.

[7] Kumar PS, Suganya S. Introduction to sustainable fibres and textiles. InSustainable fibres and textiles 2017 Jan 1 (pp. 1-18). Woodhead Publishing

[8] Shefali C, Nilofer S. Gaduchi-the best ayurvedic herb. The Pharma Innovation. 2013 Jun 1; 2(4).

[9] Sinha K, Mishra NP, Singh J, Khanuja SP. Tinospora cordifolia (Guduchi), a reservoir plant for therapeutic applications: A Review

[10]Rana P, Chopra S. Extraction and characterization of inherently antimicrobial fibres from aerial roots of banyan tree. Journal of Natural Fibers. 2022 Dec 1; 19(13):6196-213sing a proposed TOL model," Comput. Educ., vol. 117, pp. 102–115, (2018), doi: 10.1016/j.compedu.2017.10.004

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Reuse of Peracetic Acid Bleach Bath for Bleaching of Different Ligno Cellulosic Fibres

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Abstract:

Our country several resources of plant fibres like jute, banana, ramie, flax, etc, which is grown in different parts and agro climatic zone and are having immense impact on the socioeconomic values. These fibres consist of cellulose, hemicellulose and lignin as major constituents and due to their biodegradable and renewable in nature are becoming popular in textile and non-textile applications as a replacement of synthetic fibres and plastic items. Several diversified and value-added items are produced from these fibres like upholsteries, lifestyle products, varieties of fashion bags, handcrafts, etc along with mainstream products. So, chemical processing of these fibres has become essential and standardization of different unit operations like pre-treatments, bleaching, dyeing, printing, finishing, etc are needed to make them look beautiful and feel better. A few processes have been developed and require further modification for their sustainability. Bleaching is the heart of the chemical processing for all the subsequent processes are solely dependent on it for optimum results. Traditional bleaching using hydrogen peroxide is very popular in industry but along-with the achievement of high whiteness and brightness indices it results in substantial loss in tensile properties as the process is carried out at high alkaline condition as well as temperature, which damages these lignocellulosic fibres. So, an innovative peracetic acid bleaching process has been developed that is carried out at lower temperature in mild alkaline condition. Jute, banana, ramie and flax fibres contain cellulose, hemicellulose, and lignin in different proportions in different fibres. Hence optimized condition of chemical processing varies for individual fibres. The peracetic acid bleaching process has been optimized for individual fibres using Taguchi Experimental Design (TED) and the optimized processes produces satisfactory whiteness/ brightness with high retention of tensile strength. To make the process sustainable, the left out bleach bath formulation has been re-claimed and it has been found that the left out liquor need to be used for further two batches of grey fibres to produce semi-bleached and quarter-bleached fibres which can be utilized for dyeing in variety of shades. The reuse of bleach bath can be done by different methodologies like compensation of bath or without. It is found that 1st reuse can be done without compensation but 2nd reuse produces better effect if compensation is done for liquor and pH correction.

Keywords: *Banana, Bleaching, Fibre, Flax, Jute, Peracetic acid, Ramie, Reuse*

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1. Introduction

India has different agro-climatic zones that exist in different parts of our country, and varieties of fibre yielding plants are available. Hence, India is blessed with a number of plants resources that produce different natural cellulose to lignocellulosic fibres. A few popular lignocellulosic fibres include jute, flax, ramie, banana, etc. are used for making different textile and non-textile product [1 - 4]. In the category of textile items, such fibre are used to produce coarse yarns, which are used for making packaging materials, low-cost bags, handicraft items etc. and are mostly used for making low-value products cost [5]. The main advantages of these fibre-based products are biodegradable, environmentally friendly and annually renewable, so it has the potential to be used for making various value-added products. Recently lot of work has been carried out for development of processes which can produce finer yarns after suitable blending, advanced extraction process for obtaining finer fibres, chemical modification or treatment of fibre for making it softer, colouration of fibres with eco-friendly synthetic and natural dyes for making home textiles, upholsteries and even fashion or outer garments [6 - 9].

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The cellulose, hemicellulose and lignin elemental composition varies from fibre to fibre, derived from the different plant sources. From the fibre chemical composition point of view, ramie and flax contain lower lignin percentage as compared to banana and jute fibres. This also leads to produce finer fibre by the plant during its bio-synthesis in the plant body. So, in order to produce value-added textile products, chemical processing of such fibres like pre-treatment, bleaching, dyeing, printing, finishing etc. are important and such chemical interventions has profound effect on fibre colour, feel, look, fineness and rigidity [7]. Hydrogen peroxide bleaching is conventionally carried out for discolouration/de-pigmentation of the lignocellulosic plant fibres to change their natural hue golden (dark to light) yellow to white, bright and clean fibre [10 - 12]. It also cleans the fibres which enhances their absorbency due to removal of natural and added oil, fat and waxy material from the fibre surface. The hydrogen peroxide bleaching is carried out at high alkaline condition at elevated temperature of 80–90 °C and produces very good whiteness and absorbency, but the process leads to damage of fibre to some extent. The lignocellulosic fibres are sensitive to alkaline solutions, resulting high weight loss percentage due to removal of hemicelluloses and a part of lignin macro-molecules. Recently, some work has been carried out to carry out on bleaching of lignocellulosic fibres at low temperature and mild alkaline condition to produce satisfactory whiteness without much loss of its weight as well as tensile properties

[10, 13 - 15]. Peracetic acid is strong new oxidizing agent having high reactivity and may be used for bleaching on lignocellulosic fibres at milder process condition [16]. Study has been done on optimisation of peracetic (PAA) acid bleaching conditions for different lignocelluloic fibres like jute, banana, flax and ramie. The PAA is an environment friendly bleaching agent, as it is having - COOH group and it is fast acting, non-foaming, water soluble and found to be suitable for textile bleaching [17-19]. In the water bath PAA maintains equilibrium reaction with hydrogen peroxide and acetic acid, and the bleaching mechanism mainly involves epoxidation of double bonds of impurities and coloured compounds to produce white fibres. Fibre degradation is also marginal in the case of peracetic acid bleaching.

In order to make the bleaching process sustainable and economic, the bleach bath has been reused two times in the present work, so that the left out bleached bath liquor viz., oxidizing agent and auxiliary chemicals are utilized to the fullest extent. Different parameters like liquor ratio, concentration of bleaching agents, pH of the bleach bath plays an important role in bleaching hence during selection of methodology for reuse of bleach liquor both compensation of chemicals or without has been followed. Furthermore, reuse of bleach bath in the sequential bleaching would also reduce the chemical load in the discharge effluent. The physical properties and optical properties of the treated fibres were evaluated in details at different stages of processing. The bleached fibres produced thus can find application in subsequent stages of colouration in medium to dark shades for production of value-added apparel and clothing.

2. Methodology

2.1 Materials

Lignocellulosic fibres used in this study were made available from local sources, i.e., jute (Corchorus olitorius), Banana (Musa domestica), Flax (Linum usitatissimum) and Ramie (Boehmeria nivea).

2.2 Chemicals

Various chemicals of analytical grade (MERCK, India) namely, tetrasodium-pyrophosphate (TSPP) and sodium carbonate and acetic acid were used in the bleaching process. The commercial grade peracetic acid (PAA) with active CH_3COOOH of 35% (w/v) was procured from the Chemtex Speciality Limited, Kolkata, West Bengal, India with specific gravity of 1.12-1.13 g/cc and used in bleaching of jute, ramie, flax and banana fibres. Likewise, the Ultravon JU (non-ionic surface-active agent) of laboratory grade was procured from the Charminar Enterprise, Kolkata.

2.3 Mild scouring and peracetic acid bleaching

Raw jute, ramie, flax and banana fibres were initially treated with sodium carbonate (2% on weight of fibre) and non-ionic surface-active agent (Ultravon JU, 2 g/L) at a temperature of 50 °C for 30 min, keeping M.Lr ratio at 1:20. Bleaching of mild scoured lignocellulosic fibres were carried out in a closed vessel with fibre-to-water ratio of 1:30 in the presence of non-ionic surface-active agent: 0.5 ml/l, sodium carbonate (Na_2CO_3): 1.8 g/l, tetrasodium pyrophosphate (TSPP): 3 g/l and, while changing the three important bleaching process parameters namely, treatment time, temperature and peracetic acid concentration depending on the optimised bleaching conditions of lignocllulosic fibres. The pH of the bleach bath was maintained at 7.5 – 8, using sodium carbonate and TSPP. Initially sodium carbonate and tetrasodium pyrophosphate (TSPP) solutions with concentrations of 1.8 g/l and 3 g/l, respectively were prepared in hot water and added in bleached bath. After bleaching, the fibres were washed thoroughly in fresh running water and finally dried in air.

Reuse of the bleach bath has been done as per process mentioned in the figure below and coding of the samples has also been done accordingly.

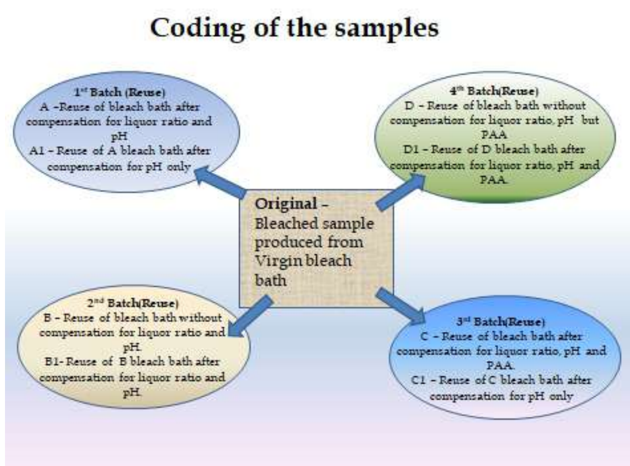

Figure 1 – Bleaching of different ligno-cellulosic fibres through re-use of bleach bath by various approaches

2.4 Fibre properties evaluation

i. Optical properties

Whiteness index (WI) on the 'HUNTER' scale and yellowness index on the 'ASTM D 1925' scale for all the banana fibre samples were measured by Spectrascan-5100 computerized colour matching system. Other colour parameters viz., colour strength (K/S), L*, a* and b* were also measured in the same equipment with the presence of D65 illuminant and 10° angle of observer. Canon 5D Mark III SLR camera (Japan make) was used to illustrate the optical images of the fibres. The reported whiteness index value is the average of 5 measurements.

ii. Bundle strength

Bundle strength of banana fibre was measured after conditioning the sample in a standard atmosphere i.e., 65.2% relative humidity, 27° C temperature for 48 h following the BIS recommendation (IS: 6359-1971). Bundle strength was evaluated using fibre bundle strength tester, worked on the principle of beam balance (with two unequal arms) following

BIS, 1986 (f) standard (Chattopadhyay et al. 2020). The reported values are the average of bundle strength of 15 fibre samples.

3. Results and Discussion

Among the different lignocellulosic fibres jute, banana, flax and ramie fibres have been well characterised and are found to be suitable for textile application either alone or in blends with other natural fibres. These fibres are composed of cellulose, hemicellulose, lignin, pectin as major constituents but their proportion varies from fibre to fibre, so the hygroscopicity of the fibres also varies which are tabulated in Table 1. Lignin content is more in jute and banana whereas pectin content is more in flax and ramie. Again, cellulose content is more in ramie and flax whereas jute and banana contain high hemicellulose percentage. Dimensions of ultimate cells of these fibres as seen in Table 2 clearly show that high L/B ratio for ramie and flax makes them suitable for finer yarns whereas low L/B ratio in case of jute and banana fibres can be used for coarser yarns. Considering textile application of these fibres either in finer apparel or coarser home textiles, these fibres require chemical processing like bleaching, dyeing, finishing, etc. to make them attractive with suitable functional properties.

Table 1 - Chemical constitution of different lignocellulosic fibres [20]

Fiber	Cellulose (wt %)	Hemi-cellulose (wt %)	Lignin (wt %)	Waxes (wt %)	Pectin (wt %)	Moisture Content (wt%)
Flax	71	18.6–20.6	2.2	1.5	2.3	10
Jute	61–71	14–20	12-13	0.5	0.4	12.6
Ramie	68.6 –76.2	13–16	0.6–0.7	0.3	1.9	8
Banana	63-67	19	5	—		8.7

Table 2 - Dimension of ultimate cells of some natural fibres [20]

Fibre	Length, L (mm)	Breadth, B (µm)	L:B ratio (average)
Jute	0.8-6	10-25	110
Ramie	20-25	15-80	3500
Flax	25-65	10-35	1700
Banana	0.9-4.0	12-33	100

Pre-treatment i.e., scouring of all these fibres were done and subjected to peracetic acid (PAA) bleaching following optimised recipe which is tabulated as in Table 3.

Table 3 - Optimized condition of different lignocellulosic fibres

Variables	Optimised condition			
	Flax	banana	Ramie	Jute
Temperature (°C)	75	73	76	75
Time (minutes)	125	135	69	127
Concentration (mL/L)	10	15.4	18	20
pH	7.8	7.5	7.0	8.0

In the present study, after bleaching of the lingo-cellulosic fibres, an effort was made to reuse of the bleach bath to reduce the effluent load along with reduction in cost of chemical involvement in bleaching. Several processes were followed for proper use of left out bleach liquor either by compensation of liquor-ratio, bleaching auxiliaries as well as bleaching agents or without compensation to achieve maximum possible bleaching effects. The left-out bleach liquor after taking out the first sample was collected and used for bleaching for another two times as per the protocol mentioned below. All the reused samples were evaluated for optical and tensile properties, which are most important for textile fibres for their application in diversified and value-added products. In this present study four different experiments were executed viz., (i) reuse of bleach bath after compensation for liquor ratio and pH, (ii) reuse of bleach bath without compensation for liquor ratio and pH. (iii) Reuse of bleach bath after compensation for liquor ratio, pH and PAA and (iv) reuse of bleach bath without compensation for liquor ratio, pH but PAA. The results of evaluation are tabulated in Tables 4-7.

3.1 Original – Bleached sample produced from Virgin bleach bath at optimised recipe

1st Batch (Reuse)

A –Reuse of bleach bath after compensation for liquor ratio and pH

A1 – Reuse of A bleach bath after compensation for pH only

2nd Batch (Reuse)

B – Reuse of bleach bath without compensation for liquor ratio and pH.

B1- Reuse of B bleach bath after compensation for liquor ratio and pH.

3rd Batch (Reuse)

C – Reuse of bleach bath after compensation for liquor ratio, pH and PAA.

C1 – Reuse of C bleach bath after compensation for pH only

4th Batch (Reuse)

D – Reuse of bleach bath without compensation for liquor ratio, pH but PAA

D1 – Reuse of D bleach bath after compensation for liquor ratio, pH and PAA.

Table 4 - Reuse of PAA bleach bath for Jute

Jute fibre	K/s	WI	YI	BI	L	a	b	B.S.
Scoured	4.10	40.3	40.2	12.6	51.8	7.8	18.0	21.2
Original	0.53	75.2	31.6	49.6	83.9	0.05	16.8	20.0
A	0.79	70.6	36.6	42.5	80.5	0.26	19.0	19.5
A1	1.20	64.4	45.1	33.8	75.7	2.79	21.4	18.4
B	0.81	69.6	36.7	41.3	79.5	0.71	18.6	20.0
B1	0.90	65.6	41.5	36.2	78.2	1.41	21.2	18.3
C	0.71	71.8	38.5	43.7	82.0	0.87	19.4	16.8
C1	0.92	68.1	40.8	38.8	78.7	1.81	20.2	15.4
D	0.75	70.8	36.1	42.7	82.3	0.57	18.8	16.7
D1	0.76	70.7	36.4	42.3	80.5	0.89	18.5	15.4

Table 5 - Reuse of PAA bleach bath for Banana fibre

Banana fibre	K/s	WI	YI	BI	L	a	b	B.S.
Scoured	1.82	57.0	33.8	26.6	68.2	5.1	18.4	28.4
Original	0.78	74.3	40.3	46.4	84.5	0.42	22.0	27.1
A	0.81	71.8	39.8	39.8	80.3	0.74	21.2	26.9
A1	1.17	68.9	45.9	38.7	80.4	1.42	24.0	26.5
B	0.84	71.4	41.1	41.6	80.8	0.27	22.7	27.1
B1	1.20	69.3	47.1	35.1	77.9	1.67	24.8	26.2
C	1.53	64.9	49.6	33.7	77.1	2.11	25.1	22.9
C1	1.34	65.0	47.4	34.1	76.8	2.28	23.5	21.6
D	1.46	63.7	45.9	33.1	75.4	1.80	22.5	20.8
D1	1.19	68.8	46.5	38.6	80.5	1.49	24.4	20.1

Table 6 - Reuse of PAA bleach bath for Ramie fibre

Ramie fibre	K/s	WI	YI	BI	L	a	b	B.S.
Scoured	1.34	55.8	28.3	26.2	66.0	4.8	14.6	22.1
Original	0.29	76.3	23.5	52.7	83.4	1.91	10.9	21.4
A	0.32	72.6	24.1	47.3	78.9	1.74	11.3	20.6
A1	0.42	71.7	25.9	43.2	77.8	2.17	11.6	19.6
B	0.30	73.2	22.7	44.1	78.1	1.64	10.8	21.6
B1	0.40	70.5	25.1	42.3	76.9	1.81	11.5	21.2
C	0.52	69.2	28.1	42.4	77.6	2.37	12.5	21.3
C1	0.47	70.8	28.4	44.3	79.1	2.61	12.7	19.9
D	0.42	71.5	24.7	45.9	77.4	1.71	11.3	21.2

Table 7 - Reuse of PAA bleach bath for Flax fibre

Flax fibre	K/s	WI	YI	BI	L	a	b	B.S.
Scoured	3.09	49.0	42.2	18.6	61.7	3.7	22.3	13.2
Original	0.78	72.0	38.0	43.8	82.2	-0.38	20.7	12.7
A	1.06	67.9	34.6	40.0	78.1	-2.32	19.0	12.2
A1	1.38	62.9	39.3	33.2	74.1	-1.15	20.1	11.8
B	0.81	70.1	34.8	41.1	79.0	-1.54	19.2	12.3
B1	1.01	67.2	39.9	37.7	78.1	0.11	20.6	11.1
C	0.83	70.2	36.0	42.2	79.3	-1.51	19.9	12.7
C1	1.23	64.9	39.5	35.1	76.0	-1.33	20.8	12.3
D	0.81	71.0	33.2	44.2	80.7	-1.33	18.0	12.1
D1	0.96	67.6	34.8	39.2	77.8	-1.54	18.54	11.3

The above tables show that reuse of the bleach bath can be done with compensation of auxiliaries and bleaching agent or without any compensation. Studies of indicate that in case of all the fibres compensation of liquor and chemicals does not produce any major improvement of optical properties but some deterioration in bundle strength for flax and ramie fibres. In some cases, addition of bleaching agent marginally improves whiteness value increasing process cost hence not recommended. So, same bleach bath can be used for 3 times. Moreover, compensation of chemicals increases cost of bleaching also. Hence considering cost of bleaching, improvement of optical properties and retention of tensile strength, 2nd batch i.e., 1st reuse can be done without any compensation, but adjustment of liquor ration and pH correction is needed during 2nd reuse for achieving satisfactory results.

4. Conclusion

Peracetic acid bleaching of jute, banana, flax, and ramie produces satisfactory whiteness index with retention of high tensile strength at optimized bleaching condition. The peracetic acid (PAA) bleach bath can be reused for two times with sufficient whiteness to be used subsequently for medium to deep shade coloration. For the 1st reuse no compensation of bleaching auxiliaries, bleaching agent (PAA) or water is needed. However, in the case of 2nd reuse bath little compensation of only water and bleaching auxiliaries are needed to maintain the liquor ratio and pH of the bath. All the fibre samples, bleached in the reused bath showed maximum retention of bundle strength. After the 2nd reuse, the achievable whiteness in the banana, flax, jute and ramie fibre are 69.3, 67.2, 65.6 and 70.5, respectively.

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References

[1] Samanta, K. K., Roy, A. N., Baite, H., Debnath, S., Ammayappan, L., Nayak, L. K., Singha A., & Kundu, T. K. (2023). Properties of Himalayan Nettle Fibre and Development of Nettle/Viscose Blended Apparel Textiles. J. Nat. Fibers. 20, 2183924. https://doi.org/10.1080/15440478.2023.2183924

[2] Basak, S., Shakyawar, D. B., Samanta, K. K., Debnath, S., Bhowmick, M., & Kumar, N. (2022). Development of natural fibre based flexible composite: A sustainable mimic of natural leather. Mater. Today Commun. 32, 103976-103985. https://doi.org/10.1016/j.mtcomm.2022.103976

[3] Roy, A. N., Samanta, K. K., Patra, K. (2019). Physico-chemical properties of black yak fibre and its modification for blending with jute fibre. J. Nat. Fibers. 16(2), 225-236. https://doi.org/10.1080/15440478.2017.1414652

[4] Sheshama, M., Khatri, H., Suthar, M., Basak, S., & Ali, S. W. (2017). Bulk vs. Nano ZnO: Influence of fire retardant behavior on sisal fibre yarn. Carbohydr. Polym. 175, 257-264. DOI:10.1016/j.carbpol.2017.07.032

[5] Samanta, K. K., Basak, S., Chattopadhyay, S. K. (2016). Potential of Ligno-cellulosic and Protein Fibres in Sustainable Fashion. In: Sustainable Fibres for Fashion Industry (Ed. Muthu, S.S., Gardetti, M.A.), Springer Publication, vol. 2, pp.61-109

[6] Varma, D. S. (1986). High performance organic fibres for industrial applications. Man-Made Textiles in India. 29, 380–86

[7] Chattopadhyay, S.N., Pan, N.C., Roy, A.N., & Samanta, K.K. (2020). Pretreatment of jute and banana fibre – its effect of blended yarn and fabric. J. Nat. Fibers. 7(1), 75-83. https://doi.org/10.1080/15440478.2018.1469450

[8] Shahid, M., Mohammad, F., Chen, G., Tang, R-C., & Xing, T. (2016). Enzymatic processing of natural fibres: white biotechnology for sustainable development, Green Chem. 18, 2256-2281. DOI https://doi.org/10.1039/C6GC00201C

[9] Ghosh, S., Singh, S., & Maity, S. (2021). Thermal Insulation Behavior of Chemically Treated Jute Fiber Quilt. J. Nat. Fibers. 18, 568-580. https://doi.org/10.1080/15440478.2019.1636744

[10] Chattopadhyay, S.N, Pan, N.C., & Day, A. (2003). Pseudo single bath process for ambient temperature bleaching and reactive dyeing of jute. Indian Journal of Fibre & Textile Research, 28, 450-455

[11] Basu, G., & Chattopadhyay, S.N. (1996). Ambient temperature bleaching of jute - its effect on mechanical properties and dyeing behaviour. Indian Journal of Fibre & Textile Research, 21, 217-223

[12] Chattopadhyay, S.N., Pan, N.C., & Day, A. (2004). A wet processing of jute at ambient temperature. AATCC Review, 4: 27-27

[13] Chattopadhyay, S.N., Pan, N.C., & Day, A. (2006). Reuse of reactive dyes for dyeing of jute fabric. Bioresource Technology, 97, 77-83. https://doi.org/10.1016/j.biortech.2005.02.033

[14] Pan, N.C., Chattopadhyay, S.N., & Day, A. (2004). Pseudo single bath process for alkali treatment and bleaching of jute at ambient temperature. Indian Journal of Fibre & Textile Research, 29, 79-84

[15] Chattopadhyay, S.N., Pan, N.C., & Day, A. (2001). Bleaching of jute at ambient temperature and its reuse. Textile Trends, XLIII (12), 23-25

[16] Chattopadhyay, S. N., Pan, N.C., Roy, A.N., & Samanta, K.K. (2022). Low Temperature Bleaching of Jute using Peracetic Acid: A Novel Process. AATCC Journal of Research, 9, 98-105. https://doi.org/10.1177/247234442210814

[17] Chattopadhyay, S. N.; Pan, N. C.; Khan, A.; Bhowmick, A.; Chakraborty, S. Bleaching of jute with Per Acetic Acid, The Indian Journal of Natural Fibre, 2018, 4 (2), 73-79.

[18] Duan, L.; Yu, W.; Li, Z. Analysis of Structural Changes in Jute Fibers after Peracetic Acid Treatment, Journal of Engineered Fibers and Fabrics, 2017, 12 (1), 33-42.

[19] Cai, Y.; David, S. K. Low Temperature Bleaching of Jute Fabric Using a Peracetic Acid System, Textile Research Journal, 1997, 67 (6), 459-564.

[20] Data Book on Fibres Allied to Jute. 2012. Published by Director-National Institute of Research on Jute and Allied Fibre Technology: 1-70

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Development of Needle Punched Non-Woven Mulch Mat for Weed Suppression

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Abstract:

The primary factor in the rise of sedentary human civilization is agriculture, which is the science and art of cultivating plants and livestock. Herbicides are chemicals applied to control unwanted plant species. Herbicides that target particular weed species are able to suppress them with minimal damage to the intended crop. Because natural fibers are good for reinforcing components and have convenient renewability, biodegradability, and environmental friendliness, there is increased interest in using natural fibers like Sisal, Banana, and Coir. The primary goal of the research study was to develop composites made of natural and unconventional fibers for use in agriculture. The mulch mats are composed of cotton mixed with sisal and areca nut fiber. The tomato plants were planted in pots and covered their stem with developed mulch mats and have observed for 60 days. These mulch mats are biodegradable and eco-friendly to the environment. The difference between the controlled sample and the using sample using developed mulch mat were analyzed and calculated. This technique was very helpful for the cultivation of plant growth and to avoid weed control.

Keywords: *Biodegradable, eco-friendly, Mulch mats, natural fibers, non-woven*

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1. Introduction

Technical textiles are produced with function as the primary consideration rather than aesthetics, and they have been recognized as one of the most exciting and promising segments of the textiles industry for the future. Technical textile materials and goods are produced more for their functional and performance qualities than for their aesthetic or decorative characteristics [1]. In agriculture, textiles are used to shield crops from harsh weather. Agro textiles include knitted, nonwoven, and woven materials. The world's largest industry is agriculture. In the field of science, textiles are utilized for agricultural and animal cultivation, harvesting, storage, and protection because of modernization and significant technical breakthroughs. Textile materials are essential for gathering, storing, and safeguarding agricultural products. Agro-textiles promote a healthy farming culture by reducing the need for water, fertilizers, pesticides, and herbicides. In general, textiles used in agriculture are environmentally beneficial [2].

2. Methodology

Through test methodologies, this article examines the materials, methodology, and procedures used for the development of the agro textile product known as "the mulch sheet."

2. 1. Materials and Methods

2.1.1 Selection of Fibers

The first step in carrying out the project is to select the required natural fiber – Areca, Sisal and reclaimed Cotton. The fiber is selected as per literature and it is found out that Areca and Coir fiber are the most suitable fiber that can be used in the project to support plant growth effectively. Reclaimed Cotton fiber is chosen for needle punched mat [3, 4].

