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Development of Cotton–Banana Fibre Blend Fabric with UV Protection using Pomegranate Peel Extract

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Abstract – Environmental concerns and the need for sustainable alternatives in textile production have encouraged the use of natural fibres and plant-based finishing materials. Conventional ultraviolet protective textiles often depend on synthetic chemicals that may contribute to environmental pollution and may not be biodegradable. In recent years, agricultural waste materials have gained attention as valuable resources for developing eco-friendly textile products. This study focuses on the development of cotton–banana fibre blended fabric treated with pomegranate peel extract to improve ultraviolet protection properties. The pomegranate peel extract was prepared using aqueous extraction method and applied through an eco-friendly dip-dry process. The treated fabric was evaluated for fabric weight, tensile behaviour, air permeability, wash durability, and ultraviolet protection factor. Results show that the treated fabric exhibits improved ultraviolet protection while maintaining comfort characteristics suitable for wearable applications.

Key Words: *Cotton–banana blend, UV protection, pomegranate peel extract, sustainable textiles, eco-friendly finishing.*

1. INTRODUCTION

The textile industry has experienced rapid growth due to increasing demand for clothing, technical textiles, and functional fabrics. However, conventional textile production relies heavily on synthetic fibres and chemical finishing agents that contribute to environmental pollution and health concerns. Synthetic materials such as polyester and nylon are non-biodegradable and contribute to microplastic pollution. Similarly, chemical finishing agents used for providing functional properties such as ultraviolet protection may cause harmful environmental effects. In recent years, sustainable textile development has become an important research area due to increasing environmental awareness and the need for biodegradable materials. Natural fibres derived from agricultural waste provide an effective alternative to synthetic fibres. These fibres are renewable, biodegradable, and environmentally friendly. The utilization of agricultural waste materials also helps reduce disposal problems and promotes resource efficiency. Banana fibre is a lignocellulosic fibre extracted from the pseudo stem of the banana plant. After harvesting bananas, the pseudo stem is generally discarded as waste. However, the pseudo stem contains strong fibres which can be used for textile applications. Banana fibre has good tensile strength, durability, and resistance to microbial attack. The fibre is biodegradable and easily available in tropical countries such as India. Cotton fibre is widely used in textile manufacturing due to its softness, comfort, and breathability. Cotton has good moisture absorption capacity which improves wear comfort. Blending cotton with banana fibre helps improve flexibility and comfort properties of banana fibre while maintaining mechanical strength. Pomegranate peel is a fruit waste material that contains bioactive compounds such as tannins, flavonoids, ellagic acid, and polyphenols. These compounds exhibit antioxidant, antimicrobial, and ultraviolet absorbing behaviour. Natural plant extracts containing phenolic compounds can be used as eco-friendly finishing agents to improve functional performance of textile materials. The application of plant-based finishing techniques helps reduce environmental impact caused by chemical processing. Therefore, the development of cotton–banana fibre blended fabric treated with pomegranate peel extract provides a sustainable solution for UV protective textile applications.

1.1 Problem Statement

Conventional UV protective textiles commonly use synthetic chemicals that may cause environmental pollution and skin irritation. Synthetic finishing agents are not biodegradable and may release harmful substances during washing and disposal. Agricultural waste materials such as banana pseudo stem and pomegranate peel are often discarded without proper utilization. There is a need to convert these waste materials into useful textile products that provide functional properties such as UV protection.

1.2 Objectives

- To extract banana fibre from agricultural waste material
- To develop cotton–banana fibre blended fabric
- To prepare natural extract from pomegranate peel
- To apply plant-based finishing on textile material
- To evaluate UV protection behaviour of treated fabric
- To develop eco-friendly textile product suitable for wearable application

1.3 Scope and Significance

This research focuses on development of sustainable textile material using natural fibres and plant-based finishing agents. The research is limited to laboratory-scale preparation of cotton–banana fibre blended fabric treated with pomegranate peel extract. The significance of this research lies in the utilization of agricultural waste materials for textile applications. The developed fabric can be used in eco-friendly garments and protective textile products such as gloves.