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(a) (b) ©

Figure 1: a) Reclaimed Cotton b) Areca c) Sisal

2.2 Fabric Formation

2.2.1 Blending Ratio of Natural Fiber

The fibers are weighed accurately and blended in right proportion. The selected natural fibers have been blended in different combinations as follows:

Table 1: Blending ratio of natural fibers

Fibre	Blending Ratio (As per fiber quantity)	
Areca : cotton	50:50	75:25
Sisal: Cotton	50:50	75:25

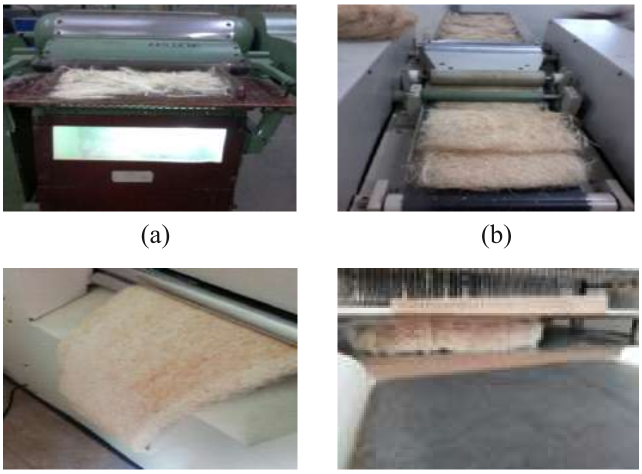
2.2.2 Nomenclature of Sample

Table 2: Nomenclature of samples

Sr. No.	Sample code	Description
1	AC1	Areca + Cotton (50:50)
2	AC2	Areca + Cotton (75:25)
3	SC1	Sisal + Cotton (50:50)
4	SC2	Sisal + Cotton (75:25)
5	C	Coir (Commercial Mat)
6	CP	Control Plant

2.2.3 Needle Punching Technique

Lap is formed in a pilot run machine. The fibers are placed on the carding machine for cleaning and then passed over the needle punching machine to convert the fibers into lap formation. The major reasons needle punching techniques have been used are because of their excellent tearing strength and high, consistent tensile strength. Compared to other ponding techniques, needle punching technology is a low-energy, environmentally beneficial approach. The fibers are mixed and fed into the card feeder after being opened into tiny tufts in the fiber opening channel. After further opening the material from the fiber opener, a web is generated and fed into the carding machine. A thin sheet of carded web is made after the matt generated by the card feeder is opened and carded. After being shaped into a lap, the thin web sheet generated through roller carding is fed to a needle punching machine. Needle punching technology is used to produce the non-woven material and punch the lap [5, 6].



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

Figure 2: a) Arrangement of fibers into carding machine b) loading of fibers into carding machine c) Outcome of lap from carding machine (d) Needled punching method

I. Fabrication

Mulch mat is a special kind of textile product used in agricultural fields to meet various needs. The performance of this mulch sheet is determined by taking into account the following characteristics. Measured intrinsic attributes include thickness, GSM, and width. MAG thickness gauge was used to measure the fabric's thickness in accordance with ASTM D1777 standard.

ii. Analysis

Environmental conditions

The study was carried out in the Tamilnadu district of Coimbatore, in an agro-ecological area. The average of the weather conditions during the three months prior to the present is noted.

iii. Measurements

Measurements of the soil moisture content were carried out three, six, and nine weeks after planting, as well as during the harvesting stage, at depths of 15 and 30 cm.

iii. Growth factors of plants

The length, width, number of leaves per plant, stem length, and girth of D-leaf (strong, longest, and healthy plants) were specifically recorded. [7]

v. Testing's

For the experimental recordings, tomato plants are used because of their fast growing characteristics. Two same sized pots with identical soil types are taken. The plants' subsequent growth and quality metrics were visually monitored. Weed control, plant growth, water obtainability, and other factors were observed and measured for both mulched and unmulched potted plants. As subjective tests, these are also noted during field research. The decomposition properties of mulch mat are investigated under three different types. Three samples were buried in different types of soil, watched over every four months, and then compared. Consequently, the soil burial test yielded findings [8]

3. Results and discussion

The fibers of Areca and Sisal were straight, silky, and yellow in color. These fibers were chosen because they are strong, resilient, stretchable, and don't break down in salt water. The growth, weed control, and water retention characteristics of the non-mulched, Coir, Areca, and Sisal mulched plantations were observed; the field test yielded good results for the Sisal mulched plantation.

3.1 Visual Analysis

3.1.1 Comparative study of soil temperature and weed control measures.

Figure 3: Measure of weed control

Figure 3 shows mulch in pot leaving only the seeded area barley for photosynthesis of plant seedlings.

3.2 FTIR analysis of fibers

The primary components of Areca, including cellulose, hemicelluloses, and lignin, correspond to specific bands in the FTIR wavelength peaks collected between 4000 cm-1 and 500 cm-1. The peak values between 3334.92 and 2941.44 cm-1 were attributed to the stretching of hydrogen bonds, or OH, on the surface of cellulose. The presence of cellulose and shemicelluloses is shown by the next peak value of 2129.41 cm-1, which displays the CH stretching of the alkyl group. The acetyl and uronic groups' ester of the hemicelluloses or the ester linkage of carboxylic groups of the ferulic and p-coumeric acids of the lignin or hemicelluloses are linked to the prominent peak of the Areca at 1734.01 cm-1. The cellulose chain's -C - O - C bond is the cause of the band at 1462.04 cm-1.

Sisal's FTIR spectra was recorded between 4000 and 500 cm-1. It is noted that the intensities of the peak corresponding to the -OH stretching vibrations in the 3352.28 cm-1 area are higher due to the esterification of the hydroxyl groups through benzoylation. The -CH stretching vibration peak at 2941.44 cm-1 indicates the existence of cellulose and hemicelluloses [5]. The presence of lignin and the C = O stretching of the carboxyl group are indicated by the peak value of 1735.93 cm-1. The hydroxyl group of cellulose exhibits typical axial vibration, which gives rise to a peak at 1620.21 cm-1. The related hydrogen group is responsible for the peak at around 1058.92 cm-1. The wave numbers are 777.31cm-1, as shown by the presence of aromatic rings. [9, 10]

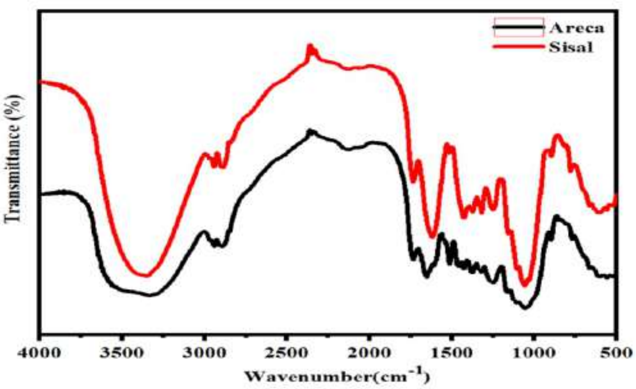


Figure 4: FTIR of Areca and Sisal fiber.

3.3 XRD analysis of fiber

Powder XRD for equatorial reflections, performed at a scanning rate of one degree per minute, produced two notable peaks in the diffractogram at 20.0 and 18.0 (figure 5), indicating the semi-crystalline character of the Areca and Sisal fiber. The peak values are represented by the relative intensities I20 = 1272, I20 = 1032, and I18 = 760, I18 = 900, the crystalline index and percentage crystallinity have been determined as follows:

$$C.I. = (I_{20} - I_{18}) / I_{20}$$

The crystalline and amorphous intensities at 2ø scale at 20o and 18o, respectively, are denoted by I20 and I18. Therefore, the crystalline index for the Areca and Sisal inflorescence fiber is 0.40, 0.12.

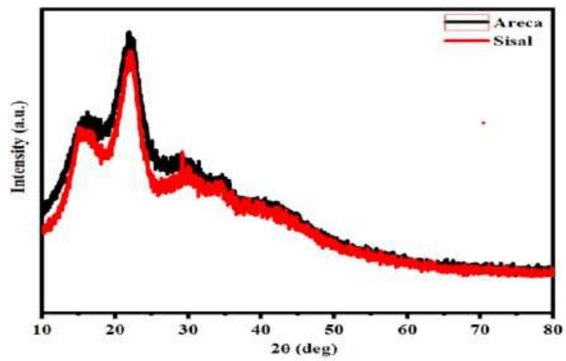


Figure 5: XRD pattern of Areca and Sisal fiber.

3.4 Fabric weight (GSM)

Table 3: Fabric weight (GSM)

Sr. No.	Fabric	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)
1.	Non-woven	677	790	1303	1869
2.		696	753	1200	1900
3.		654	802	1189	1760
4.		690	781	1400	1800
5.		632	788	1580	1560
Mean value		**669.8 gms**	**782.8 gms**	**1334 gms**	**1778 gms**

From Table 3, it is observed that Fabric Weight of the sample AC1, AC2, SC1, and SC2 samples showed variations. The Fabric Weight was statistically analyzed using T-Test and observed that AC1 with the value 669.8gms, AC2 with the value 782.8gms,SC1 with the value 1334gms and SC2 with the value 1778gms.SC2 value was found to be higher than the other samples. [11]

3.5 Thickness of the Non-woven

Table 4: Thickness of the non-woven

Sr. No.	Fabric	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)
1.	Non-woven	6.29	3.44	6.62	4.02
2.		5.92	5.24	6.09	4.39
3.		6.19	5.55	7.19	4.69
4.		6.85	5.82	6.44	5.29
5.		5.25	6.21	6.10	5.79
Mean value		**669.8 gms**	**6.1mm**	**5.25 mm**	**6.49 mm**

From Table 4, it is observed that Thickness of the sample AC1, AC2, SC1, and SC2 samples showed variations. The Fabric thickness was statistically analyzed using T-Test and observed that AC1 with the value 6.1mm, AC2 with the value 5.25mm, SC1 with the value 6.49mm and SC2 with the value 4.48mm.SC1 value was found to be higher than the AC1. [12]

3.6 Air Permeability of Non-Woven

Table 5: Air Permeability of the non-woven

Sr. No.	Fabric	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)
1.	Non-woven	17.75	19.72	27.6	51.28
2.		15.77	17.75	27.6	49.30
3.		19.75	19.72	25.64	47.33
4.		13.70	17.75	23.66	45.36
5.		19.72	15.77	21.69	47.33
Mean value ($cm^3/s/cm^2$)		**17.33**	**18.14**	**25.24**	**28.12**

From Table 5, it is observed that Air permeability of the sample AC1, AC2, SC1, and SC2 samples showed variations. The air permeability of fabric was statistically analyzed using T-Test and observed that AC1 with the value17.33 $cm^3/s/cm^2$, AC2 with the value 18.14 $cm^3/s/cm^2$,SC1 with the value 25.24 $cm^3/s/cm^2$ and SC2 with the value 28.12 $cm^3/s/cm^2$.SC2 value was found to be higher than other fibers and the least is AC1.

3.7 Porosity of Non-woven

Table 6: Porosity of Non-woven

Sr. No.	Fabric	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)
1.	Non-woven	0.94	0.97	0.97	**0.97**
2.		0.96	0.99	0.99	**0.97**
3.		0.97	0.97	0.98	**0.99**
4.		0.94	0.98	0.97	**0.96**
5.		0.96	0.97	0.98	**0.98**
Mean value (gm/cm^3)		**0.95**	**0.97**	**0.97**	**0.97**

Table 6 and figure 6, it is observed that Porosity of the sample AC1, AC2, SC1, and SC2 samples showed variations. The Porosity of fabric was statistically analyzed using T-Test and observed that AC1 with the value 0.95 g/cm^3, AC2 with the value 0.97 g/cm^3, SC1 with the value 0.97 g/cm^3 and SC2 with the value 0.97 g/cm^3.AC2, SC1, and SC2 values were found to be equal and AC1 shows slight variation.

3.8 Soil burial test

Field method

Table 7: Soil burial test of non-woven in field

Sr. No.	No. of Days	Weight of the sample before testing (gms)				Weight of the sample after testing (gms)			
		50:50		75:25		50:50		75:25	
		AC1	SC1	AC2	SC2	AC1	SC1	AC2	SC2
1.	70	0.630	0.860	0.680	0.650	0.610	0.850	0.660	0.630

From the above Table 7, in that field method showed weight changes in a sample when compared with laboratory method. It is observed that there were weight changes with AC1 showed a value of 0.630gm before testing and 0.610gm after testing whereas AC2 showed a value of 0.680gm before testing and 0.660gm after testing. Whereas SC1 showed the value of 0.860gm before testing and 0.850gm after testing.Like that SC2 showed the value of 0.650gm of before testing and 0.630gm of after testing. [13]

Figure 6 Images of Soil burial Test

3.9. Weeds growth tabulation

Table 8: Weeds growth

Sr. No.	Weeks	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)	C	CP
1.	1	0	0	0	0	0	0
2.	2	0	0	0	0	0	6
3.	3	0	0	0	0	1	14
4.	4	0	0	0	0	4	17
5.	5	1	1	1	1	5	23

From the Table 9shows a weed suppression. It is observed that there was no growth of weeds for four continuous weeks for all the developed non-woven mulch mat covered pots, whereas there was weed growth of 6 nos in 2ndweek,14 nos in 3rdweek,17 nos in 4thweek and 23 nos in 5thweek. And finally, in the last week, it is observed that there were 1 no of weed growth in AC1 &AC2 and SC1 & SC2, whereas in control plant the growth was 23.This proved that there was great weed suppression. [14]

3.10 Wicking test

Table 9: Wicking test

Sr. No.	Fabric	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)
1.	Non-woven	1.6 mm	1mm	3.8mm	5.4mm

From the above Table 9, the findings of the wicking of the needle punched fabrics are shown. SC2 has a superior wicking of 5.4 mm which was followed by sample SC1 of3.8 mm wicking. AC1 &AC2 has lower wicking of 1.6 & 1 when compared to all the samples SC1 showed good wicking.

3.11 Sinking test

Figure 10: Sinking test

Sr. No.	Fabric	AC1 (50:50)	AC2 (75:25)	SC1 (50:50)	SC2 (75:25)
1.	Non-woven	50 min	45 min	20 min	14 min

From the above Table 10, represents the results of the sinking test of needle-punched samples. Sample AC1 takes the maximum time of 50 mins to sink were as AC2 of 45 mins and SC1 of 20 mins and SC2 of 14 mins respectively. Thus the sample SC2 showed good results.

4. Conclusion

This study has shown the prevention of weed control and helps to grow a tomato plant easily in potted plants. The mulch mat made from Areca, Sisal, and Cotton was developed using a needle punching machine with two different ratios. Two fibers are evaluated in FTIR and XRD analysis. Mats are evaluated in various testing like GSM, non- woven thickness, air permeability, soil burial test, porosity of non-woven, density of non-woven. The application process of mulch mat be simple and effective. This property on agriculture increases plant growth. Areca and Sisal fiber are abundantly available in India as well other countries. Atlast, the developed non-woven needle-punched is eco-friendly & bio-degradable. From the research work it is found that Sisal fiber SC2 is found to be the best fiber weed suppression. [15]

References

[1] Grace Annapoorani, S.: Agro Textiles and its application, ISBN- 9789385059360, Wood Head Publishing India Pvt Ltd, (2018)

[2] Bhavani,K.,;Ningdalli Mallikarujun,; Sunilkumar, N.M.: Agro textiles – Their applications in agriculture and scope for utilizing natural fibers in agrotech sector, International Journal of Applied Home Science, Vol.4 (2017) No (7 & 8), pp. 653-662, ISSN – 2394 1413

[3] Subrahmaniyan Kasirajan et al. Polyethylene and biodegradable mulches for agricultural applications: a review. Agronomy for Sustainable Development, 2012, 32, p.501-529

[4] Mohankumar, G.C.2008. A study of short areca fibre reinforced Phenol formaldehyde composites. Proceedings of the World Congress on Engineering, 2: 978-988

[5] Rajan A, Kurup JG, Abraham TE. Biosoftening of arecanut fiber for value added products. Biochemical Engineering Journal, 2005, 25(3):237-42

[6] Srinivasa CV, Arifulla A, Goutham N, Santhosh T, Jaeethendra HJ, Ravikumar RB, Anil SG, Kumar DS, Ashish J. Static bending and impact behaviour of areca fibers composites. Materials & Design, 2011, 32(4):2469-75

[7] Areca, Publication of Central Plantation Crops Research Institute, Kasargod, India, 2007

[8] Journal of Scientific and Industrial Research, Volume 36,p 2Paulo. R.L.Lima,;Rogerio.J.Santos,; Saulo.R.Ferreiro.; Romildo.D. Toledo Filho,: Characterization and treatment of sisal fiber residues for cement-based composite application. Engineering Agriculture, Vol .34 (2014), No (5), pp. 234-238

[9] Sreekumar .P.A,; RedouanSaiab,; Jean Marc Saites,; Nathalie Leblanc,; Kuruvilla Joseph,; Unnikrishnan.G,; Sabu Thomas,: Thermal behavior of chemically treated and untreated sisal fiber-reinforced composites fabricated by resin transfer molding. Composite Interfaces, Vol. 15 (2008), No (6), pp. 629 – 633

[10] Kasirajan and Mathieu, "Polyethylene and Biodegradable mulches for agricultural application: A Review", Agronomy for Sustainable Development, April 2012

[11] "Mulches and Mulching for erosion control", Technical notes U.S department of agriculture natural resources conservation service plant materials-8, Spokane, Washington, February 2005

[12] "Mulch mats a novel way for trees to outgrow weeds", Science Spin, Issued 27

[13] International Journal of Research in Engineering, Science and Management, Volume-2, Issue-4, April 2019, B.Jeyanthy, S.Geetharani, J.R.Krishnaindhu, "Development of Needle Punched Mulch Mat using Natural Fibers"

[14] Kasirajan and Mathieu, "Polyethylene and biodegradable mulches for agricultural application: A Review", Agronomy for Sustainable Development, April 2012

[15] "Mulch mats a novel way for trees to outgrow weeds", Science Spin, Issue 27

Washing Effect on Fabrics Made of Cotton and its Blends with Modal and Tencel

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Abstract:

Natural fibers made from cellulosic materials are in constant demand owing to their beneficial properties. The climatic conditions of nature affect the production and supply of cotton fibers, which are both constrained. Regenerated fibers have been created to meet the demand for cotton fibers. Viscose fiber, a member of the first generation of regenerated cellulosic fibers, has a lower wet modulus than cotton. In order to address the shortcomings of first-generation cellulosic fibers and improve the qualities of the regenerated cellulose fiber, some modified cellulosic regenerated fibers, such as Modal and Tencel fibers, have been produced. The numerous washings could alter the physical structure of yarn and fabrics hence affecting the physical properties of the fabrics. In the present study, three types of fibrous materials: cotton, a blend of modal-cotton and tencel-cotton have been used to produce single jersey knitted fabrics and the effect of repeated washings on the physical properties (stitch density, fabric weight, fabric thickness, shrinkage and pilling) of knitted single jersey fabrics has been investigated. It has found that all three physical factors (stitch density, fabric weight and thickness), fabric shrinkage increase while pilling decreases drastically in the first two washing cycles thereafter little change has been observed in further washing cycles. Pilling has good correlation with all three physical factors but shrinkage shows good correlation with stitch density only.

Keywords: *Dimensional stability, Pilling Modal, repeated washings, Shrinkage, Tencel*

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1. Introduction

In the present competitive textile market, to survive and also establish themselves as market leaders, textile manufacturers are searching for new products with improved properties to enhance the value and versatility of the product [1]. Cotton fibres provide good quality to the fabric but have low production [2]. Because to limited availability of cotton fibres, some regenerated cellulosic fibres have been developed, but these first-generation regenerated fibres have low wet-modulus. To overcome the drawback of the first-generation cellulosic regenerated fibres, some modified fibres have been developed in which the Modal® and Tencel® LF are two important cellulosic regenerated fibres manufactured by Lenzing Company, Austria [3, 4]. These are new developments of viscose rayon and are considered high wet modulus fibres.

The scope of knitted fabrics is increasing rapidly, especially in sportswear and leisurewear [5, 6]. This is due to some positive qualities such as softness, flexibility and moisture absorption, etc. The new generation is very fond of knitted fabrics. The properties of a fabric mostly depend upon constituent raw material (chemical nature and fibre morphology), yarn structure, and fabric structure. The structure of fabric is governed by physical factors such as stitch density, fabric weight and thickness [7, 8]. Mostly, cotton yarn is used to produce knitted fabrics, but a blend of cotton with Modal and Tencel can also be used to develop some special properties.

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Both shrinkage and pilling behavior affect the serviceability of garments [9]. Shrinkage affects the dimensional stability of a fabric and leads to a large number of customer complaints. In comparison to other faults such as poor abrasion resistance, dimensional change can appear early in the life of a garment, so making a complaint more likely. Fabric shrinkage can cause problems in two main areas, either during garment manufacture or during subsequent laundering by the end user. Pilling is a surface defect of textiles that arises in wear due to the formation of small 'pills' of entangled fibre giving it an ugly appearance. Pills are formed by rubbing action on loose fibres which are present on the fabric surface.

Dimensional stability of a fabric is an important issue for both consumers as well as fabric manufactures because unacceptable dimensional change is often the main reason for product rejection by the consumer [1, 10, 11]. Garment requires several washings in its lifetime. During washing, the garment is subjected to complex mechanical, thermal and chemical actions that may alter the fabric structure such as shrinkage (hence stitch density), fabric thickness and fabric weight (GSM), which ultimately change the fabric properties and performance [11, 12]. The knitted fabric may easily alter its structure after repeated washings. The changes in structure of fabric may depend upon the type of fibrous material and number of washings.

In a previous study on cotton fabric [10], the effect of repeated washings (in four steps: 4-wash, 8-wash, 12-wash and 16-wash) on cotton woven fabric properties: fabric physical factors and dimensional stability was analyzed. It was found that after repeated washing, the fabric cover factor, fabric thickness, fabric weight and fabric shrinkage increased and this increased abruptly in the first step (of four washes) and thereafter slightly changed. In another study [3], the effect of wet processing on the comfort and mechanical properties of woven fabrics made using yarns of cotton fibres and their blend with modal and tencel fibres in weft was studied. In an extended study [7], models have also been developed to predict the comfort and mechanical properties through three structural parameters (cover factor, fabric weight and fabric thickness) of woven fabrics. There is lack of study, which give clear view about the impact of repeated washings on dimensional stability and pilling behavior of knitted fabric made from 100 % cotton, cotton-modal blend and cotton Tencel blend fibres.

The aim of the present study is to analyze the effect of repeated washings on the physical properties of single jersey knitted fabrics made using 100% cotton fibre yarn, 50:50% cotton-modal blend and 50:50% cotton-tencel blend yarns. The study is focused on the investigation of the fabrics for their physical factors (stitch density, GSM and thickness), dimensional stability and pilling behavior as these are important properties for any garment.

2. Material and Method

2.1 Material

Three types of plain knit single jersey fabrics were prepared by using ring spun yarns of 100% cotton fibres, 50:50% cotton-modal, and 50:50% cotton-tencel blended yarns. The above fabric samples were washed in four steps: 0-wash, 2-wash, 4-wash and 6-wash. Thus, total 12 samples were made. The details of the raw materials used for making the samples are given in Table1. The processes involved for making the samples is depicted in Figure 1.

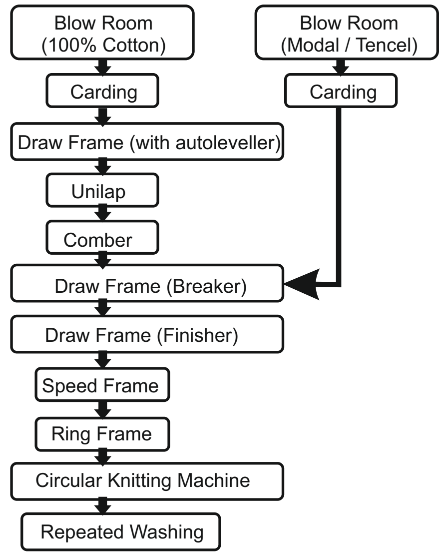

Figure 1: Flow chart of processes for making samples

Two varieties of cotton, J-34 and S-6, were mixed in a 50:50 ratio at mixing stage to produce 100% combed cotton yarn. The mixed cotton is processed through blow room, carding, draw frame (auto-leveler), Unilap comber, draw frame (breaker), draw frame (finisher), speed frame, ring frame and autoconer (Figure 1). Modal® and Tencel® fibres were blended each with cotton fibres in 50:50 ratio at drawing stage after combing to make the modal-cotton and tencel-cotton blended yarns respectively. For the production of blended yarns; the modal and tencel fibres were processed each through the blowroom and carding, blended with a combed cotton sliver (which was made for 100% cotton yarn) at the drawing stage giving two processes (breaker and finisher heads), speed frame, ring frame and autoconer [3]. The nominal yarn count and TPI of the yarn were kept 30s (Ne) and 20 respectively. Three types of plain weft knitted single jersey fabrics were made using each 100% cotton

Table 1: Detail of raw materials

S. No.	Information	Cotton	Modal	Tencel
1	Type of fibre	Natural	Natural	Manmade
2	Generic name	Cotton- combed	Cotton- combed	Lyocell-Tencel® LF
3	Material type	J-34 (Punjab), S-6 (Gujrat)	J-34 (Punjab), S-6 (Gujrat)	Lenzing AG
4	Nature of fibre	Cellulosic fibre	Cellulosic fibre	Regenerated cellulosic fibre
5	Avg. length and fineness	28.5 mm, 4.4 mic	28.5 mm, 4.4 mic	38 mm, 1.2 den
6	Moisture regain (%)	8.5	8.5	11
7	Dry Tenacity cN/tex (gpd)	29 (3.2)	29 (3.2)	38 (4.3)
8	Wet Tenacity cN/tex (gpd)	32 (3.6)	32 (3.6)	29 (3.2)
9	Elongation %(Dry/Wet)	6.8/8.1	6.8/8.1	14/16

yarn, 50-50% cotton-modal yarn and 50-50% cotton-tencel yarn on a 20-gauge circular knitting machine having a 24-inch machine diameter. The courses and wales per centimeter are kept 30 each.

To study the impact of repeated washings, each fabric sample underwent repeated washings in four stages, i.e. 0-wash, 2-wash, 4-wash and 6-wash. The concept of taking steps of two laundering cycles is because a single laundering cycle may not give significant results for comparison. The samples were laundered at 38°C in a semi-automatic washing machine using 0.8 g/l solution of non-ionic detergent-Ellen-N-100 (96% concentration). One laundering cycle was completed in 38 minutes. The samples were dried in open space in daylight. Finally, a total of 12 fabric samples were prepared for the study.

2.2 Methods

The physical factors: stitch density, GSM and thickness, dimensional stability and pilling behavior of the fabric samples were analyzed. Prior to the test, the samples were conditioned at 65±2 percent relative humidity and 27±20C temperature as per IS: 6359:1971(re-affirmed 2004) [13].

The courses per inch (CPI) and wales per inch (WPI) were determined as per ASTM D8007-15(2019) [14] and the stich density is the product of these two parameters. Fabric weight in grams per square meter (GSM) was measured as per ASTM D3776 [15] Fabric thickness is defined as perpendicular distance between the upper and lower sides of the fabric. It was measured with the help of precision fabric thickness tester as per ASTMD1777-96 (2019) [16].

Dimensional stability of a fabric is a measure of the extent to which it keeps its original dimensions subsequent to its manufacture. It was determined in terms of areal shrinkage as per BS:4931-1986[17]. 30 cm x 30 cm fabric samples were taken for the test. The samples were marked with three sets of lines in each direction, a minimum of 250 mm apart and at least 25 mm from all edges. Areal shrinkage was calculated by using the following formula:

$$Areal\ shrinkage\ \% = \frac{Area\ of\ 0\ wash\ fabric - Area\ of\ n\ wash\ fabric}{Area\ of\ 0\ wash\ fabric} \times 100$$

Fabric pilling behavior of the samples was determined with the help of a standard Fabric Pilling Tester as per BIS standard (IS: 10971) [18]. A specimen of 125 mm x 125 mm was cut from fabric (3 each, of course-wise and wale- wise). Stitched face-to-face and turned inside out. The fabric tube was then mounted on rubber tubes. The loose ends were taped with PVC tape. All the four samples were then tumbled together in a cork-lined box 9" x 9" x 9" and rotated at 60 rev/min for five hours. The specimens were taken out and removed from a rubber tube and rated for pilling. Grading was done between 1 and 5. Higher grade exhibits higher pilling resistant fabric i. e. lesser pilling.

3. Result & Discussion

The test results for various fabric samples of 4-steps of washings (0-wash, 2-wash, 4 wash and 6 wash) in physical factors (GSM, stich density and thickness), Service properties (areal shrinkage, and pilling), are tabulated in Table 2 impact of repeated washings are shown in Figure. 3-8. The results are statistically analyzed uptp 95 % significance limit.

i. Fabric physical factors

Fabric physical factors such as stitch density, GSM and fabric thickness also affect the various fabric properties. The test results are tabulated in table 3 and fabric physical factors are determined as under:

a. Stitch density

Stitch density is a product of two parameters: courses/inch and wales/inch and expressed in stitch density per square inch. Fig.-2 shows that the stitch density increases sharply in the first step of two washes; this is because in first stage of washings, the shrinkage is more and thereafter, very less shrinkage takes place. After the first step of two washes, a slight increase in stitch density can be seen upto 6-wash in all samples. In all steps of washing, the stitch density of cotton sample is the highest, followed by cotton-modal blend and cotton-tencel blend fabric samples.

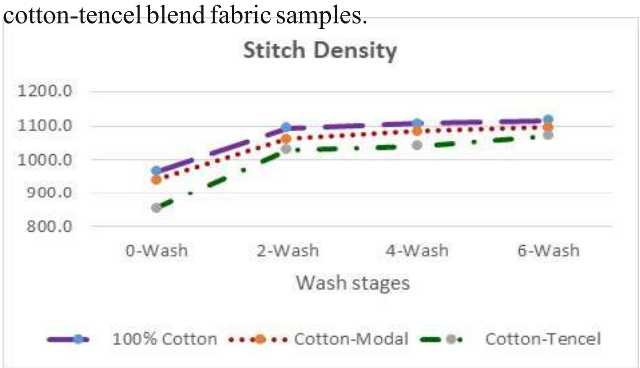

Figure 2: Effect of repeated washings on stitch density

Table 2: Physical factors and fabric properties

Blend	100% Cotton				Cotton-Modal				Cotton-Tencel			
No of washings	0-Wash	2-Wash	4-Wash	6-Wash	0-Wash	2-Wash	4-Wash	6-Wash	0-Wash	2-Wash	4-Wash	6-Wash
Stitch density/inch^2	965.3	1094.0	1105.8	1116.0	940.8	1061.6	1083.6	1095.2	855.6	1029.9	1041.2	1071.6
GSM	104.3	120.0	121.0	121.7	92.3	109.0	110.0	110.7	087.6	96.3	101.6	102.3
Thickness (mm)	0.51	0.55	0.55	0.55	0.42	0.48	0.48	0.48	0.42	0.47	0.48	0.48
Areal Shrinkage (%)	0.00	11.39	12.66	12.66	0.00	15.39	17.07	17.07	0.00	16.46	17.35	17.35
Pilling (Grade)	3.5	2.5	2.5	2.5	3.5	3.0	3.0	3.0	3.5	3.0	3.0	3.0

b. Fabric weight (GSM)

Measured fabric weight of all samples in terms of grams per square meter (GSM) is presented in Table 3. The effect of repeated washings in fabric samples made using 100 % cotton yarn, 50:50 Cotton-Modal blended yarn and 50:50 Cotton-Tencel blended yarn is shown in Fig. 3. The figure exhibits that the fabric weight of all three types of samples increases significantly in the first step of 2-washes and after that there is no significant change has seen in all the samples. It may be due to fabric shrinkage more at first step of two washes which affect the stitch density, hence fabric weight. In all the fabrics, GSM of cotton fabric is the highest, followed by cotton-modal blend and cotton-tencel blend fabrics.

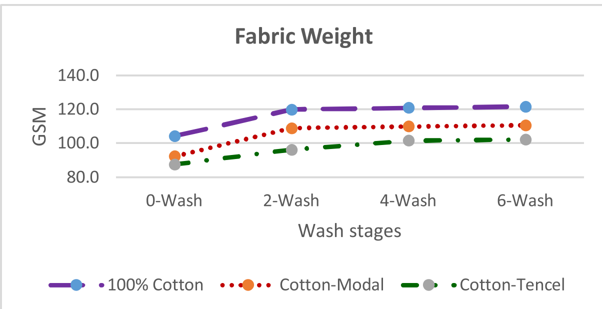

Figure 3: Effect of repeated washings on fabric weight

c. Fabric thickness.

The impact of repeated washings on each fabric sample is shown in Fig. 4. The fabric thickness of all three samples increases significantly upto first step of two washing cycles and after that there is almost no change was observed. The reason is again the same, i.e. in the first step of two washing, it shrinks more due to fabric relaxation. The fabric thickness of the 100% cotton sample is the highest among all fabric samples, while cotton-modal and cotton-tencel samples are almost the same.

Figure 4: Effect of repeated washings on thickness of fabric

ii. Dimensional stability

Dimensional stability is measured in terms of areal shrinkage; more areal shrinkage means less dimensionally stable fabric. The test results are given in Table 2 and the impact of repeated washings is shown in Fig. 5. The areal shrinkage of all the three types of samples increases sharply on the first step of two washes (due to fabric relaxation). Afterwards, the increase is very small in further washing cycles. The areal shrinkage of the cotton-tencel blend is observed highest among all the samples, followed by the cotton-modal blend and 100% cotton fabric. That means, 100% cotton fabric shows the highest dimensional stability, followed by cotton-modal blended fabric and cotton-tencel blend, during repeated washings. There was no significant difference found in the areal shrinkage of both cotton-modal and cotton-tencel blended fabric samples. The shrinkage of fabrics depends upon the nature of raw material and fabric physical factors such as stitch density, GSM and fabric thickness. The cotton-modal and cotton-tencel blended fabric's areal shrinkage is approximately similar in all washing-steps and has no significant differences. Table 3 shows that the areal shrinkage has good correlation (R=0.81) with stitch density but poor correlation with fabric weight and fabric thickness. This is because various raw materials have different physical and chemical structures which may affect shrinkage behavior of the fibrous materials.

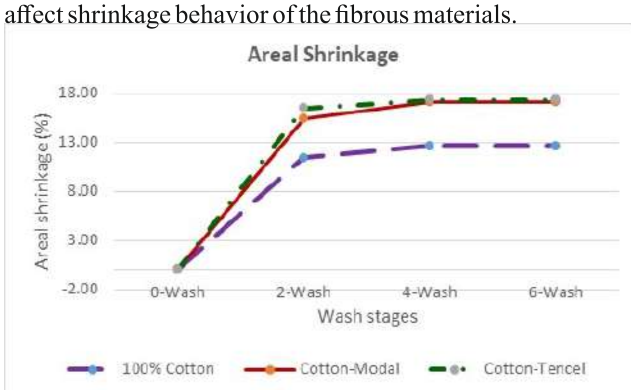

Figure 5: Effect of repeated washings on areal shrinkage of fabric

Table 3: Correlation between fabric physical factors and properties

Fabric physical factors	Correlation (R-value) with fabric properties	
	Areal shrinkage	Pilling
Stitch density	0.81	-0.86
GSM	0.44	-0.87
Thickness	0.32	-0.83

ii. Pilling resistance

The data for pilling resistance grade is presented in Table 2 and the effect of pilling is illustrated in Fig. 6. The pilling resistance grades decrease drastically up to the first step of two washes in comparison to the unwashed knitted fabric samples. After two washes, there is no change observed in the pilling resistance in further washed samples. The pilling resistance of the cotton-modal blend and cotton-tencel blended fabric is the same and is much higher than that of the 100% cotton sample. That means the cotton-modal and cotton-tencel blend fabrics have less tendency to pill than 100% cotton fabric. Pilling resistance shows good correlation (Table 3) with stitch density (R = -0.86), fabric weight (R = -0.87) and thickness (R = -0.83). These parameters have an inverse relation with pilling, i.e. if fabric stitch density or GSM or thickness increases, the pilling resistance decreases.

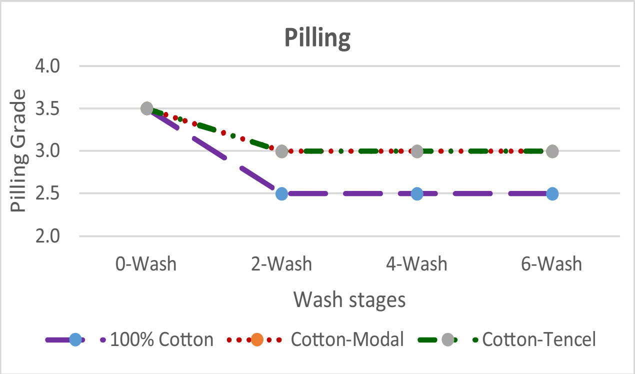

Figure 6: Effect of repeated washings on pilling resistance grades of fabric

In an overall evaluation of all three samples in respect to pilling resistance behavior and dimensional stability (Fig. 5 and Fig. 6), it was found that cotton-modal and cotton-tencel blended fabric exhibit higher pilling resistance but less dimensionally stable than cotton fabric.

4. Conclusion

Results reveals that maximum areal shrinkage took place in the first step of two washes in all three types of fabric samples. After the first step of washing, shrinkage increases slowly. Among all samples, the shrinkage of cotton-tencel blended fabric sample has highest areal shrinkage followed by cotton-modal blended and 100% cotton fabrics. The areal shrinkage in cotton-modal and cotton-tencel blended fabric samples is almost similar in all washing steps and has no significant differences. The areal shrinkage has good correlation with stitch density.

Pilling resistance decreases significantly in first step of two-washing cycles, nevertheless no further change is observed. The pilling resistance of cotton-modal blended and cotton-tencel blended fabric samples is the same and is much higher than that of a 100% cotton sample. That means the cotton-modal and cotton-tencel blended fabrics have much less tendency to pill than 100% cotton fabric. Pilling resistance has good correlation with stitch density, fabric weight and thickness. In an overall evaluation, it was found that cotton-modal and cotton-tencel blended fabric exhibit higher pilling resistance behavior but less dimensionally stable than cotton fabric.

The research findings will help to fabric manufactures, researchers and end users. Furthermore, an extensive study will require on various comfort and hand properties in future.

References

[1] Mr. A. Mukhopadhyay, Mr. S.M. Ishtiaque, Mr. D. Uttam, "Impact of Structural Variations in Hollow Yarn on Heat and Moisture Transport Properties of Fabrics", The Journal of the Textile Institute, 102/8 (700-712), (Aug' 2011)

[2] Mr. A. Basit, et al., "Comparison of mechanical and thermal comfort properties of Tencel blended with regenerated fibres and cotton Woven fabrics ", AUTEX Research Journal, 19(1), 80-85 (March' 2019)

[3] Mr. D. Uttam, Ms. G. Ahlawat, "The Effect of Wet Processing on the Comfort and Mechanical Properties of Fabrics made from Cotton Fibres and its Blends with Modal and Tencel Fibres in Weft", Recent Trends in Traditional and Technical Textiles, Ed. by Vinay Midha, A. Mukhopadhyay, Springer: 2021: pp113-125

[4] Mr. R.R. Mather, Mr. R.H. Wardman: "Regenerated Fibres", A Book of The Chemistry of Textile Fibres. Cambridge, U.K.; RSC Publications: 2011: pp.100-127

[5] Mr. D. Uttam, "Active Sportswear", International Journal of IT, Engineering and Applied Science (IJIEASR), i-Xplore International Research Journal Consortium, 2/1 (34-40), (Jan' 2013)

[6] Mr. M. Buhler, Mr. C. Iyer, "An Investigation into Opportunities for Further Developments of Functional Knitwear for the Sportswear Sector", Knitting Technique, 10/5 (303- 307), (1988)

[7] Mr. D. Uttam, Ms. G. Ahlawat, "Modelling Comfort Properties of Fabrics using Weft Yarn from Cotton and its Blend with Modal and Tencel Fibres", Man Made Textiles in India, 49/4:124-128, (2021)

[8] Mr. D. Uttam, Mr. A. Mukhopadhyay, Mr. S.M. Ishtiaque, "Modeling to Predict Thermophysiological Properties of Hollow/ Microporous Yarn Fabrics", Journal of the Textile Institute, 104/4 (407-413), (April' 2013)

[9] Mr. B.P. Saville, 'A Book of Physical Testing of Textiles', The Textile Institute, England, Wood Head Publishing Limited: 2002: pp.1-305

[10] Mr. D. Uttam, Mr. R. Sethi, "Impact of Repeated Washings on Dimensional Stability and Fabric Physical Factors on Woven Cotton Fabric", International Journal of Research in Engineering & Applied Sciences, 6/2 (126-135), (Feb.'2016)

[11] Mr. D. Uttam, Mr. R. Sethi, "Impact of Repeated Washings on Air Permeability of Woven Fabric", International Journal of IT, Engineering and Applied Science Research (i-Explore International Research Journal Consortium), 5/2 (8-11). (Feb.' 2016)

[12] Mr. D. Uttam, Mr. R. Sethi, "The Effect of Repeated Washings on Total Hand Value of Cotton Fabric" International Journal of Advanced Research in Engineering and Applied Sciences, 5/7 (29-36), (July' 2016)

[13] IS: 6359-1971 (reaffirmed 2004): Methods for Conditioning of Textiles, Indian Standard Institution, India

[14] ASTM D8007-15(2019): Standard Test Method for Wale and Course count of Weft Knitted Fabrics, ASTM International, West Conshohocken, PA 19428-2959, United States

[15] ASTM D3776 (2020): "Standard Test Method for Mass per Unit Area (weight) of fabric. ASTM International, West Conshohocken, PA 19428-2959, United States

[16] ASTM D1777-96 (reapproved 2019): standard test method for thickness of textile materials, ASTM International, West Conshohocken, PA 19428-2959, United States

[17] BS:4931-1986, Preparation, making and measuring of textile fabrics, garments and fabric assemblies in test for assessing dimensional change, British Standard Institute, UK

[18] IS10971-1 (2011): Textiles- Determination of Fabric Propensity to Surface Fuzzing and to Pilling, Part-1 Pilling Box, Bureau of Indian Standards (BIS), India

The Legacy of Rangawali Pichhaura in Indian Traditional Textiles

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Abstract:

In the rich cultural heritage of India, textiles exhibit the regional narratives, skills of the artisans, and deep-rooted connection with the traditions. Each region celebrates its unique traditional textile: the Pashmina of Kashmir, the Phulkari of Punjab, and the Patola of Gujarat. Similarly, Rangawali Pichhaura is one of the traditional textiles of the Kumaon region of Uttarakhand, which is hand-prepared by married women. This beautiful traditional veil is gifted to the bride as a symbol of protection from evil and marital bliss. The surreal landscape of Kumaon magnifies the strokes of colorful clothing worn by the people exhibiting cultural sentiments attached to it. However, this age-old tradition is thriving to maintain its originality due to the detachment of the present generation and a lack of takers of the textile. Over the years, this region has observed an adaptation to modernization and technological advancements resulting in a drift from handmade pichhaura to being machine printed. This research aims to study the unsung legacy of Rangawali Pichhaura by investigating the historical data and documenting the narrative presented by the local families and traditional artisans of Kumaon. It further details the theories revolving around the origination of pichhaura and proposes methods to retain the originality of this traditional textile.

Keywords: *Dyeing, Ornamentation, Printing, Textiles, Traditional Textiles*

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1. Introduction

In the colorful mosaic of India's ethnic landscape, Uttarakhand is a melting pot of various ethnicities epitomizing a unique blend of indigenous craftsmanship and influences from the neighboring states. Each district of Uttarakhand alludes to the unique characteristics exhibited through its customs, rituals, fairs, and festivals. Most men and women of Uttarakhand can be observed wearing their traditional costumes while participating in cultural and festive occasions. Being agrarian [1], the people of Kumaon worshipped local deities dressed in beautiful clothes highlighting their culture. J.H. Batten in his official reports has mentioned that it may be observed of the hill people, that they are extremely indifferent regarding the state of their everyday apparel and continue to wear their clothes till reduced to mere shreds and tatters but on festivals, they prefer to go out in beautiful clothes or might absent themselves from festivities than appearing in tattered garments[2].

Figure 1: Kumaoni Women Source:Jaimitra Singh Bisht, 2022

Costumes are ideally an expression of the people, their culture, traditions, and the society they live in and Indian bridal wear is one such example. In northern India, it has been a tradition for the bride to wear a veil to protect her from the evil eye [3] or maybe as an act of modesty to show respect. But, not only is every part of India diverse, but even the districts of the Kumaon region of Uttarakhand are different in terms of culture and clothing. In addition, the people of Kumaon have an unmatched sentiment attached to their costumes. Kumaoni women wear a traditional veil presented at their wedding known as pichhaura or rangawali pichhaura. It becomes customary for these married women to adorn this wrap at religious ceremonies, on auspicious occasions, or while celebrating festivities [4]. It is typically 3 meters in length and 1.5 meters in width and is paired with ghaghara and aangudi or saree depending on the personal choice of the wearer.

Figure 2: Traditional Kumaoni Costume Source: Anup Sah, 2018

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1.1 Traditional Kumaoni Bridal Wear

Aangudi/aanga/angiya - In Kumaon, an upper garment worn by the bride is commonly referred to as aangudi, also known as aangda, and angiya was one of the main upper garments. Traditionally, it was an adaptive version of a round neck 'choli' with a ¾ length or a full-length sleeve made of cotton, silk, or velvet. Aangudi is believed to have been modified to its present shape by incorporating features of the British garment 'blouse,' introduced by British ladies in 1816-1947 A.D. Hence, it generally had a front opening featuring snap fasteners or hook and eye or buttons as recalled by 97% of the respondents. Aangudi was commonly found in purple, green, red, blue, orange, and maroon. The fabric of the bride's wear would be either silk or chenille. From the pictorial evidence, it was gathered that the bride's aangudi was embellished with sequin work on the neck, cuffs, and hem or decorated with gota-patti.

Figure 3: Pichhaura paired with saree Source: Mrs. Poonam Pant, 2023

1.1.1 Ghaghara - The most common traditional lower garment worn by Kumaoni women was the ghaghara. The ghaghara was like a long floor-length circular skirt. Most bridal ghagharas were made of 5-6 meters in chenille, silk, and cotton fabrics gathered at the waist and fuller at the hem secured at the waist with the help of a drawstring. Traditionally, women of well-off families wore red, emerald green, dark blue maroon, and purple heavily embellished ghaghara of chenille with gota and dori work in gold and silver.

1.1.2 Saree - Traditionally, silk sarees were worn over aangudi. The style of wearing a saree was that the saree was worn by tucking it from one end into the petticoat at the front and the rest of the fabric was wrapped around the waist. The wearer keeps an estimated pallu length over the left or right shoulder. With the remaining loosely wrapped fabric around the waist, pleats were folded and tucked in the petticoat at the front. The palla was then adjusted over the breasts. In Kumaon, the women wore sarees in two specific styles ulta palla (left-side drape) and seedha palla (right-side drape) which represented their marital status. Married women draped the pallu over the right shoulder and unmarried women draped it on the left.

According to Mrs Munni Mehta [5] the bridal veil was traditionally prepared by the hands of married women as a blessing. Pichhaura was adorned with traditional motifs hand-drawn. However, the insights shared do not match the description of what is observed presently in the cloth markets of Kumaon. The production of rangawali pichhaura is commercialized according to the needs of the modern market. It is designed for the masses to accept. The craft is almost on the verge of extinction. Further, there has been a lack of clarity amongst the people of Kumaon as to when and how pichhaura was first introduced.

1.2 Reasons for Drifting Preferences

The following are recognized as the main reasons for a change in the choice of present generations-

1.2.1 Technological advancements - In the internet epoch, the market is highly tapped by globalization and commercialization. The handicraft industry faces challenges due to new technology interventions and increased competition from different countries [6]. Hence, the mechanical versions at economical price points have been introduced in the market for the masses to accept.

1.2.2 Modernization - The present generation is upbeat with the trends. They are adaptive to ongoing styles. Therefore, the emotions attached to the traditions have blurred over a while.

1.2.3 Challenges faced by the artisans - The preparation of traditional rangawali pichhaura was occasion-specific and was prepared by the married women of the bride's family. Due to a lack of takers, presently, only a few artisans in Almora and Bageshwar practice dyeing and printing rangawali pichhaura. As observed by the researcher, these artisans are finding it difficult to safeguard their designs. With the cheaper versions of machine-printed pichhaura, it is challenging for these artisans to sustain their business.

1.3 Objectives of the study

The objectives of the present study are-

1.3.1 To document the legacy of the Rangawali Pichhaura

1.3.2 To document the traditional steps involved in the preparation of Rangawali Pichhaura

1.3.3 To find out the factors that caused a change in the choice of the wearer from handmade pichhaura to machine-printed

2. Material and Methods

The present paper aims to study the legacy and the traditional steps involved in preparing rangawali pichhaura for posterity. The research would further evaluate the methods to accomplish its overall objectives in Kumaon. The following methodology is used by the researcher while conducting the field study-

2.1 Locale of the Study

The researcher covered all the districts of the Kumaon region to carry out this study. To understand the origination of rangawali pichhaura, it seemed crucial to capture the sentiments of the entire region rather than studying only 2-3 districts. Hence, 5 tailors and 20 families staying together for three generations were selected from Udham Singh Nagar, Almora, Nainital, Bageshwar, Champawat, and Pithoragarh and 10 traditional artisans from Almora were interviewed leading to a sample size of 160 respondents.

2. 2 Type of Research Design

2.2.1 Exploratory research: This type of research is undertaken to understand the narrative from the locals' point of view to substantiate the knowledge in comparison to the available secondary sources to get in-depth knowledge.

2.2.2 Descriptive research: This was aimed at carefully observing the Traditional Kumaoni culture and documenting the research topic.

2.3 Method of Data Collection

For primary data collection, the researcher used focused, directive, and semi-structured interviews to collect data from the respondents. The secondary data was collected from Doon Public Library; Dehradun, Almora Kitab Ghar; Almora, District Library; Nainital, and GB Pant Museum; Almora.

2.4 Sample Design

2.4.1 Purposive Sampling Method: For a systematic approach to the study, it was deemed important to connect with the historians of the Kumaon region and well-known artisans for which the purposive sampling method was selected.

2.4.2 Snowball Sampling Method: This method was selected after the existing research participants helped to identify other potential respondents who shared valuable insights in support of this study.

2.4.3 Cluster Sampling Method: This method was well suited to this study, as the population of each district of Kumaon was divided into smaller groups known as clusters and then the respondents were randomly selected among these clusters.

3. Results and Discussions

3.1 Legacy of the rangwali pichhaura

3.1.1 Folklore : According to ancient folklore narrated by a local priest of Rani Bagh, Haldwani, queen Jiya Rani of the Katyuri dynasty was bathing in the river. Distantly somewhere while hunting, the Mongol ruler found long hair floating in the river. Mongol ruler thought that the hair could be from a horsetail, so he ordered his soldiers to bring the horse for him. The soldiers tracked the hair and found that it was Jiya Rani who was bathing with her long hair let loose. However, the soldiers could not return without following the king's orders, which would have been considered disrespectful. The Mongol soldiers marched towards the queen and in her protection, the Katyuri soldiers covered their queen. The soldiers of Mongol and Katyur indulged in a fight and the Katyuri soldiers got killed while protecting Jiya Rani. The Mongol soldiers marched in unison to capture the queen. In a quick response to the situation, she wrapped her ghaghara around herself and turned into a stone. The stone was named chitrashila. Since then, it has been worshiped by the locals, and the place has been named after Jiya Rani as Rani Bagh in Haldwani. As rangwali pichhaura is meant to bring good omen and protect the bride from evil energies, some of the locals believe that maybe chitrashila is a representation of the pichhaura.

This folklore is narrated by many researchers who have worked in the field of the costumes and textiles of Kumaon. However, only 17% of respondents staying in Nainital and Almora were aware of this folklore. Still, the rest of the respondents had a different outlook on the legacy of rangawali pichhaura.

3.1.2 An age-old tradition introduced by the Sah community
Another plausible explanation was opined from an interview with Sub Lt (Dr.) Reetesh Sah [7]. According to Dr. Sah, 'around the late 15th century, during the Chand regime, some families migrated from the Saurashtra region and eventually settled in Kumaon. These Sah families were avid lovers of art and craft. In Kumaon, these families initiated Rangawali Pichhaura.' He added that whenever the Chand kings started accepting grains, oils, salt, etc., they erected a strong house called ganj or thul ghar (big house) instead of land revenue. The Shas became officers of these houses called Thulghariya Sahs. Similarly, the oldest Sahs settled in Champawat and Almora were Kummayyan Sahs. The ones who called themselves Kshatriyas were Jagati, Salimghariya, Gangola, Tola, and Kholbhiteria [8].