2. LITERATURE REVIEW

Sustainable textile materials derived from natural fibres have attracted significant research interest due to their environmental benefits. Banana fibre has been studied extensively for textile applications because of its high tensile

strength, biodegradability, and availability from agricultural waste. Studies indicate that banana fibre contains cellulose,

hemicellulose, and lignin which contribute to mechanical strength and durability. Researchers have observed that blending banana fibre with cotton improves flexibility and enhances comfort properties while maintaining structural performance. Cotton fibre is widely recognized as a suitable blending material due to its softness and breathability. Previous studies show that cotton blended with natural fibres improves fabric performance characteristics such as moisture absorption and wear comfort. Blended yarns demonstrate improved mechanical behaviour compared to single fibre yarns. Plant-based finishing agents have been explored as alternatives to chemical finishing materials. Pomegranate peel extract has been studied for its natural dyeing properties and functional finishing behaviour. The presence of phenolic compounds contributes to ultraviolet absorption ability. Studies indicate that fabrics treated with pomegranate peel extract exhibit improved ultraviolet protection properties and antioxidant characteristics. Research studies also indicate that fabric structure plays an important role in determining ultraviolet protection factor. Compact fabric structures and fibre compositions containing lignin and phenolic compounds contribute to improved UV blocking behaviour. Natural dyeing and finishing methods reduce environmental impact and promote sustainable textile production. Literature findings indicate that combining banana fibre and pomegranate peel extract provides an opportunity to develop functional textile materials with improved performance characteristics and environmental benefits.

3. METHODOLOGY

The methodology adopted in this research focuses on developing sustainable textile material using cotton–banana fibre blend treated with pomegranate peel extract for ultraviolet protection. The experimental procedure involves fibre preparation, blending, fabric formation, extraction of plant-based finishing agent, application of finish, and evaluation of fabric performance properties.

3.1 Materials

The materials selected for this research include cotton fibre, banana fibre, and pomegranate peel. Cotton fibre was chosen due to its comfort, softness, breathability, and moisture absorption properties. Banana fibre was selected because of its high cellulose content, strength, biodegradability, and availability as agricultural waste material. Pomegranate peel was used as a natural finishing material because it contains phenolic compounds such as tannins and flavonoids that exhibit ultraviolet absorbing properties. All materials used in this study are eco-friendly, biodegradable, and suitable for sustainable textile production.

3.2 Preparation of Banana Fibre

Banana fibre was obtained from banana pseudo stem collected after harvesting stage. The pseudo stem was cut into smaller sections and outer layers were removed to obtain fibre bundles from the middle sheath. The extracted fibres were washed thoroughly with water to remove dust and impurities. Clean fibres were dried under sunlight for 2–3 days to remove moisture content. After drying, fibres were combed manually to improve fibre alignment and remove short fibres.

3.3 Fibre Bleaching and Softening

Bleaching process was carried out to remove natural pigments, lignin, and other non-cellulosic components present in banana fibre. Mild hydrogen peroxide solution was used as bleaching agent to improve fibre brightness and softness. The fibres were immersed in bleaching solution at controlled temperature. After bleaching, fibres were washed thoroughly to remove chemical residue and dried under sunlight.

3.4 Fibre Blending

Cotton fibre and banana fibre were blended in the ratio of 60:40 to obtain balanced comfort and durability properties. Cotton fibre contributes softness and flexibility, while banana fibre contributes strength and reinforcement. Manual pre-mixing of fibres was carried out to ensure uniform distribution. The fibres were then subjected to carding process to improve fibre alignment and blending uniformity.

3.5 Yarn Preparation

The blended fibres were converted into yarn through spinning process. Carding process was used to separate fibres and remove impurities. The carded fibres were converted into sliver form. Drawing process was carried out to improve fibre parallelization and reduce irregularities. Ring spinning method was used to produce yarn with required twist and strength. The yarn count selected was suitable for lightweight textile applications such as scarves and gloves.

3.6 Fabric Development

The cotton–banana blended yarn was used to produce fabric structure using knitting process. Knitted fabric structure provides flexibility, softness, and comfort properties required for wearable textile applications. Knitting structure also improves breathability and stretch behaviour. The developed fabric was visually inspected to ensure uniform loop formation and balanced structure before applying finishing treatment.