Figure 4: Handmade Pichhaura Source: Mrs Prabha Sah, 2023

Further corroborated by the families in Nainital, Almora, and Bageshwar, it was shared by the respondents that pichhaura recently has been recognized as an identifier of a Kumaoni women, whereas, it was not the case historically. Only the women of Sah families used to prepare handmade pichhaura, it was only after the girl of the Sah family got married to a different community that this tradition travelled to other districts of Kumaon. Prof. (Dr.) Girija Pande [9] also shed light on the topic and discussed that traditionally pichhaura was not observed in districts like Udham Singh Nagar and Pithoragarh but when the Kumaoni families migrated to these districts or maybe due to social media and societal influence pichhaura got wider acceptance.

3.2 Traditional steps of preparation of a rangwali pichhaura

Mrs Prabha Sah shared the process of dyeing pichhaura, according to her, 'the raw materials available these days are completely different from what was used years ago' [10]. The process of dyeing pichhaura was taught by her grandmother in 1970. Mrs. Sah also shared another interesting process from her memory in the late 19th century, the roots of Kilmora or Bhilmora were rubbed against the fabric leaving a mustard tint on the base. It is believed that pichhaura is a blessing of the whole universe to the woman it is presented to in her marriage.

Table 1: Tradition Tools and Raw Materials Used

S. No	Material Required	Quantity
1.	Schiffli Dupatta	1
2.	Turmeric	12-15 *tola* or 139-174 grams
3.	*Sindoor* or Vermillion	1 *tola* or 11.6 grams
4.	*Gulenaar*	4-5 *tola* or 46-58 grams
5.	*Gud* or *Batasha*	75 grams
6.	Copper vessel or aluminium vessel or earthen pot	1
7.	25 paisa or traditional silver coins	4-5 coins

*1 tola= 11.6 grams

Note: Traditionally term tola was referred to measure the quantity of raw material used. The term is still commonly used by traditional artisans while dyeing pichhaura

Figure 5: Printed pichhaura using mechanical methods of printing like screen printing Source: Internet accessed on 12th June 2022

3.2. Steps involved in the traditional process were as follows;

- A plain or embroidered white cotton fabric of 3 meters in length and 1.5 meters in width was taken by the bride's mother or grandmother.
- In a copper or aluminium vessel, 139-174 grams of turmeric mixed with water was boiled and the cotton fabric was dipped in the solution for the dyeing.
- Traditionally, the dyebath was prepared in copper or aluminium vessels to brighten the dye colors.
- The fabric was left in the solution for half an hour and removed.
- The excess solution was squeezed out of the fabric.
- After achieving the base color mustard yellow, the moist fabric was spread on the ground in a shaded room for the fabric to refrain from drying.
- Simultaneously, a paste was prepared using 1 tola sindoor or vermillion, 4-5 tola gulenaar, and 7-8 tola gud or batasha added to the red dye mixture to thicken the paste.
- The printing was again carried out by the married women of the family as old silver coins during the British era or 25 paisa coins or small cotton balls used to be dipped in the paste and applied onto the dyed cotton fabric, creating small dots all over.
- The dotted patterns were achieved on each corner radiating towards the center.
- The lines were drawn by the edge of a coin, holding it vertically and continuously dipping in the paste.
- After completing the corners of rangwali pichhaura, the women worked in the middle where a four-cornered swastika was hand-drawn with the help of a coin.
- In each corner of the swastika, the sun, the moon, conch, bell, kalash devi, devta, etc., were adorned (figure 6).
- Finally, the pichhaura was dried in direct sunlight..

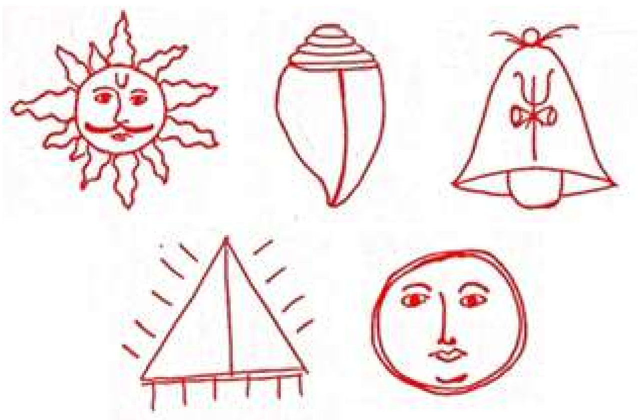

Figure 6: (L-R) Traditional Motifs of Surya Devta, Shankh, Ghanti, Kalash, and Chandrama

3.2.2 Traditional motifs and symbols adorned on pichhaura are as follows-

Swastika- In the middle of rangawali pichhaura, a four-cornered swastika was put. The swastika is an auspicious religious symbol of Hindu culture which is highly regarded before a new beginning. The sun, moon, shell, and kalash were adorned in each quadrant of this symbol.

Celestial Bodies - In Kumaoni culture, worshipping the celestial bodies is considered a blessing of the whole constellation. Hence, the sun, moon, and stars revered as celestial bodies were hand drawn on the rangawali pichhaura. The stars were drawn in small dots all over, whereas in each quadrant surya devta (the Sun God) and chandrama (the Moon God) were adorned.

Shell- In one of the quadrants, the shell or conch was another auspicious symbol. In Hinduism, the conch is blown during auspicious ceremonies.

Kalash- Lastly, kalash was integral to religious and ceremonial occasions like weddings. It represents the universal mother goddess, fertility, good fortune, and success in life. [11]

Jali- Jali or jaal alludes to repeated patterns typically seen on the wraps draped by the women. The round motif achieved by dipping a cotton ball in sindoor (vermillion) representing the stars on pichhaura is an example of jali.

3.3 The Present Scenario

It is opined from the data, that 93% of respondents of the age group 18-28 years and 78% of respondents of the age group 29-39 years preferred machine-printed pichhaura, whereas 70% of respondents of 40 years and older preferred handmade pichhaura. As observed, the younger generations (18-28 years) in the Kumaon region did not have an in-depth understanding of the importance of pichhaura.

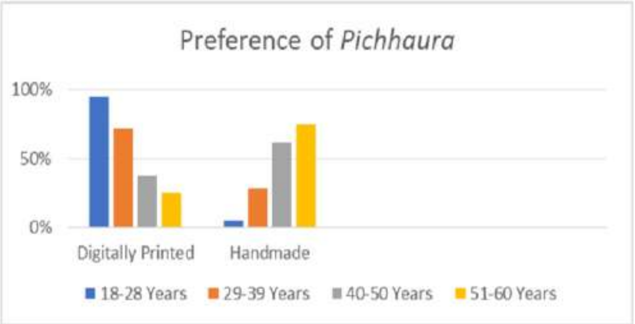

Figure 7: Response of different age groups on handmade and machine-printed pichhaura (n= 120)

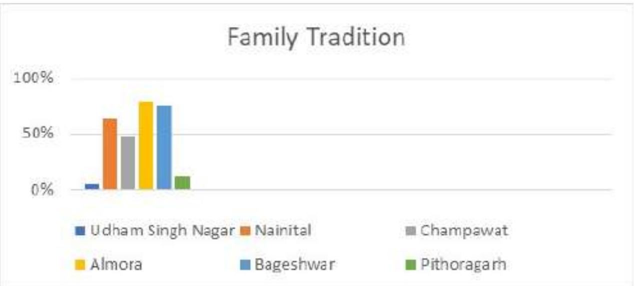

Figure 8: Response of Kumaoni women to the tradition passed down as a legacy (n= 120)

From the above study, it is opined that 72%, 84%, 48%, and 82% of respondents from Nainital, Almora, Champawat, and Bageshwar respectively were handed down the legacy of dyeing pichhaura as a tradition travelled within the family since the 19th century, whereas, the respondents from Udham Singh Nagar and Pithoragarh shared that they were inspired by the society and started wearing machine printed pichhaura as it was not a family tradition.

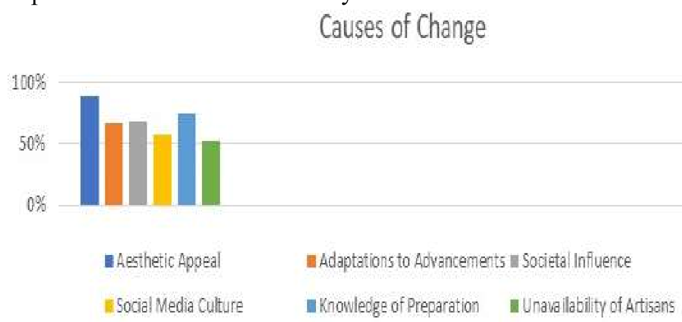

Figure 9: Response on causes of change in choice of pichhaura (n= 120)

Figure 10: Water stain on pichhaura Source: Mrs Munni Mehta, Almora, 2020

Figure 10 depicts the response of women from all the districts of Kumaon to causes that led to a change in the choice of machine-printed pichhaura over handmade. 89% of the respondents shared that the aesthetic appeal of machine-printed pichhaura is better than hand-prepared ones as in traditional methods, dye fixation was not done (figure 10) may be due to inadequate knowledge. In contrast, commercially available varieties follow the standard industry procedures of dyeing and printing which are easy to maintain. The dye of handmade pichhaura requires attention and care, whereas, the print on machine-printed pichhaura is neat and clear to the viewer. 75% of the respondents did not acquire the knowledge and skills to prepare rangawali pichhaura and bought it from the readymade garments shop. 68% of the respondents felt that their choice changed as a cause of societal influence. 67% of the respondents shared that their sentiments attached to the age-old tradition have blurred due to migration and adaptations to geographical advancements. Watching videos on social media and regional short films influenced 58% of the respondents. Lastly, 53% of the respondents shared that they did not know how to contact the artisans who can prepare handmade pichhaura, as the tradition is not recognized as a commercial craft, and only a few families in Almora and Bageshwar have acquired the right skills.

4. Conclusions

The study has been able to establish the fact the age-old tradition of preparing rangawali pichhaura for the bride is eventually fading away. Due to the above-mentioned factors the present generation is opting for more practical solutions with easy maintenance. While conducting this research it was observed that a maximum number of people (other than respondents) had very little clarity on the origin of pichhaura. However, they were aware of the religious sentiments attached and the importance of this traditional wrap but it was surprising that they never tried to understand the legacy of pichhaura. In conclusion, it is considered crucial to hold on to the essence of this tradition and the following are the proposed methods in solution:

4.1 Takers in the Present Generation

The respondents belonging to the younger generations were enthusiastic to learn the traditional process of preparing handmade pichhaura. It was observed that by encouraging and recognizing the importance of pichhaura as a regional handicraft, respondents were willing to understand the legacy and follow the practice of dyeing and printing for their family members.

4.2 Better Dyeing Properties

Traditional printing offered poor color fastness leading the dye to leach out of the wrap. The artisans may or may not opt for the natural dyes however presently both acid and basic dyes are used. Better options are available for contemporary printing. Presently, ladoo peela and gulaabi dyes are used to achieve yellow and maroon colors respectively that offer better color fastness.

4.3 Recognition as a Regional Handicraft

In today's progressive era, artisans are facing several problems and threats caused by digitalization. In the interview, it was found that rangawali pichhaura is not recognized as a regional handicraft, hence the number of orders is limited to the region only. It is only possible after the state government, fashion institutions, influencers, and enthusiasts work together to promote the tradition with accurate information.

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References

[1] Negi S.S. 'Kumaun: The Land & People,' 1st ed., Delhi; Indus Publishing Company: 1993
[2] Batten J.H. 'Official Reports on the province of Kumaon,' 1st ed., Agra; Secundra Orphan Press: 1851
[3] Jain S. 'Encyclopedia of Indian Women through the Ages: The Middle Ages,' 2nd vol., Delhi; Kalpaz Publications: 2003
[4] Atkinson E.T. 'The Himalayan Gazetteer', 1st vol, 2nd part, Delhi; Cosmo Publications: 1881
[5] An interview was conducted with the respondent, Mrs Munni Mehta (age 65 years) on 02nd October 2020 at Matina village, Almora
[6] Majeed I. "Indian Handicraft Industry and Globalization: An Analysis of Issues and Challenges," American International Journal of Research in Humanities, Arts and Social Sciences, 25(1), December 2018- February 2019, pp. 129-135
[7] An interview was conducted with the respondent, Sub Lt (Dr) Reetesh Sah, Professor of History, on 23rd November 2022, at Kumaon University, Nainital
[8] Pande B.D. 'History of Kumaun,' 2nd vol., Almora; Almora Book Depot: 1993
[9] An interview was conducted with the respondent, Prof (Dr) Girija Pande, Professor of History, on 22nd November 2022, at Uttarakhand Open University, Haldwani
[10] An interview was conducted with the respondent, Mrs Prabha Sah (age 63 years) on 26th November 2022 at Johari Bazaar, Almora
[11] Katare V. and Sharma R.B. "Symbolic Motifs in Traditional Indian Textiles and Embroideries." International Journal of Research in Economics and Social Sciences https://euroasiapub.org/wp-content/uploads/2016/09/30ESSMarch-3350-2.pdf

Optimizing Characteristics of Agave Americana Fibre Reinforced Polymer Matrix Composites Using Taguchi Grey Relation Analysis

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Abstract:

The present study focuses on the optimization of thermal and mechanical characteristics of Agave Americana Fibre Reinforced Composites (AAFRC) using Taguchi Grey Relational Analysis. The composite samples were manufactured through compression molding, with three factors being varied: type of polyester resin, fibre volume fraction, and composite thickness. Each factor had three levels, and a Taguchi L9 orthogonal array was employed to design the experiment, resulting in nine experimental runs. The Taguchi-GRA approach identified optimal parameters: Isophthalic Polyester Resin (Mechanical Grade), a fibre volume fraction of 0.40, and a composite thickness of 9mm. This method significantly contributed to determining the best combination of factors, enhancing the composite's overall performance An Analysis of Variance was conducted to determine the primary influential factor, and all three factors were found to be significant. The fibre volume fraction emerged as the factor with the highest significant influence, accounting for 54.51% of the observed characteristics of manufactured composites. The tensile, flexural, impact and compressive strength of the composites exhibited a positive correlation with the fibre volume fraction, indicating the reinforcing effect of the fibres. Confirmation experiments conducted with the optimal parameters demonstrated an impressive 83.22% improvement in the grey relation grade.

Keywords: *Grey Relational Analysis, Impact Strength, Leaf Fibre, Optimization Procedure, Orthogonal Array, Textile Composite, Thermoset Resin, etc.*

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1. Introduction

The demand for lightweight and eco-friendly materials in various industries, including automotive, aerospace, and construction, has driven the exploration of natural fibres as an alternative to conventional synthetic reinforcements. Agave Americana, commonly known as the century plant, possesses promising mechanical properties and is abundantly available in various regions. These fibres exhibit attractive properties such as high strength, low weight, and biodegradability, making them a promising alternative to synthetic fibres in various applications. Agave Americana leaf fibre (AALF) has gained significant attention in recent years as a potential reinforcement material for composite applications [1].

The effect of fibre volume fraction, surface treatment, fibre length, type of matrix, and manufacturing process parameters on the mechanical and thermal properties of AALF-reinforced composites have been studied extensively. Several studies have explored the use of Agave Americana fibres in composite materials. Many authors investigated the mechanical properties of composites fabricated with Agave Americana fibres and found them to exhibit promising tensile strength and modulus [2], [3]. However, to fully exploit their potential, optimization of their characteristics is essential. This research focuses on optimizing the thermal and mechanical properties of Agave Americana Fibre Reinforced Composites (AAFRC) using Taguchi Grey Relational Analysis (GRA). By systematically varying key process parameters such as fibre content, matrix type, and composite thickness, we aim to enhance the performance of AAFRC.

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The application of Taguchi GRA in composite material optimization is novel and offers a systematic approach to explore multiple parameters and their levels, providing insights into the intricate relationship between process variables and composite properties. By integrating Taguchi design with GRA, this methodology allows for efficient determination of the optimal combination of parameters to maximize desired performance characteristics [4], [5].

2. Materials and Methods

2.1 Material

This investigation used discontinuous Agave Americana leaf fibre as reinforcement in three thermoset polyester resin variants: Isophthalic (Mechanical Grade), Vinyl Polyester, and Unsaturated Polyester. Cobalt naphthenate and MEKP were added for faster curing. Cobalt naphthenate acts as a catalyst, promoting curing, while MEKP is a hardener, initiating crosslinking.

2.2 Fabrication of Composites

Agave Americana fibres were randomly chopped to lengths ranging from 25-50 mm before composite fabrication. Chopped AALF-reinforced composite specimens were

Table 1 Taguchi design (for compo

Expt. No.	Coded			Uncoded		
	A	B	C	Matrix/ Resin	Composite Thickness (mm)	Fibre Volume Fraction
1	1	1	1	Isophthalic Polyester (ISO)	3	0.10
2	1	2	2	Isophthalic Polyester (ISO)	6	0.25
3	1	3	3	Isophthalic Polyester (ISO)	9	0.40
4	2	1	2	Vinyl Ester (VER)	3	0.25
5	2	2	3	Vinyl Ester (VER)	6	0.40
6	2	3	1	Vinyl Ester (VER)	9	0.10
7	3	1	3	Unsaturated Polyester (UPR)	3	0.40
8	3	2	1	Unsaturated Polyester (UPR)	6	0.10
9	3	3	2	Unsaturated Polyester (UPR)	9	0.25

manufactured using a compression molding machine. The specimens were prepared in a square mold made of EN90 steel, with dimensions of 350 x 350 x 10 mm. Before starting the fabrication process, the mold was coated with a release wax. Specimens were fabricated according to the design provided by the Taguchi L9 orthogonal array, as shown in Table 1.

A mixture of 2% Cobalt naphthenate and 3% MEKP was mixed with the resin. Reinforcing agents were impregnated with this mixture. Chopped fibres were impregnated with their respective resin and cold-pressed. These prepregs were combined until the desired fibre-resin ratio and thickness were achieved. Molds were kept under pressure for three hours. Post-curing was carried out for 24 hours at room temperature.

2.3 Characterization of Composites

Fabricated composites were evaluated for thermal and mechanical properties acceding to ASTM (American Society for Testing and Materials) standards under standard atmospheric conditions. Moisture Absorption, Thermal Conductivity, Tensile Strength and Elongation, Flexural Strength, Izod Impact Strength, and Compressive Strength of composite samples were determined according to ASTM D570, ASTM C518-04, ASTM D638, ASTM D790, ASTM D256 and ASTM D695 respectively [6].

2.4 Statistical Analysis

After testing, results (responses) were analysed by using MINITAB® statistical software and Microsoft Excel. Statistical methods like Analysis of Variance (ANOVA), regression analysis, general linear model and Taguchi, and grey relation analysis were used to analyse the data.

2.4.1 S/N Ratios in the Taguchi Method

The Signal to Noise (S/N) ratio analysis was used to evaluate the quality characteristics of AAFRC, considering two types of responses: smaller-is-better (moisture absorption and thermal conductivity) and larger-is-better (mechanical properties) [4], [7]. For the smaller-is-better responses, a lower S/N ratio, calculated using Eq. (I), indicates better performance in terms of moisture resistance and thermal insulation [8]. For mechanical properties, a higher S/N ratio, calculated using Eq. (II), indicates better performance in terms of strength and stiffness.

$$S/N_{SBT} = \eta dB_{SBT} = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \quad ....(I)$$

$$S/N_{LBT} = \eta dB_{LBT} = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_i^2}\right) \quad ....(II)$$

Analysing S/N ratios helps determine the optimal combination of process parameters to achieve desired performance across all responses, balancing moisture resistance, thermal insulation, and mechanical strength [9].

2.4.2 Grey Relation Analysis

Optimizing multiple performance characteristics requires careful consideration compared to optimizing a single characteristic. While the Taguchi method is commonly used for single response optimization, real-world engineering applications often involve multiple response problems [10]. To effectively address these multi-response problems, it is beneficial to transform all objectives into a single equivalent objective. The integration of the Taguchi method with GRA enables the solution of such multi-response problems. GRA quantifies the absolute differences between sequences and approximates the correlation among them [11]. In this study, our goal was to minimize two performance characteristics, namely moisture absorption and thermal conductivity, while simultaneously maximizing five performance characteristics: tensile strength, elongation, flexural strength, impact strength, and compressive strength. This objective was achieved by selecting appropriate fabrication parameters, specifically the type of matrix, fibre volume fraction, and composite thickness [5], [8]. Before GRA responses for each experiment for desired composite characteristics were obtained and S/N ratios were computed.

a. Normalized S/N Ratios

The initial step is to normalize the S/N ratios, each corresponding to a specific performance characteristic to be maximized or minimized. Normalizing the objective functions allows for consistent evaluation and comparison on a standardized scale. The S/N ratio values were normalized within the range of 0 to 1 for the various responses, categorized as "smaller is better" or "larger is better" [12].

I. Smaller is Better: For the responses related to moisture absorption and thermal conductivity, a lower value indicates better performance. Here, the S/N ratio min represents the minimum S/N ratio value obtained for the specific response. The S/N ratio values were normalized using Eq. (III):

$$x_{ij} = \frac{max(y_{ij})-y_{ij}}{max(y_{ij})-min(y_{ij})} \text{ ....(III)}$$

$$x_{ij} = \frac{y_{ij}-min(y_{ij})}{max(y_{ij})-min(y_{ij})} \text{ ....(IV)}$$

Where X_{ij} denoted the normalized S/N Ratios (sequence) for i[th] experiment and j[th] response and γ_{ij} represents the initial S/N Ratio of the mean of the responses [5].

ii. Larger is Better: For the mechanical properties, such as tensile strength, flexural strength, and other relevant characteristics, a higher value indicates better performance. In this case, the S/N ratio max represents the maximum S/N ratio value obtained for the specific mechanical response. The S/N ratio values were normalized using Eq. (IV). The normalized S/N ratio values in the range of 0 to 1 provide a relative measure of the performance of the composite material. A value closer to zero indicates better performance for moisture absorption and thermal conductivity (Smaller is Better), while a value closer to one indicates superior performance for mechanical properties (Larger is Better) [13].

b. Deviation Sequences

After normalizing the objective functions (S/N Ratios), deviation sequences are obtained using Eq. (V). These sequences measure the deviation of each objective function from its ideal value. Deviation sequences offer insights into the contribution of each parameter level to the deviation from the ideal value for each objective function. By analysing the deviation sequences, we can identify experiments that perform exceptionally well or poorly compared to the overall mean. This information can help in identifying the factors and levels that contribute to superior or inferior performance in terms of the various responses.

$$\Delta_{ij} = |x_{0j} - x_{ij}| \text{ ....(V)}$$

Where, $\Delta_{ij}, x_{ij}, x_{0j}$ refer to the deviation, comparability, and reference sequences, respectively.

c. Grey Relation Coefficient (GRC)

The grey relation coefficient (ξ) is computed by evaluating the deviation sequences for each objective function using Eq. (VI). The GRC evaluates the correlation between the deviation sequences and the ideal sequences for each objective function. It quantifies the extent of agreement between each parameter level and the ideal value associated with each objective function [14].

To determine the acceptability of the deviation, the distinguishing coefficient (ξ) of 0.5 is employed. Normalized deviations ≤ 0.5 indicate proximity to the ideal value, denoting acceptability. Deviations > 0.5 suggest a significant deviation from the ideal value, indicating undesirability. The grey relation coefficient is calculated as the average of normalized deviations for each parameter setting. A higher grey relation coefficient indicates a stronger correlation with the desired performance.

$$\xi(x_{0j}, x_{ij}) = \frac{(\Delta_{min}+\zeta\Delta_{max})}{(\Delta_{ij}+\zeta\Delta_{max})} \text{ ....(VI)}$$

In the given context, $\xi(x_{0j}, x_{ij})$ represents the GRC of individual response variables, which is calculated based on the minimum deviation (Δ_{min}) and maximum deviation (Δ_{max}) values associated with each response variable [5], [13].

d. Grey Relation Grade (GRG) and Rank

The Grey Relation Grad denoted as γ_i assesses the overall performance of each parameter level relative to the ideal values across all objectives. It quantifies the correlation between parameter levels and desired objectives in multi-objective optimization. The GRG is computed by averaging the Grey Relational Coefficients obtained for all responses (Eq. (VII)) [15].

$$Y_i = \frac{1}{n}\sum_{j=1}^{n} \xi_i(j) \text{ ....(VII)}$$

In this context, γ_i represents the GRG value computed for the ith experiment, with n denoting the number of performance characteristics targeted for optimization. On the other hand, ξ_i refers to the grey relation coefficient associated with the ith experiment.

The parameter levels are ranked based on the GRG values. The rank reflects the relative effectiveness of each parameter level in achieving the desired objectives. Levels with higher GRG values are considered more optimal for multi-objective optimization [5], [13], [16].

e. Selection of Optimal Levels of Process Parameters

The selection of optimal levels for process parameters is based on the rankings obtained in the previous step. The levels associated with higher rankings are chosen as the optimal configuration for multi-objective optimization. These levels effectively balance various performance characteristics, resulting in overall improvement.

f. Prediction and Validation

Once the optimal level of composite manufacturing has been identified, the subsequent step entails predicting and verifying the improvement in performance characteristics using the selected composite manufacturing parameters. The predicted grey relational grade denoted as γ_{pred} can be calculated using Eq. (VIII) [4], [13]

$$y_{pred} = y_{expt} + \sum_{j=1}^{k}(y_j - y_{expt}) \text{ ....(VIII)}$$

Where, γ_{pred} represents the predicted value, γ_{expt} is the overall mean response (GRG) for the entire orthogonal array, yj is the mean response (GRG) for the factor at the optimum level, and k denotes the number of main factors affecting the response [4], [17].

3 Results and Discussion

After manufacturing the Agave Americana fibre reinforced composites according to Taguchi L9 orthogonal array, all the samples were characterized for thermal and mechanical characteristics. Table 2 represents the properties of AAFRC for every experiment.

The ANOVA results are presented in Table 3. ANOVA analysis reveals that matrix type, composite thickness, and fibre volume fraction significantly affect most AAFRC properties. Contribution (%) written in bracket gives the information about the degree of changes brought by a specific factor to the tested property of composite. Composite thickness has the most significant impact, while matrix type is insignificant for thermal conductivity and fibre volume fraction is insignificant for elongation. These findings offer scientific guidance for optimizing the manufacturing parameters of these composites to achieve desired performance characteristics based on the specific property of interest.