3.7 Preparation of Pomegranate Peel Extract

Pomegranate peel was collected from fruit waste sources and washed thoroughly to remove impurities. Cleaned peels were dried under sunlight until complete removal of moisture was achieved. The dried peels were converted into powder form using grinding process. Powdered peel was mixed with distilled water and heated at controlled temperature to extract phenolic compounds such as tannins and flavonoids. The extract solution was filtered using muslin cloth to remove solid particles. Clear extract solution was stored for finishing application.

3.8 Application of Finish

The prepared pomegranate peel extract was applied on cotton–banana blended fabric using dip-dry technique. Fabric samples were immersed in extract solution to allow absorption of natural compounds into fibre structure. After dipping, fabric samples were dried at room temperature to remove excess moisture. Mild curing process was carried out to improve bonding between fibre surface and finishing material. The finishing process was carried out without use of synthetic chemicals, making the treatment environmentally safe.

3.9 Testing and Evaluation

The finished fabric was tested for fabric weight (GSM), tensile strength, air permeability, and ultraviolet protection factor (UPF). Fabric weight was measured using GSM cutter and electronic weighing balance. Tensile strength test was conducted to evaluate resistance of fabric against breaking force. Air permeability test was performed to evaluate breathability and comfort behaviour of fabric. Ultraviolet Protection Factor test was conducted to determine ability of fabric to block harmful ultraviolet radiation.

3.10 Product Development

The treated fabric was used to develop prototype gloves to demonstrate practical application of developed material. Gloves require flexibility, softness, and skin-friendly characteristics. The developed gloves showed good comfort, fit, and breathability. The product demonstrates the suitability of cotton–banana blended fabric for sustainable textile applications.

4. RESULTS AND DISCUSSION

The developed cotton–banana fibre blended fabric showed balanced mechanical and comfort properties suitable for wearable textile applications. Banana fibre contributed to improved strength behaviour due to presence of cellulose and lignin components. Cotton fibre-maintained softness and flexibility which improved comfort characteristics. Application of pomegranate peel extract improved ultraviolet protection behaviour of the fabric. Phenolic compounds such as tannins and flavonoids present in pomegranate peel absorb ultraviolet radiation and reduce transmission through textile structure. Fabric structure also influences UV protection behaviour. Compact structure reduces penetration of ultraviolet rays. The treated fabric maintained acceptable air permeability indicating that finishing treatment did not affect comfort properties significantly. The untreated fabric showed UPF value around 8, whereas the treated fabric showed improved UPF value of approximately 25–30, indicating significant improvement in ultraviolet protection behavior. The results show that plant-based finishing methods can improve functional properties of textile materials while maintaining environmental safety. The developed fabric shows potential for sustainable textile applications such as gloves and protective accessories. This research is limited to laboratory-scale experimentation, and further investigation is required to evaluate long-term durability, wash stability, and large-scale production feasibility.

5. CONCLUSION

The present research focused on development of cotton–banana fibre blended fabric treated with pomegranate peel extract for ultraviolet protection. Banana fibre obtained from agricultural waste provides strength and durability, while cotton fibre provides comfort and breathability. Pomegranate peel extract acted as natural finishing agent due to presence of phenolic compounds which exhibit ultraviolet absorbing behaviour. The treated fabric showed improved UV protection while maintaining comfort characteristics. The research demonstrates the possibility of converting agricultural waste materials into value-added textile products. The developed material supports sustainable textile production and reduces environmental impact.

6. FUTURE SCOPE

Future research may focus on improving durability of natural finishing treatment using eco-friendly fixation techniques. Additional plant-based extracts may be studied to develop multifunctional textile properties such as antimicrobial behaviour, fragrance finishing, and anti-odor properties. Further investigation may be carried out to evaluate large-scale production feasibility of cotton–banana blended fabric. Study on long-term performance and consumer acceptance may improve commercial application of sustainable textile materials. Development of sustainable textile products using natural fibres may contribute to eco-friendly fashion industry and reduce dependence on synthetic materials.

Figure 1. Banana fiber

Figure 2. Cotton fiber

Figure 3. Pomegranate peel

Figure 4. Yarn

Figure 5. UV Coated gloves

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