Table 2 Properties of Agave Americana Fibre Reinforced Composites

Expt. No.	Coded Factors			Responses						
	A	B	C	Moisture Absorption (%)	Thermal Conductivity (W/mK)	Tensile Strength (MPa)	Elongation (%)	Flexural Strength (MPa)	Impact Strength (J/m²)	Compressive Strength (MPa)
1	1	1	1	0.7	0.08417	31.01	4.06	17.74	30.8	5.41
2	1	2	2	2.34	0.04839	96.08	3.61	67.26	125.98	17.65
3	1	3	3	5.99	0.03578	173.98	3.03	115.41	216.45	33.03
4	2	1	2	3.12	0.06828	31.17	3.12	20.56	31.98	6.11
5	2	2	3	5.92	0.10511	110.94	2.32	72.97	129.06	20.82
6	2	3	1	5.16	0.04176	62.73	3.12	43.91	60.47	14.05
7	3	1	3	6.69	0.11916	53.92	1.98	35.81	48.7	11.19
8	3	2	1	5.31	0.07514	30.98	2.34	21.06	25.71	6.60
9	3	3	2	9.12	0.02542	97.06	1.94	64.66	114.15	17.59

Table 3 Factor-wise p-Values and Contribution (%)

Property	Matrix	Composite Thickness (mm)	Fibre Volume Fraction
Moisture Absorption (%)	0.019 (48.26%)	0.027 (32.68%)	0.048 (18.14%)
Thermal Conductivity (W/mK)	0.312 (6.56%)	0.045 (62.27%)	0.095 (28.2%)
Tensile Strength (MPa)	0.049 (14.48%)	0.017 (43.15%)	0.018 (41.62%)
Elongation (%)	0.008 (75.67%)	0.104 (5.04%)	0.03 (18.71%)
Flexural Strength (MPa)	0.016 (13.99%)	0.005 (45.54%)	0.006 (40.23%)
Impact Strength (J/m²)	0.049 (19.66%)	0.025 (40.19%)	0.025 (39.12%)
Compressive Strength (MPa)	0.018 (12.16%)	0.005 (46.72%)	0.005 (40.89%)

3.1 Grey Relation Analysis

3.1.1 S/N Ratios

For moisture absorption and thermal conductivity, a smaller S/N ratio is preferred (smaller is better). Conversely, for mechanical properties, a larger S/N ratio is desired (larger is better). S/N ratios calculated for each response are shown in Table 4.

Experiments three consistently exhibit higher S/N ratios, indicating superior performance across multiple characteristics, while experiments 1 and 9 consistently have lower S/N ratios, suggesting poorer performance. These findings can guide the optimization of the manufacturing process to enhance the desired characteristics, considering the influence of the factors studied in the experiment [18]. Since multi-objective optimization is to be performed, these S/N ratios need to be normalized on a scale of 0 to 1. Using Eq. (III) and Eq. (IV), normalized S/N ratios were obtained for all the responses and reported in Table 5.

3.1.2 Normalized S/N Ratios

The normalization of values enables a comparative evaluation of the factors and their influence on the responses. The experiments with lower values for moisture absorption and thermal conductivity are desirable. From the data, we can see that experiment one has the lowest normalized value for moisture absorption, indicating better moisture resistance. Experiment nine has the lowest normalized value for thermal conductivity, suggesting lower heat transfer characteristics.

Table 4 Signal to Noise Ratios

Expt. No.	Coded Factors			S/N Ratios						
	A	B	C	Moisture Absorption (%)	Thermal Conductivity (W/mK)	Tensile Strength (MPa)	Elongation (%)	Flexural Strength (MPa)	Impact Strength (J/m^2)	Compressive Strength (MPa)
1	1	1	1	3.10	21.50	29.83	12.17	24.98	29.77	14.66
2	1	2	2	-7.38	26.30	39.65	11.15	36.56	42.01	24.93
3	1	3	3	-15.55	28.93	44.81	9.63	41.24	46.71	30.38
4	2	1	2	-9.88	23.31	29.87	9.88	26.26	30.10	15.72
5	2	2	3	-15.45	19.57	40.90	7.31	37.26	42.22	26.37
6	2	3	1	-14.25	27.58	35.95	9.88	32.85	35.63	22.95
7	3	1	3	-16.51	18.48	34.64	5.93	31.08	33.75	20.98
8	3	2	1	-14.50	22.48	29.82	7.38	26.47	28.20	16.39
9	3	3	2	-19.20	31.90	39.74	5.76	36.21	41.15	24.91

Table 3 Factor-wise p-Values and Contribution (%)

Expt. No.	Coded Factors			Normalized Signal to Noise Ratios						
	A	B	C	Moisture Absorption (%) *	Thermal Conductivity (W/mK) *	Tensile Strength (MPa)#	Elongation (%) #	Flexural Strength (MPa) #	Impact Strength (J/m^2) #	Compressive Strength (MPa) #
1	1	1	1	0	0.7750	0.0006	1	0	0.0848	0
2	1	2	2	0.4701	0.4167	0.6559	0.8409	0.7117	0.7460	0.6536
3	1	3	3	0.8362	0.2213	1	0.6038	1	1	1
4	2	1	2	0.5822	0.6396	0.0035	0.6434	0.0788	0.1024	0.0673
5	2	2	3	0.8317	0.9188	0.7393	0.2422	0.7552	0.7573	0.7449
6	2	3	1	0.7781	0.3213	0.4088	0.6434	0.4840	0.4014	0.5275
7	3	1	3	0.8793	1	0.3211	0.0276	0.3751	0.2998	0.4017
8	3	2	1	0.7893	0.7015	0	0.2538	0.0916	0	0.1099
9	3	3	2	1	0	0.6618	0	0.6906	0.6997	0.6517

Experiment three has the highest normalized value exhibiting the highest values for most of the mechanical properties, indicating better overall performance. It suggests that the factors corresponding to experiment 3 may contribute positively to achieving the desired mechanical characteristics in the AAFRC.

3.1.3 Deviation Sequences

The deviation sequences represent the deviation of each response value from the overall mean for that particular response. It allows us to understand the relative performance of each experiment compared to the mean. Computed deviation sequences are given in Experiment 3 with lower deviation sequences to most of the characteristics contributing to superior in terms of the various responses to achieve the desired optimization objectives.

Table 6. Experiment three with lower deviation sequences to most of the characteristics contributes to superiority in terms of the various responses to achieve the desired optimization objectives.

3.1.4 Grey Relation Coefficient and Grey Relation Grade

Based on the provided grey relation coefficient, grey relation grade and rank table (Table 7), we can draw several findings regarding the performance of the experiments. The grey relation coefficient represents the closeness or similarity of each experiment to the ideal solution, while the grey relation grade provides a comprehensive ranking of the experiments based on their performance.

Based on the grey relation grade, experiment 3 (A1B3C3) has the highest grade, indicating its overall best performance across all the considered factors. Experiment five follows with the second-highest grade, suggesting its strong overall performance. Experiments can be ranked based on their grey relation ranks. Experiment 3 (A1B3C3) holds the first rank, indicating its superior overall performance. Experiment 5 (A2B2C3) secures the second rank, followed by experiment 2 (A1B2C3) in the third rank.

Table 6 Deviation Sequences

Expt. No.	Coded Factors			Deviation Sequences						
	A	B	C	Moisture Absorption (%)	Thermal Conductivity (W/mK)	Tensile Strength (MPa)	Elongation (%)	Flexural Strength (MPa)	Impact Strength (J/m^2)	Compressive Strength (MPa)
1	1	1	1	1	0.2250	0.9994	0	1	0.9152	1
2	1	2	2	0.5299	0.5833	0.3441	0.1591	0.2883	0.2540	0.3464
3	1	3	3	0.1638	0.7787	0	0.3962	0	0	0
4	2	1	2	0.4178	0.3604	0.9965	0.3566	0.9212	0.8976	0.9327
5	2	2	3	0.1683	0.0812	0.2607	0.7578	0.2448	0.2427	0.2551
6	2	3	1	0.2219	0.6787	0.5912	0.3566	0.5160	0.5986	0.4725
7	3	1	3	0.1207	0	0.6789	0.9724	0.6249	0.7002	0.5983
8	3	2	1	0.2107	0.2985	1	0.7462	0.9084	1	0.8901
9	3	3	2	0	1	0.3382	1	0.3094	0.3003	0.3483

Table 7 GRC, GRG and Rank

Expt. No.	Coded Factors			Grey Relational Coefficient							GRG	Rank
	A	B	C	Moisture Absorption (%)	Thermal Conductivity (W/mK)	Tensile Strength (MPa)	Elongation (%)	Flexural Strength (MPa)	Impact Strength (J/m^2)	Compressive Strength (MPa)		
1	1	1	1	0.3333	0.6896	0.3335	1	0.3333	0.3533	0.3333	0.4823	7
2	1	2	2	0.4855	0.4615	0.5924	0.7586	0.6343	0.6631	0.5907	0.5980	3
3	1	3	3	0.7533	0.3910	1	0.5579	1	1	1	0.8146	1
4	2	1	2	0.5448	0.5811	0.3341	0.5837	0.3518	0.3578	0.3490	0.4432	9
5	2	2	3	0.7481	0.8603	0.6572	0.3975	0.6713	0.6732	0.6622	0.6671	2
6	2	3	1	0.6927	0.4242	0.4582	0.5837	0.4921	0.4551	0.5141	0.5172	6
7	3	1	3	0.8055	1	0.4241	0.3396	0.4445	0.4166	0.4553	0.5551	5
8	3	2	1	0.7035	0.6262	0.3333	0.4012	0.3550	0.3333	0.3597	0.4446	8
9	3	3	2	1	0.3333	0.5965	0.3333	0.6178	0.6247	0.5894	0.5850	4

Based on the grey relation coefficients, grades, and ranks, experiment 3 (A1B3C3) demonstrates the best overall performance, while experiment 4 (A2B1C2) shows a weaker performance. Experiments 5, 2, 9, and 7 also display favourable performance in various aspects. These findings provide valuable insights into the relative performance of the experiments and can assist in identifying the most promising solutions or factors contributing to optimal results.

3.1.5 Selection of Optimal Levels

From the grey relation grade, it is evident that experiment three gives the most desired composite characteristics. The obtained grey relation grades were further analysed to validate the prediction and determine the exact experimental setup that gives optimal setup. The main Effects Plot for Means and S/N Ratios of Grey Relation Grade are represented in Figure 1.

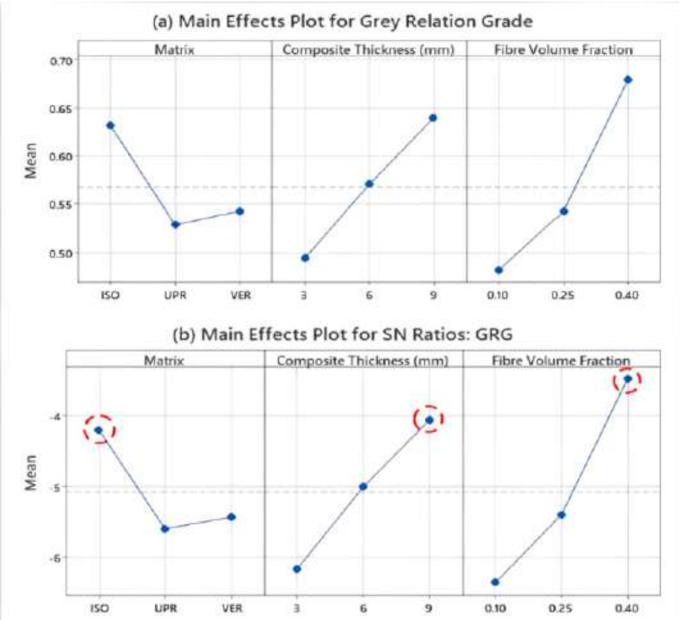

Figure 1: Main Effects Plot for Means and S/N Ratios of Grey Relation Grade

Higher grey relation grade and S/N ratio indicate the levels that contribute to superior performance in terms of the various responses. Here, composite samples manufactured with Isophthalic Polyester Resin with 9 mm composite thickness, and 0.4 fibre volume fraction exhibit higher GRG and S/N ratio. This setup corresponds to experiment 3 (A1B3C3). Hence the parameters set in experiment 3 (A1B3C3) will be treated as optimal parameters.

Table 8 represents the level-wise mean response table for the grey relation grade. Higher GRG was obtained for level 3 of the factors composite thickness (mm) and fibre volume fraction whereas higher GRG was obtained for level 1 of Matrix indicating A1B3C3 as an optimal setting. When it comes to rank, fibre volume fraction shows a higher rank indicating a significant influence of the composite characteristics.

To evaluate the significance and percentage contribution of each factor to the multiple characteristics of AALF reinforced composites, an ANOVA analysis was performed on the GRG at a confidence level of 95%. The outcomes of this analysis, demonstrating the relative effects of the factors, are presented in Table 9 [16].

Table 8 Response Table for Grey Relational Grade

Factor	Level 1	Level 2	Level 3	Max-Min	Rank
Matrix (A)	0.631653	0.528241	0.542592	0.103412	3
Composite Thickness (B)	0.493536	0.569921	0.638329	0.144793	2
Fibre Volume Fraction (C)	0.481378	0.54207	0.678938	0.19756	1

Table 9 ANOVA of Grey Relation Grade

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Matrix	2	0.018847	16.72%	0.018847	0.009423	27.43	0.035
Composite Thickness (mm)	2	0.031736	28.16%	0.031736	0.015868	46.18	0.021
Fibre Volume Fraction	2	0.061446	54.51%	0.061446	0.030723	89.42	0.011
Error	2	0.000687	0.61%	0.000687	0.000344		
Total	8	0.112716	100.00%				

R-sq	R-sq(adj)	R-sq(pred)
99.39%	97.56%	87.65%

According to the analysis, the fibre volume fraction demonstrates the highest influence, accounting for 54.51% of the variation in the GRG. Following that, the composite thickness contributes 28.16%, while the matrix exhibits a minimal influence of 16.72%. Additionally, the p-values of all factors being less than 0.05 signify their significant impacts on the composite characteristics. The high R values indicate a good fit for the developed model. These findings provide valuable insights into the importance of each factor and contribute to optimizing the manufacturing parameters of AALF reinforced composites for enhanced performance.

3.2 Prediction and Validation

The predicted grey relation grade was computed using Eq. (VIII). Confirmation tests were carried out to validate the results of the analysis, and the average GRG was calculated based on nine experimental runs [16]. Before the optimization study, the composites were manufactured with the setting A3B2C1 and the optimized setting as per the GRA is A1B3C3. Table 10 demonstrates that the results from the confirmation experiment align well with the predicted values. Furthermore, an impressive 83.22% improvement in GRG was observed. This enhancement in experimental results validates the effectiveness of utilizing the Taguchi method in conjunction with GRA to enhance the characteristics of AAFRC. The predictions and results validation were based on the mean response of the GRG values for each experiment, as indicated in Eq. (VIII) [5].

Table 10 Composite Characteristics Using Initial and Optimal Setting

Properties	Initial Factors	Optimal Factors	
		Prediction	Experiment
Levels	A3B2C1	A1B3C3	A1B3C3
Moisture Absorption (%)	5.31		5.99
Thermal Conductivity (W/mK)	0.07514		0.03578
Tensile Strength (MPa)	30.98		173.98
Elongation (%)	2.34		3.03
Flexural Strength (MPa)	21.06		115.41
Impact Strength (J/m^2)	25.71		216.45
Compressive Strength (MPa)	6.60		33.03
Grey Relation Grade	0.4446	0.814107111	0.8146

4. Conclusion

Resin type, composite thickness, and fibre volume fraction significantly impact composite performance, with fibre volume fraction exerting the strongest influence, followed by composite thickness. The optimized parameter settings for desired characteristics entail employing Isophthalic Polyester Resin, a 9 mm thickness, and a 0.4 fibre volume fraction (experiment 3). The alignment between predicted GRG values and confirmation experiments validates the efficacy of Taguchi GRA. Confirmation tests demonstrate an impressive 83.22% improvement in GRG, providing strong evidence of the successful optimization of Agave Americana Fibre Reinforced Composites. These findings yield valuable insights into the influence of factors on thermal and mechanical characteristics, offering robust scientific guidance for optimizing the manufacturing parameters and attaining the desired performance in different application areas.

References

[1]. Hulle, P. Kadole, and P. Katkar, “Agave Americana Leaf Fibers,” Fibers, 3/1 (Feb. 2015) 64–75, https://doi.org/10.3390/FIB3010064.

[2]. S. Deghboudj, W. Boukhedena, and H. Satha, “Optimization of Bending and Compressive Strength Behavior of Agave americana Fiber Reinforced Cementitious Composite Using Response Surface Methodology,” Periodica Polytechnica Civil Engineering, 67/3 (Apr. 2023) 744–756, https://doi.org/10.3311/PPci.21696.

[3]. I. Mehrez, H. Hachem, R. Gheith, and A. Jemni, “Optimization of Mortar/Agave americana Fibers Composite Behavior Based on Experimental Design,” Journal of Natural Fibers, 20/1 (Apr. 2023) 1-17, https://doi.org/10.1080/15440478.2022.2152149.

[4]. A. Porras, A. Maranon, and I. A. Ashcroft, “Optimal tensile properties of a Manicaria-based biocomposite by the Taguchi method,” Composite Structures, 140 (Apr. 2016), 692–701, https://doi.org/10.1016/J.COMPSTRUCT.2016.01.042.

[5]. S. Navaneethakrishnan and A. Athijayamani, “Taguchi method for optimization of fabrication parameters with mechanical properties in fiber and particulate reinforced composites,” International Journal of Plastics Technology, 19/2 (Dec. 2015) 227–240, https://doi.org/10.1007/S12588-015-9128-X/METRICS.

[6]. A. Bolvari, S. Glenn, R. Janssen, and C. Ellis, “Wear and friction of aramid fibre and PTFE filled composites,” Sealing Technology, 1997/47 (Nov. 1997) 7–9, https://doi.org/10.1016/S1350-4789(00)89141-2.

[7]. S. Kumar and S. Balachander, “Studying the effect of reinforcement parameters on the mechanical properties of natural fibre-woven composites by Taguchi method,” Journal of Industrial Textiles, 50/2 (Aug. 2020)133–148, https://doi.org/10.1177/1528083718823292.

[8]. M. Heidari-Rarani, N. Ezati, P. Sadeghi, and M. R. Badrossamay, “Optimization of FDM process parameters for tensile properties of polylactic acid specimens using Taguchi design of experiment method,” Journal of Thermoplastic Composite Materials, 35/12(Oct. 2020) 2435–2452, https://doi.org/10.1177/0892705720964560.

[9]. Y. S. Tarng and W. H. Yang, “Application of the Taguchi Method to the Optimization of the Submerged Arc Welding Process,” Materials and Manufacturing Processes, 13/3(2007) 455–467, https://doi.org/10.1080/10426919808935262.

[10]. H. C. Yadav, R. Jain, A. R. Singh, and P. K. Mishra, “Kano integrated robust design approach for aesthetical product design: a case study of a car profile,” Journal of Intelligent Manufacturing, 28/7 (Oct. 2017) 1709–1727, https://doi.org/10.1007/S10845-016-1202-5/METRICS.

[11]. S. Datta, A. Bandyopadhyay, and P. K. Pal, "Grey-based taguchi method for optimization of bead geometry in submerged arc bead-on-plate welding," International Journal of Advanced Manufacturing Technology, 39/11–12 (Dec. 2008) 1136–1143, https://doi.org/10.1007/S00170-007-1283-6/METRICS.
[12]. B. Yalçın, A. Yüksel, K. Aslantaş, O. Der, and A. Ercetin, "Optimization of Micro-Drilling of Laminated Aluminum Composite Panel (Al–PE) Using Taguchi Orthogonal Array Design," Materials, 16/13 (Jun. 2023) 4528, https://doi.org/10.3390/MA16134528.
[13]. C. Lin and Z. Shan, "Use of the Taguchi Method and Grey Relational Analysis to Optimize Turning Operations with Multiple Performance Characteristics," Materials and Manufacturing Processes, 19/2 (2007) 209–220, https://doi.org/10.1081/AMP-120029852.
[14]. M. Indira Rani, A. Ramesh, K. Ramu, and N. V. Srinivasulu, "Multi response optimization of process parameters in drilling operation for jute and basalt fabric composite material," International Journal of Engineering and Advanced Technology, 9/1(Oct. 2019) 389–394, https://doi.org/10.35940/IJEAT.A9380.109119.
[15]. R. K. Sharma and J. Singh, "Determination of multi-performance characteristics for powder mixed electric discharge machining of tungsten carbide alloy," The Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 230/2 (Nov. 2014) 303–312, https://doi.org/10.1177/0954405414554017.
[16]. P. A. Sylajakumari, R. Ramakrishnasamy, and G. Palaniappan, "Taguchi Grey Relational Analysis for Multi-Response Optimization of Wear in Co-Continuous Composite," Materials, 11/9 (Sep. 2018) 1743, https://doi.org/10.3390/MA11091743.
[17]. N. Pragadish and M. Pradeep Kumar, "Optimization of Dry EDM Process Parameters Using Grey Relational Analysis," The Arabian Journal for Science and Engineering, 41/11 (Nov. 2016) 4383–4390, https://doi.org/10.1007/S13369-016-2130-6/METRICS.
[18]. D. A. Smait, F. M. Mohammed, H. A. Al-Falahi, H. L. Alwan, and S. Alani, "Analysis of Impact Loading Response on the Composites Materials as a Function of Graphite Filler Content Using Taguchi Method," Revue des Composites et des Matériaux Avancés, 33/2 (Apr. 2023) 121–125 https://doi.org/10.18280/RCMA.330207.

Rust Dyeing on Rayon Fabric and its Evaluation

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Abstract:

Background: Textile wet processing not only uses toxic chemicals that are harmful to people and the environment but also uses a large number of non-renewable resources, leading to their depletion. The study on rust dyeing of rayon fabric was conducted, to address these issues by exploring the use of rusted objects to produce unique designs using very low quantities of water and chemicals.

Methods: Rust dyeing was carried out using two methods: Method I used vinegar as a mordant and steaming (for 1 hour) for fixation, and Method II was carried out for 3 days in the absence of vinegar and steaming. Both the samples were visually assessed and tested for their physical properties (tensile strength and bending length), colour fastness, pH, and anti-microbial properties. The samples were also aged and assessed for the above-mentioned properties after aging. This was done mainly to evaluate the change in the tensile strength of the fabric.

Results and Conclusion: The results obtained were good, as both methods showed excellent colour fastness properties. Method II came out to be more economical, sustainable, and safer. Using this approach, the fabric experienced lesser loss of strength but gave a deeper range of shades and sharp imprints.

Keywords: *Color fastness, Dyeing, Iron, Rayon, Rust, Sustainable*

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1. Introduction

The textile and apparel sector is unsavoury these days due to the number of problems it is causing to the environment, as well as the people living in it. To recover its reputation, it needs to restore its structure by slowing down the consumption of water and various chemicals [1]. Now, the industry is working to achieve a balance between the development of the economy and the protection of the environment [2]. Some brands have started using natural dyes considering the ill effects of synthetic dyes on the environment and human health [3]. On the other hand, there are brands developing new and eco-friendly techniques of dyeing and printing, like CO2-based dyeing (aka, water-less dyeing), invented by a Dutch company named Dyecoo [6]; air dyeing developed by Colorep Inc.; salt-free dyeing by using ECOFAST Pure developed by Dow Company [4,5], dyeing through pigments extracted from microbes and dyeing with REYCROM, powder dyes extracted from textile fibres, developed by Italy-based Officina+39 [5].

Contact dyeing is one of the traditional techniques of dyeing, which also uses very few chemicals and provides beautiful designs by creating bundles with the use of natural materials in low liquor ratios [7]. According to Kadolph and Casselman [8], contact dyeing has the potential to be a more sustainable way of dyeing than immersion dyeing, with the benefits of lower costs, fewer equipment, less labour, safer methods, and reduced water consumption. Kadolph and Casselman[8] highlighted contact dyeing as a cost-effective method for generating intricate patterns and colours using novel materials like organic waste and kitchen pantry items.

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Eco-printing is a type of art that uses natural dyes found in plants, fruits, vegetables, waste materials, by-products, etc. to make interesting visual effects. It is a contact method that uses plants as natural templates to make amazing and interesting colours, textures, traces, and marks on the surface of the fabric [9]. Similarly, there's another application that is referred to as 'Rust Dyeing'. This technique also uses a similar approach to produce very unique designs but with rusted objects instead of any natural material. The resulting colours may be slightly similar, but the resulting effect of the colours varies significantly and is quite interesting. Fabrics that are rust-dyed are safe to wear as they satisfy the requirements of safety for different metals like copper, lead, etc. [10].

The process of rust dyeing is already executed using different natural fabrics like cotton, silk, linen, etc. However, this study of rust dyeing was carried out using rayon fabric, which is a man-made fabric, using the same concept and techniques. Rayon is used as a fashion fabric by various brands to develop numerous categories of garments. So, this study will benefit designers, textile specialists, and fashion and textile students as they can adopt this method to produce innovative and interesting styles of garments that are sustainable and eco-friendly. This was an exploratory study where rusted objects were used as a substitute for dyestuff to create different designs on rayon fabrics. These objects, from their sources, are sent to scrap yards for recycling.

The study focuses on using them before they go to recycling.

The procedure of rust dyeing uses very few chemicals, water, and energy resources as compared to conventional dyeing techniques. This in turn also reduces the overall cost as fewer materials and resources are used. The study was carried out with the following objectives:

- To dye rayon fabric by using rusted objects with two methods - with/without the use of vinegar and steaming
- To test the following properties of the rust-dyed fabric before & after aging the samples: anti-microbial, pH, tensile strength, stiffness, colour fastness
- To rust dye stitched garment/product

2. Materials And Methods

The present study, "Rust Dyeing on Rayon Fabric and its Evaluation" was undertaken to assess the feasibility of the process of rust dyeing, which can be an alternative and a sustainable method to produce unique designs on rayon fabric. The dyeing of the fabric and aging of the dyed fabric were carried out in Dyeing & Printing Lab of the Department of Fabric & Apparel Science, Lady Irwin College. The testing of the fabric samples was carried out in the Instrument Lab, Department of Fabric and Apparel Science, Lady Irwin College.

2.1 Materials Used

2.1.1 Fabrics

The following fabrics were used during the study:

- Rayon fabric: Main fabric, used for rust dyeing
- Wool Fabric: Used for making samples for Perspirometer & Laundrometer to check colour fastness to perspiration & washing

2.1.2 Chemicals & Materials

The following chemicals and materials were used for the study:

- Rusted iron objects: Used as dyestuff, for dyeing, procured from nearby households and scrapyards
- White Vinegar: Used for mordanting
- Sodium Chloride (Common Salt, NaCl): Used to make salt water which helps in fixation of the rust

2.2 Methods Used for Rust Dyeing

Rust dyeing was carried out using two methods:

- Using white vinegar and steaming: Chakirra Claasen [11] in her study cited Charlie Bradley Ross [12], a textile artist who has worked with rusted objects and also shared the process of rust dyeing.
- Without using vinegar and steaming

Both methods were conducted to assess which one is more sustainable and feasible.

2.2.1 Method I – Rust Dyeing Using White Vinegar and Steaming

Stage I – Preparation of the Fabric

a. Scouring: It is one of the pre-treatments given to the fabric to remove all kinds of impurities. This process is most important, as it majorly removes the hydrophobic character of the fabric making it more absorbent. The process of scouring was followed by rinsing of fabric with plain water at room temperature.

b. Mordanting: After scouring, the fabric was mordanted with white vinegar. The vinegar-water solution, with 2 parts water and 1 part vinegar, was used at room temperature. The fabric was mordanted in this solution for half an hour. This was done to hasten the process of dyeing.

Stage II – Contact Dyeing Using Iron Objects

a. Placing of the Rusted Iron Objects: After half an hour, the mordanted fabric was laid out on a big table. The iron objects sourced from different areas were placed over it after planning out the designs [Figure 1]. One can also place the objects randomly to get abstract designs.

b. Bundle Formation: After placing the iron objects, a bundle was formed as shown in Figure 2, according to the design, and it was then wrapped in a plastic sheet, which helped to keep the fabric moistened. The bundle formation and plastic wrapping ensured that the objects stay there and don't shift or fall.

c. Dyeing: Once the bundle was formed, it was placed inside the steamer for 1½ hour. The high temperature of the steamer helped the fabric structure to open up and allowed the ferric oxide to go inside and form bonds with the fibre [Figure 3].

Figure 1: Laying Down Rusted Iron Objects on the Fabric

Figure 2: Formation of Bundle

Figure 3: Dyeing

a. Salt Treatment: After dyeing, the fabric was put in a salt-water bath for 15 minutes, which helped to fix the colour. This is because salt is an electrolyte, which may aid to accelerate the speed of the ferric ions to move towards the fabric [11,12].

b. Washing: The fabric was soaped, washed under running water at room temperature, and dried under the sun. This helped to remove the leftover rust residue, which is in powdered form, from the dyed fabric.

2.2.2. Method II – Rust Dyeing in Absence of White Vinegar and Steaming

Stage I – Preparation of the Fabric

a. Scouring: Same as Method I

Stage II – Contact Dyeing Using Iron Objects

a. Placing of the Iron Objects: Same as Method I

b. Bundle Formation: Same as Method I

c. Dyeing: Once the bundle was formed, it was placed inside a big tub with little water inside.

This bundle was left for 3 days. The water inside the tub helped the fabric to stay moistened and the fabric structure to open up, so that dye can penetrate inside and form bonds with the fabric.

Stage III – Fixation & Washing

a. Salt Treatment: Same as Method I

b. Washing: The fabric was soaped and washed under running water at room temperature and dried under the sun. This helped to remove the leftover rust residue, which is in powdered form, from the dyed fabric.

2.3 Assessment of the Dyed Samples

After dyeing by both methods, samples were evaluated before and after aging them. Evaluation, a crucial phase of the study, helped to know more about the strengths and weaknesses of this dyeing technique.

Aging of the samples

Aging is a technique where the textile material is exposed to standard heat and moisture which simulates its natural aging. This helps researchers and scientists to judge the overall properties of the textile material after it is aged for a particular time period.

Since rust was the main dyestuff used in the process, it is considered a significant factor in the degradation of fabrics. Therefore, the fabric was wet-heat aged for 72 hours (3 days) at 80˚C in a relative humidity of 65% which is equivalent to approximately 25 years of natural aging [13]. This was done to evaluate the difference between the physical and colour fastness properties of the dyed fabric before and after the process of aging.

2.3.1 Tensile Strength

Strength of the fabric is an important property which can be measured by Tensile Strength Tester. For the experiment, 4 fabric samples were prepared to be tested (BW, BS, AW, and AS). From each fabric sample, test samples were measured at 6" x 4" and cut, 3 each from the warp and weft directions. Following formula was used to assess the tensile strength:

$$\text{Elongation \%} = \frac{\text{Initial Length}}{\text{Final Length} - \text{Initial Length}} \times 100$$

Key: BW: Before Aging without Steaming Sample, BS: Before Aging with Steaming Sample, AW: After Aging without Steaming Fabric, AS: After Aging with Steaming Sample

2.3.2 Bending Length

The samples were tested for stiffness by using Shirley Stiffness Tester.

2.3.3 Wash Fastness

A Laundrometer was used to assess the wash fastness of the dyed sample as per the ISO - III test method. The change in colour and staining of the undyed fabric sample was visually examined by BIS Standard 5 – Point Greyscale.

2.3.4 Light Fastness

Colour fastness test to light is used to assess the colour fading of the dyed material when exposed to a defined source of light. MBTF (Mercury Blended Tungsten Filament) Lamp and Light Fastness Tester (Fadometer) was used for measuring the resistance to fading of the dyed samples [14]. The test samples were placed along with the Std. Blue Wool samples specified by BIS.

2.3.5 Crock/Rub Fastness

The instrument which was used to find the colour fastness to rubbing/crocking is referred to as Crock meter [15]. For measuring the colour fastness against crocking, six test samples each, were measured, 14 cm X 5 cm, and cut from four dyed samples (BW, BS, AW, and AS), three for dry and other three for the wet crocking test.

2.3.6 Perspiration Fastness

Perspirometer was used for the testing where, three test samples each were measured, 10 cm x 4 cm, and cut from four dyed fabric samples (BW, BS, AW, and AS). After testing, the change in colour and staining was assessed by using 5 – Point Grey Scale.

2.3.7 Assessment of the pH of the dyed samples

A pH test was done using the Standard ISO 3071:2020 or AATCC 81 method.

2.3.8 Assessment of the anti–microbial properties

The Parallel Streak Method, was used to evaluate the antimicrobial properties of the test sample (AATCC 147).

The method used two test organisms: Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli. The culture mediums used for the test were Nutrient Agar for S. aureus and EMB Agar for E. coli. Five test samples, a control, BW, BS, AW, and AS, measuring 25 mm X 50 mm, were taken. The test was carried out in the Microbiology Lab, Department of Food and Nutrition, Lady Irwin College and Microbiology Department, Mahatma Jyotiba Phule Rohilkhand University, Bareilly. Instruments used during the test were an autoclave, an incubator, a UV light chamber, and a laminar flow chamber.

2.4 Product Development

The final aim of the study was to develop products using the most efficient and sustainable method for rust dyeing.

3. Results and Discussion

The goal of the present study, "Rust Dyeing on Rayon Fabric and its Evaluation," was to determine whether it was possible to put the rusted iron objects into use and dye the rayon fabric with them to create unique and abstract designs. Two methods were used to apply the rust dye to the fabric, the first method was carried out in the presence of vinegar and steaming, and the second one was done in the absence of vinegar and steam. Color fastness properties and physical properties, like tensile strength and stiffness, were assessed. In addition to these, to check whether it was fit for human skin or human use, a pH and anti-microbial test was also conducted.

3.1 Visual Assessment of Rust-Dyed Samples Using Methods I and II

Dyeing was done using two methods. On comparing the samples dyed with both the methods, Figure 4 and 5 revealed that samples dyed with Method II showed a deeper range of shades and a slightly more uniform and clear impression of the objects used for the process.

Figure 4: Rust Dyed Fabric Using Method I

Figure 5: Rust Dyed Fabric Using Method II

3.2 Assessment of Colour Fastness Properties

After dyeing and aging, the 4 samples (BW, BS, AW & AS) were then tested for colour fastness against light, washing, rubbing/crocking and perspiration. The following Tables display the ratings of the same.

Table 1: Wash Fastness Rating of Rust Dyed Samples

Colour Fastness	Type of Method	Grey Scales	Before Aging	After Aging
Wash Fastness	With Vinegar and Steaming (BS)	CC	5	5
		SS	5	5
		SW	5	5
	Without Vinegar and Steaming (BW)	CC	5	5
		SS	5	5
		SW	5	5

Table 2: Light Fastness Rating of Rust Dyed Samples

Colour Fastness	Type of Method	Before Aging	After Aging
Light Fastness	With Vinegar and Steaming (BS)	8	8
	Without Vinegar and Steaming (BW)	8	8

Table 3: Crock/Rub Fastness Rating of Rust Dyed Samples

Colour Fastness	Type of Method	Condition W/D	Grey Scales	Before Aging	After Aging
Crock	With Vinegar and Steaming (BS)	W	CC	5	5
			CS	5	4/5
		D	CC	5	5
			CS	4	4/5
	Without Vinegar and Steaming (BW)	W	CC	4/5	5
			CS	4/5	4/5
		D	CC	5	5
			CS	4	5

Table 4: Perspiration Fastness Rating of Rust Dyed Samples

Colour Fastness	Medium	Type of Method	Grey Scales	Before Aging	After Aging
Perspira tion Fastness	Acidic	With Vinegar and Steaming (BS)	CC	5	5
			SW	5	5
			SS	5	5
		Without Vinegar and Steaming (BW)	CC	5	5
			SW	5	5
			SS	5	5
	Basic	With Vinegar and Steaming (BS	CC	5	5
			SW	5	5
			SS	5	5
		Without Vinegar and Steaming (BW)	CC	5	5
			CC	5	5

Key: CC – Change in Colour; SS – Staining on the Same Fabric; SW – Staining on Wool Fabric; CS – Staining on Cotton Fabric; W – Wet; D – Dry

As shown by the ratings reported in Table 1, 2, 3, and 4, it was evident that the samples dyed with both methods have an excellent wash, light, and perspiration fastness whereas the crock fastness vary from good to excellent. The reason for this could be the strong complex bonding between rust (ferric ions) and cellulose (hydroxyl groups), which causes the colour to be permanent [16].

3.3 Assessment of the Physical Properties of the Dyed Samples

During the pilot study, due to the use of rusted objects for dyeing, various concerns were raised regarding the physical properties of the dyed fabric, like its stiffness and strength. To address them, assessments for stiffness and tensile strength were conducted.

3.3.1 Tensile Strength

The test assessed tensile strength of dyed fabric to determine if it decreased, focusing on load applied to break the fabric. The strength was also checked after aging the sample. The control sample's load at break and % extension, reported in Table 5, was compared to the dyed samples in both warp and weft directions.

Table 5: Load at Break and % Extension of Control Sample in Warp-wise and Weft-wise Direction

Direction	Load (kg)	Peak Value	Elongation (in)	% Extension
Warp-wise	24.4	3.2	1.6	40
Weft-wise	21.5	2.8	1.4	35

Further, the Tables 6, 7, 8 & 9 display the average readings for Load, Peak Value, Elongation and % Extension of the samples before and after they're aged. Additionally, it displays the % Decrease in Load of the same samples.

Table 6: Load at Break and % Extension of Samples Dyed Using Steaming & Vinegar (Before Aging) in Warp-wise and Weft-wise Direction

BEFORE AGING				
Sample Dyed using Steaming & Vinegar				
Direction / **Warp-wise**	**Load (kg)**	**Peak Value**	**Elongation (in)**	**%Extension**
Average	22.8	3.5	1.3	33.3
% Decrease in Load			**6.6 %**	
Weft-wise	**Load (kg)**	**Peak Value**	**Elongation (in)**	**% Extension**
Average	19.5	2.5	1.4	35.8
% Decrease in Load			**9.5 %**	

Table 7: Load at Break and % Extension of Samples Dyed Without Using Steaming & Vinegar (Before Aging) in Warp wise and Weft wise Direction

BEFORE AGING				
Sample Dyed without using Steaming & Vinegar				
Direction / **Warp-wise**	**Load (kg)**	**Peak Value**	**Elongation (in)**	**%Extension**
Average	22.2	3.3	1.2	22.2
% Decrease in Load			**9.2 %**	
Weft-wise	**Load (kg)**	**Peak Value**	**Elongation (in)**	**% Extension**
Average	19.3	3.3	1.4	34.2
% Decrease in Load			**10.4 %**	

Table 8: Load at Break and % Extension of Samples Dyed Using Steaming & Vinegar (After Aging) in Warp -Wise and Weft-Wise Direction

AFTER AGING				
Sample Dyed using Steaming & Vinegar				
Direction Warp-wise	Load (kg)	Peak Value	Elongation (in)	%Extension
Average	21.2	3.8	1.2	30.8
% Decrease in Load			13.0 %	
Weft-wise	Load (kg)	Peak Value	Elongation (in)	% Extension
Average	19.1	3.5	1.3	32.5
% Decrease in Load			11.3 %	

Table 9: Load at Break and % Extension of Samples Dyed Without Using Steaming & Vinegar (After Aging) in Warp-wise and Weft-wise Direction

AFTER AGING				
Sample Dyed without using Steaming & Vinegar				
Direction Warp-wise	Load (kg)	Peak Value	Elongation (in)	%Extension
Average	19.3	3.4	1.1	27.5
% Decrease in Load			20.8 %	
Weft-wise	Load (kg)	Peak Value	Elongation (in)	% Extension
Average	15.9	4.3	1.2	29.2
% Decrease in Load			26.0 %	

Tables 6, 7, 8, and 9 reveal that the fabric's strength slightly decreased after dyeing fabric with rusted objects, with Method II showing slightly more loss compared to Method I. This comparison of Method I and II, before and after aging the samples is represented through a graph in Figure 6 and 7 which shows %Decrease in Load, before and after aging of samples dyed with both the methods. The reason behind the loss of strength is, in Method II, the fabric was kept in contact with the rusted articles for 3 days, causing an increase in the concentration of the dye molecules in the fabric affecting its strength. Furthermore, post-aged dyed samples show reduced strength compared to rust-dyed samples that weren't aged, due to less load applied to break the aged fabric.

The % Extension of all the samples was calculated and found to be more in the weft-wise direction, maybe because in a woven structure, weft yarns are more loosely woven than warp yarns.

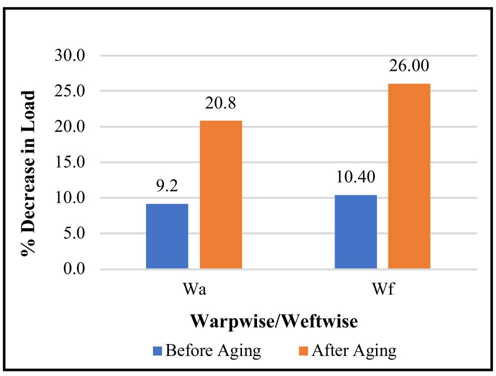

Figure 6: %Decrease in Load Before and After Aging of Samples dyed without using Steam and Vinegar

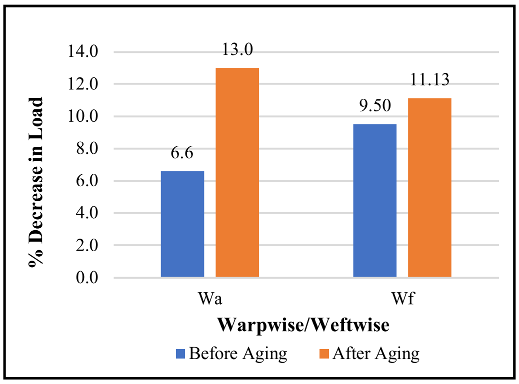

Figure 7: %Decrease in Load Before and After Aging of Samples dyed using Steam and Vinegar

3.3.2 Bending Length

The bending lengths of control and dyed samples reported in Tables 10 and 11, respectively, reveal that there was no significant difference except in warp direction, which was slightly less than that of the control sample, suggesting the technique didn't significantly affect fabric stiffness when kept for 1½ hours in Method I and 3 days in Method II. This may increase if the time of contact is increased.

Table 10: Bending Length of the Control Sample in Warp-wise & Weft-wise Direction

Control Sample	Sides	Directions	
		Warp-wise	Weft-wise
Readings (cm)	Front	1.5	1.1
	Back	1.5	1.0

Table 11: Bending Length of the Dyed Samples in Warp-wise & Weft-wise Direction

Aging	Before Aging				After Aging			
Method	With Vinegar and Steaming (BS)		Without Vinegar and Steaming (BW)		With Vinegar and Steaming (AS)		With Vinegar and Steaming (AS)	
Direction	W_p	W_f	W_p	W_f	W_p	W_f	W_p	W_f
Average of Readings (cm)	1.13	1.17	1.22	1.08	1.20	1.03	1.23	1.10

3.4 Assessment of the pH Properties of the Dyed Samples

On testing, the results which are presented in Table 12, were found to be in the range of 6.8 – 7.5, which is likely to fall within the neutral range and is an acceptable range of fabric pH for adults. This meant that the garment made from rust-dyed fabric can be comfortably used by human beings, as rust didn't change the pH of the fabric.

Table 12: Resulted pH of the Rust Dyed Samples

Aging	Before Aging		After Aging	
Method	With Vinegar and Steaming (BS)	Without Vinegar and Steaming (BW)	With Vinegar and Steaming (AS)	Without Vinegar and Steaming (AW)
Average of Readings	6.8	7.4	7.5	7.3

3.5 Assessment of the Antimicrobial Properties of the Dyed Samples

The study evaluated the anti-microbial activity of control and rust-dyed samples against Gram-positive S. aureus and Gram-negative E. coli. The results showed minimal growth of S. aureus (Fig. 8) and E. coli (Fig. 9) on the dyed fabrics, implying the possibility of very slight antibacterial properties in the dyed fabric.

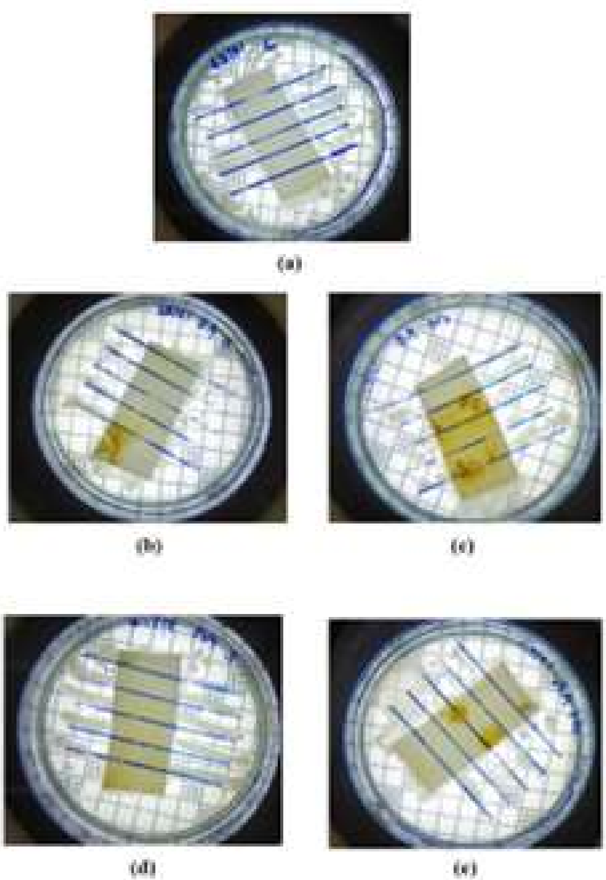

Figure 8 - Qualitative Evaluation of Anti-Microbial Activity of Control and Rust Dyed Samples in Neutral Medium against Gram Positive Bacteria (S. aureus) [(a) Control Rayon Sample, (b) Before Aging with Steaming & Vinegar, (c) Before Aging without Steaming & Vinegar, (d) After Aging with Steaming & Vinegar, (e) After Aging without Steaming & Vinegar]

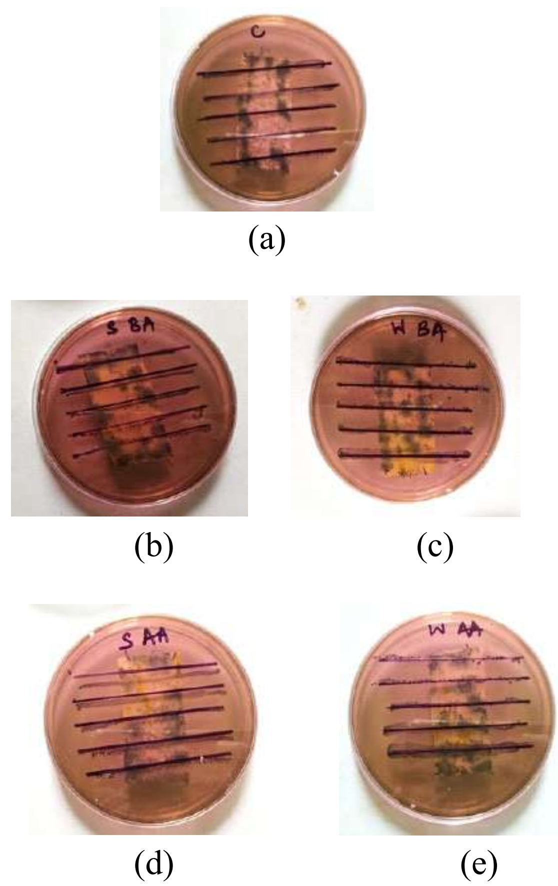

Figure 9 - Qualitative Evaluation of Anti-Microbial Activity of Control and Rust Dyed Samples in Neutral Medium against Gram Negative Bacteria (E. coli) [(a) Control Rayon Sample, (b) Before Aging with Steaming & Vinegar, (c) Before Aging without Steaming & Vinegar, (d) After Aging with Steaming & Vinegar, (e) After Aging without Steaming & Vinegar]

3.6 *Product Development*

The product was developed using Method II, in which rust dyeing was done in the absence of vinegar and steaming. The reason for this is that this method is much more efficient as it uses less water, energy and chemicals. The products developed were a tank top and a cushion cover as shown in Figure 10 and 11 respectively.

FRONT BACK NECKLINE

Figure 10: Tank Top Made with Rust Dyeing

Figure 11: Cushion Cover Made with Rust Dyeing

4. Summary and Conclusion

This study used two methods for carrying out rust dyeing. Out of the two methods, Method II, where dyeing took place in the absence of vinegar and steam, showed deeper shades of colour and slightly clearer impressions of the objects used, whereas samples dyed using Method I showed lighter shades of orange and brown. All the samples showed great fastness properties due to the formation of strong complexes between ferric ions and the hydroxyl groups of cellulose present in rayon fabric. Furthermore, the tensile strength decreases as the fabric is aged, and it also depends on the time of contact. It will decrease with an increase in the concentration of dye molecules and time of contact. The rust-dyed fabric proved to be safe and comfortable for human skin, as its pH ranged from 6.8 to 7.5. Additionally, it showed little anti–bacterial properties also. The absence of hazardous chemicals, low water consumption, and energy-intensive procedures led to the further conclusion that Method II is safer and sustainable.

This research may have future implications for enhancing fabric strength through rusted object dyeing. Investigating different contact durations can inform improvements in color fastness and physical properties across various fabric types, potentially leading to innovative and sustainable designs. Furthermore, this study also highlights the limitation of producing colour variations which can be studied later to explore possible solutions.

5. Acknowledgement

I am extremely grateful to Dr. Alok Srivastava, Associate Professor, Department of Microbiology, M. J. P. Rohilkhand University, Bareilly, for giving permission to conduct an antimicrobial test in the university facilities.

References

[1] E. Csanák,"The Rise of Sustainable Fashion – Glossary for an Article",Journal of Textile Science & Fashion Technology, (4/1) (Nov'2018), https://doi.org/10.33552/jtsft.2018.01.000517

[2] F. Vermandel. Dyeing needs to be Sustainable; Fibre2Fashion, [Jun'2016; accessed on Nov' 2022, 25], http://www.fibre2fashion.com/industry-article/7752/dyeing-needs-to-be-sustainable

[3] M. Kasiri, S. Safapour, "Natural dyes and antimicrobials for green treatment of textiles", Environmental Chemistry Letters, (12/1) (1-13), (Mar'2014), https://doi.org/10.1007/s10311-013-0426-2

[4] R. Mitra. Sustainable dyeing techniques– preventing water pollution; CRB: Centre for Responsible Business; [Apr'2021; accessed on Nov'2022, 27], https://c4rb.org/sustainable-dyeing-techniques-preventing-water-pollution/

[5] V. Mogilireddy. Sustainable dyeing innovations: Greener ways to color textiles; Prescouter; [Nov'2018, accessed on November 2022, 25] https://www.prescouter.com/2018/11/sustainable-dyeing-innovations-greener-ways-color-textiles/

[6] S. Willis. How Sustainable Dyeing is Changing the Textile Industry; Plug and Play; [Apr'2023; accessed on Nov'21, 2022] https://www.plugandplaytechcenter.com/resources/how-sustainable-dyeing-changing-textile-industry/

[7] L. Barker, P.Wietocha, E. Ekstrom, A. Winters & U-J. Yu. Colorfastness of Naturally-Dyed Fabrics Using Contact Dyeing Method; International Textile and Apparel Association Annual Conference Proceedings; Iowa State University Digital Press, (Jan'2017)

[8] S. Kadolph, K. Casselman. "In the Bag: Contact Natural Dyes"; Clothing and Textiles Research Journal, (22/1-2) (15-21), (Jan'2004) https://doi.org/10.1177/0887302X0402200103

[9] Ö. Erdem İşmal. "Patterns from Nature: Contact Printing"; Journal of the Textile Association, (77) (81-91), (Jul'2016) https://www.researchgate.net/publication/310751734

[10] S. D. Ramadhani & A. Hendrawan. Penerapan Teknik Rust Dyeing Sebagai Pewarna Alami Alternatif Ramah Lingkungan; eProceedings of Art & Design, Telkom University Open Library; [Aug'2020, accessed on Oct'6, 2022] https://openlibrarypublications.telkomuniversity.ac.id/index.php/artdesign/article/view/12557/12312

[11] C. Claasen. Documenting a creative process: rust as means to create innovative textiles for fashion/art; UNAM; [Nov'2021; accessed on Oct'4, 2022] https://repository.unam.edu.na/handle/11070/3177

[12] C. B. Ross. Unusual Eco Design Technique: Rust Dyeing; The Sustainable Fashion Collective; [Jun'27, 2015; accessed on Oct'4, 2022] https://www.the-sustainable-fashion-collective.com/2015/05/27/unusual-eco-design-technique-rust-dyeing/

[13] J. Liu, Y. Li, D. Hu, H. Xing, X. Cao & Z. Jia. "Correction to: A new method for the conservation of ancient colored paintings on ramie textiles", Heritage Science, (9/1) (38), (Dec'2021) https://doi.org/10.1186/s40494-021-00510-7

[14] M I. Kiron. Working Principle of Color Fastness to Light; Textile Learner; [Dec'2021; accessed on Feb'2023, 12] https://textilelearner.net/color-fastness-to-light/

[15] M I. Kiron. Features, Specifications and Working Principle of Rubbing Fastness Tester; Textile Learner; [Dec'2021; accessed on Feb'2023, 12] https://textilelearner.net/features-working-principle-of-crockmeter/

[16] B. Miao, Z. Zhao, P. Guo, H. Li, Y. Wang. Cleaning iron rust compounds from cotton textiles: application to Qing Dynasty armor, Heritage Science, (11/1) (56), (Mar'2023) https://doi.org/10.1186/s40494-023-00885-9

Vilas Gharat

Mr. Vilas Gharat is working as a Managing Director, for Gharat & Associates, having over 50 years' experience in manufacturing function in all composite sectors of Textile Industry. Out of which more than a decade in Operations and HR with emphasis in Business Process Consulting,

Mr. Gharat is having Specialization in various field of textile value chain like;

- Change Management, Business Development and Project Management
- Project Management, Business Development
- Supply Chain Management
- Resource Allocation
- Process Reengineering
- Change Management, Production and Business
- Planning Function
- Training and Mentoring CEO's

He has wide experience in:
Business Consultant for Oswal Hammerle, for their upcoming state of art technology plant for manufacture of sophisticated Yarn Dyed Shirting Project, primarily catering to the needs of international garment manufacturers. This is a Joint Venture project of Oswal group and F.M. Hammerle (Austria)

His previous assignment involves restructuring and transformation of a large Textile units

He worked with various executive capacities as Executive Director -Suvin Advisors Pvt Ltd.; Senior President in S Kumar's., Technical & Commercial Advisor in J. K. Cotton Mills, Senior President in Morarjee Brembana Ltd., Birla's in Indonesia, Oswal Hammerle, Bhojsons, Nigeria etc.

Awards:
Mr. Gharat was awarded with Best General Manager Award in MSTC - National Award for energy conservation for Simplex Mills & MSTC and Best Vendor Award from Johnson & Johnson.

Mr. Gharat was awarded with FTA by The Textile Association (India) in 1999,

Mr. Vilas Gharat was a President of The Textile Association (India) - Mumbai Unit during 2017-2019 and 2019-2021. Now he is on the Board of Trustees of TAI – Mumbai Unit.

E-mail: vilasgharat@gmail.com, gharatandassociates@gmail.com

Opportunity to India Garment Industry for 2025-26

Vilas V. Gharat,
Managing Director (Gharat & Associates); Board Member of Trustees (The Textile Association (India) – Mumbai Unit); GEM of Mentor India (AIIM-NITI Aayog, Govt. of India

Bangladesh Crisis: In view of short supply from Bangladesh, India can avail following benefits

The ongoing political instability in Bangladesh presents a significant opportunity for Indian garment exporters to capture a larger share of the global apparel market, with potential to gain substantial new orders from global brands seeking alternative suppliers due to disruptions in Bangladesh's production, particularly in regions like Tiruppur, which could see a substantial influx of new business.

Key points about the opportunity for Indian garment exports

Shifting orders

As Bangladesh faces political unrest, a portion of its garment export orders are expected to shift towards India, potentially boosting Indian exports by hundreds of millions of dollars per month.

Increased demand from global brands:

Major international brands relying on Bangladesh for apparel may look to diversify their sourcing by placing more orders with Indian manufacturers due to concerns about production disruptions.

Focus on specific regions

Indian textile hubs like Tiruppur are well-positioned to benefit from this shift due to their established knitwear production capabilities.

Potential for higher margins

Depending on the scale of the shift, Indian exporters could see increased profit margins as they attract new business from global brands.

However, some points to consider:

Temporary nature:

While the current crisis in Bangladesh presents a short-term opportunity, the long-term viability of increased Indian garment exports will depend on factors like maintaining competitiveness in terms of price and quality.

Need for infrastructure development

To fully capitalize on this opportunity, India might need to further strengthen its textile infrastructure and production capacity.

Potential for market fluctuations:

The extent of order shifts will depend on how the situation in Bangladesh evolves and how quickly other competing garment exporting countries can respond.

Predicting the future of the Indian garment industry for 2025 involves looking at current trends, government policies, technological advancements, and market demands. Here are some key aspects that could shape the industry.

Sustainability and Eco-Friendly Practices

An increasing global awareness of environmental issues is pushing the textile and garment industry towards more sustainable practices. By 2025, we can expect a significant number of Indian garment manufacturers to adopt eco-friendly materials and processes. Organic cotton, recycled fabrics, and water saving dyeing techniques will become more prevalent.

Technological Advancements

Technology will play a pivotal role in transforming the Indian garment industry. Automation, artificial … Expanding global market reach by 2025 requires Indian garment manufacturers to adopt strategic, innovative, and sustainable practices that cater to the changing dynamics of the global apparel market.

Here are key strategies that can help accomplish this goal:

Embrace Sustainable and Ethical Manufacturing: With a significant global shift towards sustainability, Indian manufacturers should focus on sustainable production methods. Utilizing organic materials, reducing water consumption, and minimizing carbon footprints could become key selling points. Ethical labor practices will also attract more global buyers looking to invest in responsible sourcing.

Enhance Quality Standards: Competing on an international level means matching or surpassing global quality standards.

Indian exporter's eye gains as global garment brands Shun Bangladesh

Indian garment manufacturing hub set for gains as global escape the uncertainty of a restive Bangladesh, deals worth billions of Dollars start shifting borders.

- The political unrest in Bangladesh is turning into a financial bonanza for Indian textile and garment industry.

Gautam Singhania

Billions of Dollars in fresh orders from Marquee buyers in the west are shifting to Indian textile companies.

- Bangladesh is a garment sector powerhouse, having seen exports surge by 90per cent to $47 billion in 2023. The country was the third largest exporter of cloths last year after China and the European Union (EU), and the sector accounts for over 80 percent of the its total export earnings. India's garment export, in comparison are less than half the size at the sixth position.

- Indian garment manufacturers have multiple opportunities to explore niche markets that can significantly enhance their global footprint and profitability. Here are some potential niche markets worth considering:
- Ethical and sustainable fashion: With an increasing global emphasis on sustainability, there is a growing demand for garments made from organic, recycled, or eco-friendly materials. Indian manufacturers could leverage their access to organic cotton and traditional, eco-friendly dyeing and weaving techniques.
- Performance and technical wear: This includes sportswear, active wear, and clothing designed for specific environmental conditions or activities. Given India's advancements in textile technology, there is potential to develop garments with unique properties (such as moisture-wicking, temperature regulation, or antimicrobial).
- Plus-size fashion: The demand for plus-size clothing is rising globally, offering a significant market opportunity. Indian manufacturers could cater to this segment by

producing fashionable, well-fitting, and diverse clothing options.

- Handcrafted and artisanal products: There is a niche but growing international market for handcrafted garments that showcase traditional Indian craftsmanship, such as handloom weaving, block printing, and embroidery. These products can command a premium in markets appreciative of artisanal quality and cultural value.
- Virtual fashion for digital platforms: As digital and virtual platforms grow, so does the demand for virtual fashion, including garments designed for use in digital environments and social media. Indian manufacturers could explore this futuristic market by partnering with tech companies.
- Adaptive clothing for the differently abled: There's an increasing awareness and demand for fashion that caters to people with disabilities or body shapes that require specially designed clothing. This includes garments with easy-to-use closures, adjustable features, and comfortable fits.
- Maternity and nursing wear: While not entirely niche, there is always a steady demand for maternity and nursing wear that combines comfort, functionality, and style. Innovative designs that cater to pre and post-pregnancy needs can capture a loyal customer base.
- Heritage revival: Focusing on reviving ancient Indian techniques and textiles, but with modern designs that appeal to the contemporary market. This can include using rare fabrics, traditional methods, or regional designs that have lost prominence.
- Tech-integrated wearables: Garments integrated with technology for health monitoring, connectivity, or enhanced convenience. Although a highly specialized field, it's burgeoning, with applications ranging from sports to daily health management.
- Limited edition and collaboration collections: * Creating limited edition collections or collaborating with designers, artists, or celebrities can generate hype and exclusivity, appealing to premium markets.
- For Indian garment manufacturers, success in these niches depends on a combination of innovation, understanding market needs, quality production, and effective marketing. Leveraging India's rich cultural heritage and recent advancements in textile technology can create a unique selling proposition in these niche markets.

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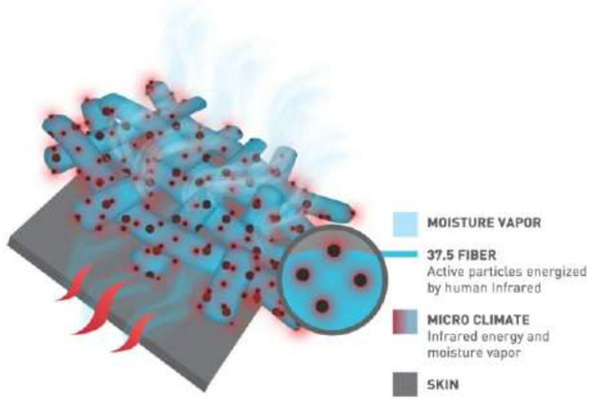
E-mail: vilasgharat@gmail.com
www.gharatandassociates.com

New Materials Based Disruptive Textile Technologies

Radhakrishnaiah Parachuru
Georgia Institute of Technology, Atlanta, GA

37.5® Technology – Sustainable Temperature Regulating Materials for Clothing, Home Goods and Footwear
https://www.thirtysevenfive.com/thermoregulation-technology/
https://www.youtube.com/watch?v=0IOBcyrHMtU

Proprietary 37.5® Technology helps body to stay in its natural comfort zone. It provides temperature regulating fabrics and materials that help to keep the body cool when it is hot and warm when it is cold. It helps to design high performance clothing and bedding products.



- **Active Natural Particles**

The technology permanently incorporates ultra-porous volcanic minerals and coconut-derived activated carbon into fabrics, insulations, foams, and laminate materials using a proprietary process.

- **Powered by Body's Own Energy**

The temperature regulating material works by absorbing the infrared (IR) energy naturally emitted by the body, which energizes the active particles to speed up evaporation and remove humidity next to the skin.

- **Increased Surface Area**

Billions of micro-pores in the active particles massively increase the surface area of fibers and other materials to remove moisture at the vapor stage before the body begins to accumulate sweat. Unlike wicking materials that simply distribute moisture, the temperature regulating fabrics and materials with 37.5 Technology actually remove it.

- **How It Started**

The technology was created by a scientist with physical chemistry background. In 1992, while in Japan on a postdoctoral fellowship, he was taken to the volcanic sand baths on Mt. Aso. At first, he thought he would only be able to stand the heat for a few minutes, but once buried in the sand, he found it surprisingly comfortable. So comfortable, he ended up staying in the sand for an hour. Through this experience, he realized that comfort comes from a balance between heat gain and heat loss. The volcanic sand was removing the sweat vapor from his skin so fast that he was continually cooled by sweat evaporation. It dawned on him that removing the sweat vapor before it turns to liquid sweat is key to comfort. While other researchers were focused on wicking—spreading liquid sweat on fabric—he focused on reducing humidity next to skin to maximize evaporative cooling. His approach enhanced comfort performance by reducing the core temperature buildup.

Name Explains What the Technology is about

It is known that human performance and comfort depend on maintaining core temperature of around 37.5°C, along with a next-to-skin humidity of 37.5%. 37.5 Technology does just that. The thermoregulating fabrics and materials are designed to help the body stay at 37.5°C and 37% humidity level. Temperature and humidity levels are maintained at all activity levels.

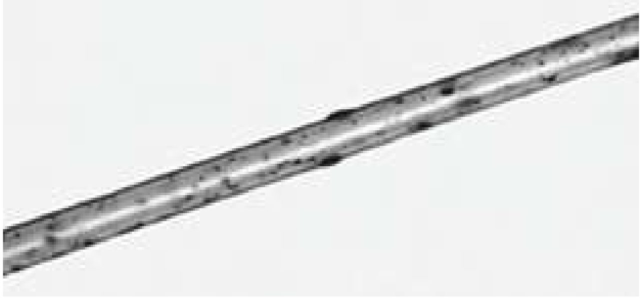
Permanently Performing Non-Chemical Materials

The active particles are permanently embedded into materials. This means durable lifetime thermoregulating performance. In contrast, 'wicking' materials are usually treated with a chemical finish which can progressively wear out over a few laundry cycles.

Traps & Releases Odors

The active particles in 37.5 Technology actually trap odor molecules and release them in the wash. Products with 37.5 Technology come out smelling fresh after wash.

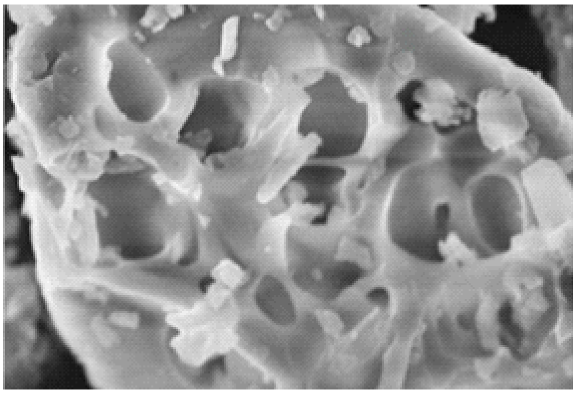
37.5 Technology Up-Close



In a single yarn filament, one can see active thermoregulating particles. They are permanently embedded and will not wash out.

Looking under a microscope, one can see the massive surface area each particle brings to the material. This exposed surface is what interacts with sweat.

https://www.thirtysevenfive.com/thermoregulation-technology/



i. Summary of the Invention

37.5 Technology helps body to regulate temperature through the use of active particles that are permanently embedded within the materials. These particles attract moisture vapor and move it away from the skin. The more of these active particles present in a clothing system or bedding system, the more efficiently they can move the humidity away from the skin.
https://www.youtube.com/watch?v=Abv6nukdHcg

ii. A New approach to enrich and regenerate soil using end of life-cycle clothing that is mostly dumped in open air and land fills

This article describes the pioneering work of a clean technology company based in Australia. The progressive textile recycling company, BlockTexx has demonstrated how end of life cycle clothing that is currently causing major environmental pollution can be turned around and used for the mitigation of the rapidly deteriorating environment. The Loganholme-based company has worked with Logan City Council to engineer a new type of mulch and seed mixture that could increase grass coverage at a local park. BlockTexx's hydromulch – a blend of recycled cotton fibers, grass seed and fertilizer -- is promoting turf growth by increasing nutrient levels in soil and helping soil to retain moisture.

Figure 1. Illustration of healthy grass grown on bear soil using cotton-mixed hydromulch

BlockTexx's textile recycling process uses discarded 100% cotton and cotton/polyester clothing to accomplish the miracle. While using blends, it chemically separates cotton fibers from polyester. The cotton is then reused in a cellulose clay that can be added to hydromulch. The separated polyester material has also been found suitable for re-use in textile and nontextile applications.

City of Logan Mayor Jon Raven said the council was proud to support innovative local companies such as BlockTexx that are exploring new solutions to combat climate change and reduce waste in landfills. Raven also says encouraging local businesses to explore new ideas is a priority for his council, especially when those ideas help reduce waste heading into landfill or create new revenue streams for people.

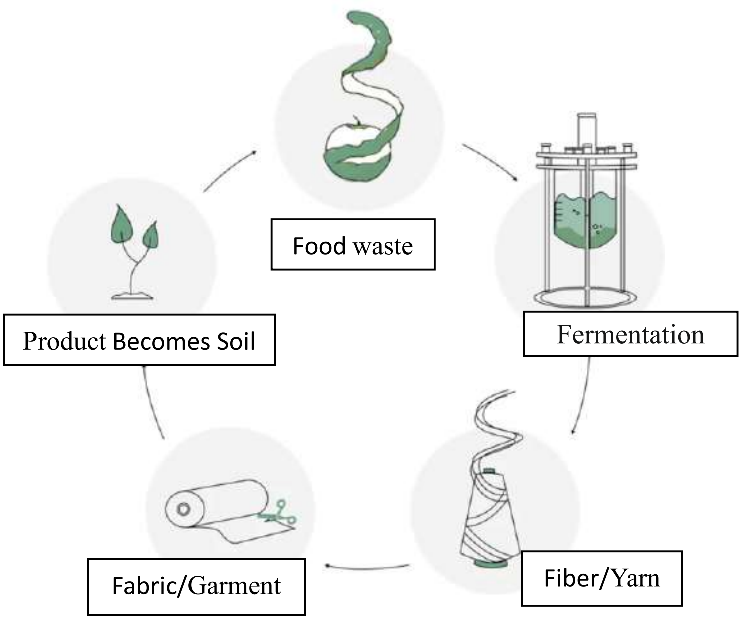
BlockTexx co-founder Graham Ross said the company was delighted to work with the council to find new environment friendly applications for textiles that get dumped in the soil and keep polluting water, air and soil for decades. According to Ross, cotton breaks down to cellulose, which contains about 43 per cent embedded carbon and is the building block of plants and animals. By combining cellulose into a hydromulch mix of fertilizer, grass seed and water, the company is taking what grows in nature in the first place and is putting it back into nature. This is incredibly important not only for our environment, but also for product development. Recycling is good in itself, but resource recovery goes much farther and establishes full circularity.

The company applied hydromulch to a section of ground in the local park while another section in the same park was used for the city council's regular turf growth procedure. Four weeks later, a thick layer of grass was seen in the hydromulch site which looked considerably healthier than the comparison grass patch. BlockTexx scientists have also recorded higher levels of moisture retention in their patch. It is hoped that sharing of this amazingly beneficial development can promote its rapid adoption around the globe.

iii. 360 Degree circular polyester apparel from abundant food waste

This story is a description of an attractive innovative new approach developed by two Toronto residents who own ALT TEX, a company that aims to revamp the fashion industry by creating sustainable garments. This particular development is very attractive from the economic and environmental benefits it offers. The company shows how to create a radically sustainable polyester alternative, from one of the world's largest landfill materials – food waste. The world generates close to one billion tons of food waste every year. Putting it to good use can not only reduce environmental damage but also generate new income and public welfare around the globe. ALT TEX takes the abundant waste and turns it into fashion garments. The patent pending technology of the company simply works as shown below to convert food waste into completely recyclable fashion garments.

Food ⟶ Fermenta on ⟶ Fiber ⟶ Fabric/Garment ⟶ Soil



ALT TEX claims that its process leads to radically circular textiles and helps the industry and public in multiple ways.

Aids the Carbon Neutral Strategy of the industry: Roughly 1/3 of the fashion industry has committed to carbon neutrality by 2050. By capturing emissions from landfill-destined food waste and using a process that uses 60% less energy than polyester manufacturing, the ALT TEX solution is carbon neutral.

The End-Product is Fully Biodegradable: Not only is the ALT TEX fabric is derived from a waste source, it's biodegradability means it can be decomposed in industrial digestors to return back to the earth.

The Process is Very Cost Effective: By utilizing one of the world's largest waste materials that harms the environment as feedstock, ALT TEX's process is cost competitive to other premium sustainable fabric alternatives.

The End-Product Offers Full Functionality: The ALT TEX polymer behaves like polyester and is melt extruded, giving it mechanical benefits similar to polyester such as high durability and versatility in a variety of textile applications

ALT TEX came together as a group of scientists and entrepreneurs passionate about the fashion industry. They decided to develop an alternative synthetic material that could reduce the impact of fast fashion's wasteful and adverse environmental practices. After years of research, the team created the first ALT TEX fabric from food waste, scaled it 100X, raised millions of dollars and is working to commercialize its technology.

https://www.linkedin.com/company/alt-tex/

Website: http://www.thealttex.com

Reminisces – on the 4th Death Anniversary of Shri Late Arvind Sinha

By Mr. Satyanarayan Rath (Research Scholar, EDII & Ex- IACC)

Late Shri Arvind Sinha ji
A man who is loved and respected by many

This write-up is a memoir about my interaction with the late Shri Arvind Sinha ji, with whom I had worked closely during my short stint at the Indo-American Chamber of Commerce in Mumbai. I have considered penning this as an individual experience for some years but have failed many a times. Today, my attempt to write on his 4th Death Anniversary (15-07-2024) is to share my experience while working with him for nearly 5 years and the loving aspect of being humane.

Mr. Sinha was an Advisor for the IACC Textile Forum; later, he became the Co-Chairman of the Textile Forum and held many prestigious positions. Before joining IACC, he was the Past President of the Textile Association (India), one of the largest textile industry associations. He had worked closely with the World Bank and IMF. His hobby was collecting lapel pins from various countries, which he later showed it to me recognized by Guinness World Records. Having all these distinctive professional accomplishments, people know him as incredibly kind and gentle as a human being and a true Punjabi at heart.

After studying at various B-schools, I learnt that leadership lessons can't be taught in a formalized environment. Instead, it comes with a culture. In my views, the best way to learn about leadership is to closely associate with a leader and learn by watching how they do things differently rather than doing different things. The best way to learn things is to learn by doing or by watching others doing.

Most of our textile meetings happened at the Indo-American Chamber of Commerce Office, Churchgate, or we used to have it in the Chairman's Office at Fort. During those days, Mr. Suresh Kotak was the Chairman of the Textile Forum. We used to have long meetings at his fort office. Most meetings revolved around strategizing and making textiles an essential commodity for the Indo-US trade and an attempt to make it a part of Strategic Commercial Dialogue. The discussions were informative and insightful and it always ended with a course of action.

The forum was highly active and doing well with input from Mr. Sinha and the involvement of the Chairman. The forum organized many successful meetings. Under the leadership of Mr. Kotak and Mr. Sinha, the textile forum organized its first meeting with the Head of US Commercial Service, Mumbai. Later, with assistance from Mr. Sharad Tandon, CEO, Standon Consulting the forum organized meetings with the Southern Gujarat Chamber of Commerce and Industry (SGCCI), one of the active chambers having members from the garment cluster. The discussion revolved around making Surat a destination for Indo-American trade. There are many people to thank in this endeavor and the support from Mr. J B Soma from TAI was indeed helpful in organizing many virtual as well as offline programs. I could think of this quote where it says "alone we can do so little; together we can do so much." – Helen Keller.

Then we had the mega Conference on Textiles with the theme "Achieving USD 100 Billion Trade in Textiles- A rising Crescendo". From a bilateral point of view, it was made clear that Indo-US trade won't end with a zero-sum game. However, this was challenging for our partners to understand. We used to have frequent meetings with the US Consulate in Mumbai. The best part was having two States of USA (North Carolina and South Carolina) as strategic partners to promote collaboration and joint investments.

Mr. Sinha was dynamic and passionate in contributing to the Indian textile industry. For long hours, he used to discuss how USA can benefit from Indian textiles and the growing demand of camouflage fabrics in USA defense industry can be scope for collaboration.

He played an important role in getting Reliance Industries into the Textile forum board. The forum was blessed to receive guidance and bilateral trade inputs from many respectable textile manufacturers having their base at USA, such as Welspun, Indo Count, Sutlej Textile Industries, and Reliance Industries.

Whenever there used to be any hurdle, he would have an alternative solution to the problem. I always used to ask him, Sir, how do you come up with so many ready-made solutions? How do you find a way to do it? Then, with a blink in his eyes, he says that if the solution weren't there, the problem probably wouldn't have been there, so every issue comes with a solution.

Mr. Sinha was immaculately thorough in his well-researched writings on cross cultural aspects of trade and development. When I would approach him with a brief briefing note, he would smile and say better next time. Their way of teaching lessons was quite sharp, but invaluably it will remain with you for long and will develop your professional skills.

I have seen him on the ground as a transformational leader; he enjoyed motivating others to achieve goals, and sometimes, he played being an authentic leader who guided and inspired everyone with genuine feedback. He was a die-hard optimist and a faithful lion member.

I was fortunate to have worked with him and learned some of the best management lessons, which I wouldn't have learned from anywhere else. I am deeply grateful for sharing his wisdom and will cherish our association forever.

APPEAL TO TAI MEMBERS

Dear Members,

You are requested to update your contact details to enable us to update the mailing list.

1. Full Name (Surname, First Name & Middle Name)
2. TAI Unit Name (you are registered)
3. Membership Registration No.
4. Date of Registered
5. Corresponding Full Address (with Pin code No. & State)
6. Contact No. (Landline & Mobile No.)
7. E-mail ID

Please furnish above details to your respective Units at your earliest.
Or sent it to
taicnt@gmail.com

UNITS ACTIVITY

TAI – Ahmedabad Unit

12th April 2024

TAI-Ahmedabad Unit organized free Tricycle & Wheel Chair distribution function for handicapped with the help of Bharat Vikash Parishad (Vatva Branch) at Dinesh Hall Auditorium. It's a part of Social Activities of the Association. Association donated 30 nos. wheel chairs and 31 nos. tricycles to the individual needy handicapped persons. In the function around 300 members and beneficiaries of Tricycle & Wheel chairs were present. All the beneficiaries blessed to the association for such type of social activity for the handicapped.

22nd April 2024

The Textile Association (India) Ahmedabad Unit donated two electronic smart boards to the Textile Technology Department classroom of L. D. College of Engineering, Ahmedabad. All office bearers of Association attended the Inaugural Function of Smart Board held at L.D. College of Engineering, Ahmedabad. This is a part of educational activities of our association. Shri T. L. Patel, Trustee inaugurated the function and delivered a speech about its necessity of smart board enabled classroom in this prestigious college

23rd May 2024

TAI Ahmedabad Unit & The Administrative Staff College of India (Hyderabad) with support from UNIDO jointly organised Half day Seminar on "Eliminating Hazardous Chemicals from Textile Supply Chain in India" at Seminar room of Association. Around 25-30 participants attended the meeting from different textile mills/organization. The presentation was very much informative to the participants.

15th June 2024

TAI-Ahmedabad Unit was one of the supporting organisations of GCCI Textile Leadership Conclave 2024 held on 15th June 2024 at Golden Glory Hall, Karnavati Club, Ahmedabad. Shri Hasmukhbhai S. Patel, President- TAI Ahmedabad Unit & Member of Parliament graced the function as a Chief Guest. During his deliberation as chief guest he said that "The Textile Industry had a much higher share in total production and exports till 2000, but due to slow policy decisions its share in India's exports came down. Also many composite mills closed due to lack of labour reform and new technology".

18th June 2024

A Panel discussion was held on 18th June 2024 on CIRCULARITY IN TEXTILES at Hotel Crown Plaza, Ahmedabad. Dr. Ashwin I. Thakkar, Chairman – TAI Ahmedabad Unit was one of the panelists in the panel discussion.

27th – 28th June 2024

An internship of Textile Students was arranged by the TAI-Ahmedabad Unit for Sem-2 students of Diploma in DTMT (RCTI), Ahmedabad. Shri H. R. Soneji, Retired Lecturer-RCTI provided lecture on the topic of Introduction to Textile Industry during two days training program.

Overseas Conference in Sri Lanka

After the very successfully organised first truly International Conference beyond the seas in Bangkok in 2015,
The Textile Association (India) set yet another landmark in its illustrious track record of building up platforms for introduction and brainstorming on current issues of relevance to the textile fraternity, industry interaction and business development. Towards this end TAI organized its 2nd Overseas Conference with the theme "Global Textiles and Apparel Industry Sustainable Technology" at the prestigious BMICH-Colombo on the 7th of August 2024.

Mr. T. L. Patel, President of The Textile Association (India) welcomed Chief Guest Mr. Keatan Sanghvi, Chairman, India ITME Society and presented a flower of bouquet.

Lighting of Lamp by Chief Guest and all Office Bearers. Mr. T. L. Patel, President of The Textile Association (India) delivers his Presidential address of the Conference.

Mr. R. K. Vij, President Emeritus and Conference Chairman briefed about the Conference.

Mr. Ketan Sanghvi delivers Inaugural Address.

Lastly **Mr. Mahendrabhai G. Patel,** Hon. Gen. Secretary delivers Vote of Thanks.

The conference had a healthy attendance and attracted a fair number of professionals, business stalwarts, entrepreneurs and Sri Lankan Govt. and associated officials.

The audience keenly listened to and interacted with the five prominent speakers and three panelists who presented their papers and discussed their innovative findings and solutions for the most pressing need of our times for the garmenting industry – sustainability.

The speakers were:

Mr. Subhash Bhargava: Managing Director of Colorant Ltd. India. He stressed the need for a conscious effort at reducing carbon footprint through strong and responsible research, aimed at producing more eco-friendly dyes and chemicals. He stressed the need for proper certification, use of ethical manufacturing processes and focus on reducing water usage and consumption. Educating the market to create more aware and responsible consumers was an essential step towards reaching this goal. Further, to strengthen use of ethical processes he suggested that the need was for a) Ease of certification b) Strict compliance of regulations and c) Stringent penalties for violators. He stressed that if we are to create the proper space for responsible manufacturing in the garmenting industry, this was the path to tread.

Ms Anoushka Veljee: Global Sales Manager of Frontier. Cool. Inc. A California based company that focuses on reducing wasteful expenditure on sampling activities, long time schedules, and needless movement of garment pieces for approvals an alterations before bulk production. They have developed a digital eco-system for garment manufacturers through AI empowered fabric analysis. This would go a long way in reducing lead time in sampling, unnecessary movement of unapproved fabric samples that would end up in waste, a tremendous reduction in dead fabric inventory and needless movement of garment samples that leaves a sizeable carbon-footprint.

Ms. Chandrima Chatterjee: Secretary General of Confederation of Indian Textile Industries She spoke extensively on the urgent need of Indian Textile industries exporting to the European markets to address the requirements for meeting the new and stringent requirements. The recently enacted CSDDD (Corporate Sustainability Due Diligence Directive) makes it mandatory for the European importers to scrutinize the entire value chain to identify and address human rights and environmental risks. This would make exports to those countries very difficult unless the companies become totally compliant. For facilitating the skilling on these lines regular workshops for educating the concerned parties to be skilled in these areas.

Dr. Nuwan DeSilva: Scientist at Slintec: Sri Lankan Institute of nanotechnology - Introduced the gathering to the pioneering work being done by them in isolating and developing natural dyes and conductive inks to reduce negative environmental impact on the leached dyes and chemicals into the soil. The conductive inks for use in special work wear make it possible for fabrics to be developed for apparels in the domain of high static electrical zones, thereby reducing the risks to the workers. This research ensures the efficacy of the required products without endangering the environment.

Mr. Pravin Vadambe: Principal Consultant from Gerzi Consultants – Spoke on the need to implement the use of recycled fibres in apparels and home textiles to ensure a positive impact for balancing the demands for increased fibre consumption. He stressed that at the current rate of increase on demands, there will be a 2% increase in the fibre consumption annually. He provided extensive data to present his case. He stressed that the pace of generating usage of recycled fibres had to be increased rapidly to balance the increased demands. The cotton consumption has been dropping regularly over the years and the consumption of synthetic and man-made fibres has been increasing.

Panel Discussion: Moderated by **Dr. Vijay Gotmare**, Chairman TAI with **Mr. N. D. Mhatre**, DG-ITAMMA, **Mr. Om Mantry**, MD Century Inks Pvt. Ltd. and **Dr. Ashwin Thakkar** and **Dr. Karthik N. D**. -The discussion revolved on the current practices addressing the needs of recycling in the machinery and manufacturing sectors. The main outcome of the conference was the a clear awakening and realization of the fact that we were fast approaching the tipping point and need for use of sustainable practices and technology was no longer a fad or a luxury for the more indulgent but rather a clarion call. Use of ethical practices addressing the right of the human race to a healthy and clean environment, was the most crucial call of today. Unless we become aware of our responsibilities and duties towards ourselves, our fellow human beings and Mother Nature, we are heading for an unimaginable disaster.

The brightest take-away from the conference was that this fact was recognized and acknowledged --- which in itself is a good beginning.

The Conference received overwhelming response from all over World. The theme of Conference, topics, presentations, and speakers were highly appreciated by one and all.

Mr. Kamal Misra, Chaired the valedictory address.

Colorant Limited Secures Award for Domestic Dye Sales

Mr. Subhash Bhargava, Managing Director- Colorant Limited receiving the trophy by the hands of Chief Guest, Mr. P. m. Shah

Gujarat Dyestuff Manufacturers Association (GDMA) has honored Colorant Limited with the second prize for "Sales of Self-Manufactured Dyes in the Domestic Market for the Year 2022-23" on 28th June, 2024 at Ahmedabad. This recognition highlights the Company's outstanding performance and contribution to the domestic dye market.

The award ceremony took place at Diamond Hall, Rajpath Club, S. G. Highway, Ahmedabad. Mr. Subhash Bhargava, Managing Director- Colorant Limited proudly received the trophy from the Chief Guest, Mr. P. M. Shah, Director of the Industrial Safety & Health Department.

Expressing gratitude, the company thanked all associates, team members, and esteemed customers for their unwavering support and contributions towards achieving this milestone.

“We are immensely proud of this achievement and deeply appreciate the efforts of our dedicated team and the trust of our valued customers,” said Mr. Subhash Bhargava.

Colorant Limited is an ISO 14001:2015 & ISO 9001:2015 Company, engaged in manufacturing and marketing a broad spectrum of Reactive Dyes for the Textile Industry in India and Abroad. Most of the COLRON Reactive Dyes are approved by "ZDHC Level 3 (V-3.1)", "GOTS (V-7)" (Suitable for Processing of Organic Cotton) and Eco Passport - Oeko Tex - 100.

IDF in India - Flexibility for the up-cycling of textile waste

Trützschler and the Indian company Gimatex have a long relationship that began in 2006. Since then, they have successfully collaborated on many projects. Gimatex has used Trützschler's IDF successfully in direct spinning. Now, they are using it to turn textile waste into valuable ring yarn.

Gimatex Industries Pvt. Ltd. has high standards for quality and sustainability. The company operates fully integrated facilities with ginning, spinning, recycling, weaving and processing units in Hinganghat, within India's major cotton-growing region of Vidarbha. It also runs a state-of-the art fabric processing unit in Dholka, near Ahmedabad. As a family-owned company with over 125 years of history, it has a lot in common with Trützschler. Together, the two partners are working in close collaboration with the shared aim of extending that long history far into the future.

“Our clients demand consistent quality and competitive prices,” says Mr. Vineet Mohota, Director at Gimatex. “We meet those demands by always leveraging the latest technologies to boost quality, save energy and make progress for sustainability. Trützschler is a strong partner for that work.”

Lower costs and higher productivity

Trützschler's Integrated Draw Frame (IDF) technology is at the heart of this collaboration. Gimatex is using these innovative solutions to produce high-quality yarn. In particular, IDF enables Gimatex to produce topquality yarns from a uniquely wide variety of raw materials – from 100 percent cotton through to polyester, recycled fibers and blends of various different inputs. Gimatex mainly uses

L to R: Shailesh Thakur (Deputy General Manager Sales ATE), Shiladitya Joshi (Deputy General Manager Marketing Trützschler), Vineet Mohota (Director Gimatex) and Gautam Kumar Dhang (CEO Fabric Business Gimatex)

L to R: Gautam Kumar Dhang (CEO Fabric Business Gimatex), Vineet Mohota (Director Gimatex) and Manish Deolankar (General Manager Gimatex) in front of Trützschler's Bale Opener

Trützschler IDF to manufacture rotor yarns in a direct spinning process. Direct spinning means shortening the spinning process by eliminating draw frame passages. Fiber slivers are fed directly from the card into the integrated drafting passage. This direct spinning concept uses less electricity and less space than conventional draw frame passages, which helps Gimatex to cut costs while increasing output volumes – with no compromise in quality. Most often, IDF technology is used for rotor and vortex spinning. However, the team at Gimatex is now also one of the first spinning mills in India to develop a special IDF process for producing traditional and recycled ring yarn. This allows the company to leverage the same setup it uses for open-end yarn. The ring yarn produced in this unusual way is mostly coarser varieties and recycling blends for cotton / spandex (lycra) products, with Ne 10s and Ne 16s. The yarn goes through a blow room into a TC 15 card with IDF, before entering a Trützschler TD 10 draw frame, a speed frame and a ring frame.

Longstanding partnership "The performance of Trützschler's IDF machines is great," says Mr. Mohota. "We also get support from Trützschler's expert teams. They're always available to give guidance and answer questions, and they're able to access data from around the globe to share best practices for every application." Gimatex and Trützschler have established a close relationship over a long period. IDF machines are a flexible, highly efficient and sustainable technology that is helping to extend that valuable partnership. As market conditions in India continue to evolve, we will keep working hand in hand to adapt to change successfully – while meeting high expectations from customers.

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Rieter's Recycling Toolbox

Spinning fine ring yarns with high quality and a high share of recycled fibers is possible with Rieter's recycling toolbox. Each of the three tools contributes to another yarn quality criterion. Pre-carding cleans the recycled fibers perfectly before they enter the spinning process, combing removes very short fibers and compacting adds the finishing touch to the yarn.

Improving the yarn quality of mechanically recycled cotton ring yarns remains an important requirement for many textile producers to meet their sustainability targets in the coming years. When the share of recycled fibers in blends with virgin cotton is increased, spinning becomes more challenging. The Global Recycling Standard (GRS) applies to products containing at least 20% recycled material. In the current Rieter trials, blends with up to 50% recycled material are processed to products of high quality.

Validated toolbox to improve yarn quality

The challenges of mechanically recycled cotton fibers in the spinning process are: opening degree (remaining yarn and fabric pieces), high short-fiber content, high Nep count, and high variation from lot to lot (color and foreign fibers). Rieter supports its customers by offering three tools which help spinning mills to master the challenges and turn recycled material into quality yarns. To show the impact of the different tools, Rieter conducted a trial with a blend of 50% mechanically recycled fibers and 50% virgin cotton, spun into a ring yarn with yarn count Ne 30. A regularly spun carded cotton ring yarn, which corresponds to 50% Uster Statistics, serves as a reference.

Pre-carding for full cleaning

Tool number one is pre-carding – an additional cleaning step which translates into a significant impact. This step improves

Fig. 1 - Pre-carding improves the spinning efficiency and quality of the yarns

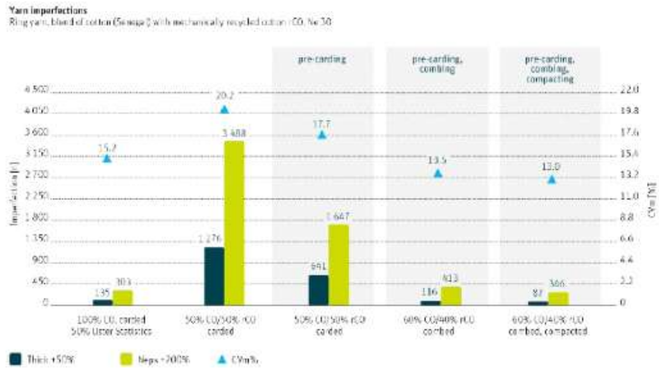

Fig. 2 - Each of the three tools helps to improve yarn quality

the spinning efficiency and quality of the yarns. Pre-carding, which can also be conducted in the spinning mill, means that the card C 77 can be connected directly to the tearing machine. This step has the twin benefits that recycled fibers will be fully cleaned from yarn pieces while the number of neps is reduced (Fig. 1). Spinners benefit from this by receiving only fully opened and cleaned fibers for their spinning line. Repeated trials have proven that the neps and thick places can be reduced by 50% in the ring yarn, while maintaining the same blend ratio.

Combing to improve yarn quality the second tool is combing. Combing is a process step that is widely recognized for its ability to improve the quality of the fiber as it removes the most disturbing short fibers, neps, and impurities. As mechanically recycled cotton is particularly challenging due to its high short-fiber content, combing these fibers proves to be beneficial. In combination with the pre-carding process, it can basically lead to a yarn quality with improved imperfection and yarn quality comparable to a carded virgin cotton yarn (Fig. 2).

The concern that a large proportion of the recycled fibers will be combed out is unfounded. With the comber E 90, Rieter offers a machine which optimally fits the needs for the best fiber processing on the market, resulting in top yarn quality and highest raw material yield. In addition, the comber noil blended with a low percentage of virgin fibers can be optimally spun into a rotor yarn.

Compacting to add the finishing touch

Tool number three is compacting the fiber blend. This tool gives the yarn the finishing touch. Compacting is especially beneficial for the tenacity and yarn abrasion, and in turn for the yarn hairiness. This improvement leads to good running performance in downstream processes and increases the lifetime of the finished products.

Rieter's recycling toolbox enables spinning mills to produce mechanically recycled cotton ring yarns with up to 50% content of recycled fibers and a yarn count of Ne 30 at a quality level, which is comparable to carded virgin cotton ring yarns.

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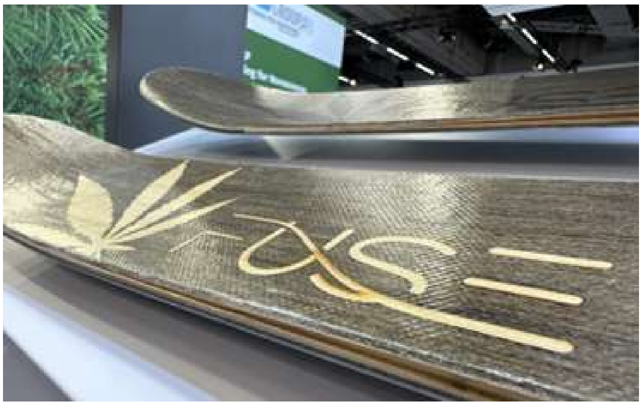
KARL MAYER GROUP

Sustainable solutions for composite reinforcements

KARL MAYER North America looks forward to participating as an innovative specialist for non-crimp fabric production at CAMX.

After a break, KARL MAYER North America will return to exhibit at CAMX, the most important composites trade show in North America, from September 9 to 12, 2024 in San Diego. The KARL MAYER GROUP subsidiary can be found at booth EE54 in the San Diego Convention Center. Here it will present as an innovative partner to the composites industry with high-performance machines such as the COP MAX 4, a flexible all-rounder to produce multilayer, multiaxial fabric structures; the COP MAX 5, specifically for processing carbon fibers; and the UD 700 fiber spreading system. Furthermore, a new machine was launched this spring. It is called MAX GLASS ECO and impresses with its perfect price-performance ratio. If the focus is on the highly productive manufacturing of goods for standard applications made exclusively from glass fibers, the new MAX GLASS ECO is worth a look.

Lutz Heinig


Hemp Ski Techtetxil 2024

Besides the machines, the experienced sector player supports customers with pioneering application developments. The focus of the medial presentation will be the processing of natural fibers into sustainable composite reinforcements. In cooperation with representatives of the winter sports industry, KARL MAYER has already processed hemp tapes and flax fibers into non-crimp fabrics for snowboards and skis with COP MAX 4. Examples were launched at the last editions of this year's Techtextil and JEC World which were very well received by visitors.

Lutz Heinig, Sales Manager at Technical Textiles at KARL MAYER North America, is excited to present to the American trade audience. "The global composites industry is under enormous pressure to reduce its ecological footprint. Our non-crimp fabrics made from natural fibers can make an important contribution to this," says the market expert. He also looks forward to welcoming customers and introducing companies new to this sector to KARL MAYER's innovative technologies.

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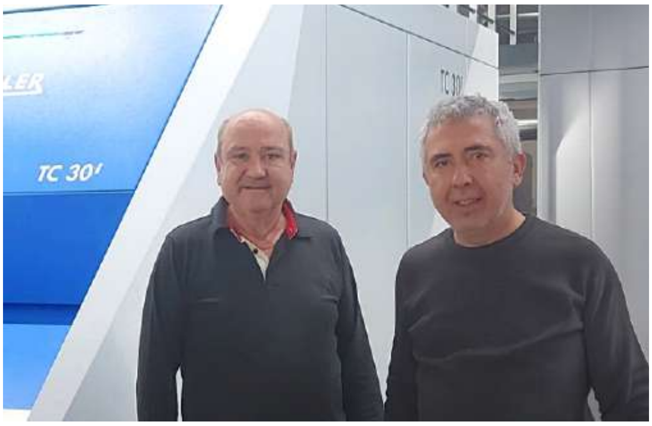
TRÜTZSCHLER SPINNING

TC 30i - Convincing customers with strong results

Trützschler's next-generation carding machine entered the market in January 2024 – and it's now convincing yarn manufacturers across the textile industry worldwide. The machines have achieved excellent results during tests with customers in Türkiye and in other countries. It achieved up to 40 % higher productivity while reducing energy consumption by up to -18 %.


Göl Iplik TC 30i

Higher productivity, less energy consumption

Mayfil Tekstil is a leading company in the Turkish textile industry for the production of textured yarn. It is headquartered in Nilüfer/Bursa. Founded in 2005, it has grown rapidly by prioritizing customer satisfaction. In 2022, Mayfil invested in a modern vortex airjet spinning facility that can produce up to 35 tons per day. And the company was keen to take a close look at the TC 30i for man-made fibers to explore its potential to drive progress toward Mayfil's ambitious growth plans. In February 2024, Mayfil Tekstil conducted tests with the TC 30i. The next-generation carding machine produced 140 kg/h viscose, which is more than 40 % higher than the 95 kg/h Mayfil produces with the current benchmark. The new carding machine also decreased electricity consumption by 18 %. Based on these results, Mayfil is purchasing further TC 30i cards.


TC 30i Türkiye

Results confirmed

Diagram Influence of TC 30i on yarn quality

Göl Iplik Şeremet Tekstil Sanayi ve Ticaret A.S., located in Inegöl Bursa, operates three factories that deliver a variety of high-quality products, with a specialization in blended yarns. Investment in modern equipment and pioneering new products that expand its portfolio are at the heart of Göl Iplik's success across almost four decades. Göl Iplik also tested the TC 30i for man-made fibers in early 2024.

This Trützschler customer took a close look at the TC 30i during rigorous viscose trials. The TC 30i achieved a 40 % higher productivity rate with the same level of qu
ality, while consuming 15 % less power. Göl Iplik now intends to include the TC 30i in its future investment strategy.

Promising feedback The TC 30i is still a newcomer in the textile industry – but its reputation is growing rapidly as spinning companies around the globe experience its range of smart features and functions. Its contributions to productivity, quality and resource efficiency are convincing. More and more companies around the world are now ordering our TC 30i. We are happy to convince more customers worldwide.

Benefits of the TC 30i:

1) Best quality from any raw material: High levels of productivity and yarn quality thanks to 35 % more active flats, the longest carding length in market and the T-GO automatic carding gap optimizer.
2) Operator-independent performance: Consistent results without relying on manual operators thanks to automatic, real-time optimization of the carding gap with T-GO.
3) Value-adding waste handling: Innovative waste suction system collects and separates different types of waste. More than 50 % of card waste can be reused or sold to third parties for an attractive price.

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Rieter Wins Major Follow-up Order from DIW

On July 16, 2024, Rieter and Shanghai Digital Intelligence World Industrial Technology Group Co., Ltd. (DIW) have signed a purchase contract for more than 700 of the company's winding machines Autoconer X6. This represents the largest order in the history of Rieter China. The agreement also strengthens the strategic partnership between the two companies that aims to develop state-of-the-art spinning operations and achieve unprecedented levels of quality, productivity and efficiency.

DIW has placed an order for more than 700 of Rieter's winding machines Autoconer X6. The winding machine serves as the final quality assurance in the ring spinning and compact-spinning process and is key to the performance of subsequent process steps. With its outstanding productivity, intelligent process automation, excellent splicing and winding quality, the Autoconer X6 is widely recognized in the market. The order will help DIW strengthen the vertical integration of its operations and accelerate its growth strategy in the cotton spinning industry, further underpinning its leading position in global markets. This order follows the initial batch placed in March 2024, when Rieter and DIW signed their first strategic partnership to develop intelligent yarn manufacturing technology that utilizes digitization and automation to minimize conversion costs and maximize value for customers.

Liu Yifang, Vice Chairman, Shanghai Digital Intelligence World Industrial Technology Group Co., Ltd., says: "This partnership is a win-win for both companies. With our

Signing Ceremony DIW Follow-up Order (July 2024)_100256_Original

Cover Autoconer X6 2606 CMYK robot modif_96416_Original

vertically integrated manufacturing operations, we are building some of the world's most advanced spinning operations which will ideally position us for growth in this industry. Together we will further enhance the overall operational efficiency of DIW, creating a major player in cotton spinning."

Michael Hubensteiner, Country Managing Director Rieter China, says: "With its high performance winding machines, Rieter will help DIW meet its steadily growing demand and requirements for higher operational efficiency. The renewed cooperation will further amplify our shared strengths, position us to capture growth opportunities together and enable long-term and stable cooperation between Rieter and DIW."

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BENNINGER

The sustainable way of discontinuous dyeing

Benninger's FabricMaster revolutionizes textile dyeing in India

The Swiss company Benninger, renowned for its innovative textile machinery, has introduced its latest marvel, the FabricMaster, to the Indian market. This soft flow machine is already making waves globally, with installations in Europe, the USA, Peru, Central America and Bangladesh. Now, it is set to transform the Indian textile industry, with production taking place at Benninger's High Tech Fabrication facility in Pune.

The first FabricMaster in India has been operational for a year at Amarnath Dyeing And Bleaching Works Private Limited. The machine's outstanding performance has led Amarnath to order a second unit, underscoring their complete satisfaction with its capabilities. This second machine is now ready to leave the Benninger Works in Pune, marking another milestone in the FabricMaster's journey.

"This innovative technology transforms our production capabilities, setting new benchmarks in the industry. Our new machines will help us reach our goal of becoming the leader in quality fabric processing while caring about ecology. The machines will help us do so by enhancing our efficiency, reducing waste, and minimizing our environmental impact. This investment not only underscores our commitment to excellence but also to sustainable practices that benefit both our customers and the planet", says Sudarshan Chandak, Director at Amarnath Dyeing And Bleaching Works Private Limited.

Excellent dyeing performance

The FabricMaster is designed to handle the most challenging dyeing tasks with ease. It excels in dyeing difficult Lycra blends of Cotton, Rayon, Nylon, and Modal fabrics in open width form, without any rope marks or edge curling.

The FabricMaster ensures optimal dye penetration and color consistency achieving uniform fabric handling during the dyeing process. This is ensured thanks to the FabricMaster's nozzle which can be precisely adjusted based on the weight of the fabric being dyed. Lightweight fabrics benefit from low liquor volume, while heavier fabrics are treated with increased flow. Furthermore, the internal fabric plaiter operates at varying speeds, accommodating different fabric types. Moreover, its automated add tank ensures accurate chemical addition simplifying chemical dosing and mixing.

Key factors are minimal consumption of water, steam, chemicals and dyestuff, to ensure right-first-time results with lowest waste. The FabricMaster boasts an optimized

FabricMaster – fast, versatile, and economic jet dyeing machine

Benninger FabricMaster – ready to be delivered to Amarnath Dyeing And Bleaching Works chamber design, resulting in the lowest liquor ratio among water-driven piece dyeing machines. The carbon footprint of the FabricMaster is designed to be the future industry benchmark for sustainability.

Why FabricMaster also stands out

The FabricMaster's self-cleaning lint filter keeps the system running smoothly to enhance productivity. It monitors lint accumulation and automatically cleans itself, minimizing downtime and maintenance hassles. Furthermore, the FabricMaster's high-capacity heat exchanger accelerates heating gradients, reducing cycle times.

After dyeing, unloading the fabric swiftly is crucial. The FabricMaster features a frequency-controlled unloading winch, ensuring efficient fabric removal without compromising quality. The fabric lift from the chamber to the reel is less than half that of competitors' machines, improving fabric transport.

The FabricMaster is a testament to Benninger's commitment to innovation and quality. As it continues to gain traction in the Indian market, it promises to revolutionize fabric dyeing processes, setting new standards for efficiency, quality and precision to textile dyeing processes.

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Launch of Model Curriculum for Undergraduate Program in Textile Engineering

The All India Council for Technical Education (AICTE) has recently launched the model curriculum for undergraduate (UG) courses in Textile Engineering. In his keynote address, Prof. T. G. Sitharam, chairman of AICTE, underscored that the model curriculum aligns with AICTE's mission to prepare students for the fast-evolving textile industry. The curriculum, developed by a team of six experts led by Prof. Abhijit Majumdar of IIT Delhi, integrates foundational courses in science and engineering with specialised subjects of textile sciences.

At present, textile engineering related undergraduate programs are offered by around 40 colleges/universities in India with various nomenclatures such as Textile Technology, Textile Engineering, Textile Plant Engineering, Textile Chemistry, Manmade Fibre Technology, Apparel Engineering, Apparel Production Management, Fashion Technology, Carpet and Textile Technology, Handloom and Textile Technology, Silk Technology and Jute and Fibre Technology. Therefore, there is a need to design a unified undergraduate curriculum of Textile Engineering.

The new Textile Engineering curriculum aims to achieve convergence through a comprehensive framework. The new curriculum has three distinct features, namely 1. Convergent yet flexible 2. Principle-based 3. Materials focused. The total credit requirement is 164 spanning over eight semesters. While the 13 core textile subjects bring convergence, the basket of elective courses has been kept open-ended to impart the flexibility needed for different specializations. This will not only facilitate a holistic understanding of the Textile Engineering subjects but also improve the job opportunities for the students in textile and allied industries. Emphasis has been given to strengthen the fundamentals of science, engineering and core textiles along with efforts to expose the students to emerging areas like artificial intelligence and machine learning, sustainability and circularity, nanotechnology, technical textiles, smart textiles, medical textiles, protective textiles, composites, supply chain management, entrepreneurship, and product development. The optimum blend of fundamental concepts and applications will create 'thinkers' capable of innovation.

The curriculum revision committee that included experts from academia, research organisations and industry met on multiple occasions in 2023-2024 to brainstorm and deliberate on the new curriculum. This was followed by gathering feedback from various stakeholders including universities and colleges. The final curriculum attempted to address the emerging needs of students, academia and industry.

Committee for Model Curriculum

Name	Designation and Organization
Prof. Abhijit Majumdar	Professor, Dept. of Textile and Fibre Engineering, IIT Delhi (Chairperson)
Prof. Bhupendra Singh Butola	Professor, Department of Textile and Fibre Engineering, IIT Delhi
Prof. G. Nalankilli	Professor, Uttar Pradesh Textile Technology Institute, Kanpur
Prof. Arobindo Chatterjee	Professor, Department of Textile Technology, NIT Jalandhar
Mr. Birendranath Bandyopadhyay	President, Kusumgar Corporates Pvt. Ltd.

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Call for Articles

Journal of the Textile Association

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