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Sustainable Fashion: Designing Eco-Friendly Fabrics From Recycled Materials

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***Abstract*—Sustainable fashion is a key driver in reducing environmental impact, and the integration of recycled materials into textile production presents a promising solution for high-performance apparel. This study focuses on the development of eco-friendly athletic gear by recycling cutting waste and eliminating the dyeing process, thereby reducing water and chemical consumption. Three fiber blends are evaluated for their potential in sustainable sportswear: 50% recycled PET + 50% recycled Modal, 50% recycled PET + 50% recycled Bamboo, and 50% recycled PET + 50% recycled Lyocell. Among these, the recycled PET + recycled Lyocell blend exhibits superior performance in terms of durability, breathability, moisture-wicking, and overall comfort. Lyocell's natural hydrophilic properties, combined with the strength and recyclability of PET, result in a fabric with enhanced sweat absorption, quick drying, and excellent wear resistance. To further improve moisture-wicking and softness, the fabrics undergo chemical treatment with eco-friendly silicone. Performance evaluations, conducted using standardized ASTM tests, assess key attributes such as tensile strength, abrasion resistance, and long-term moisture management efficiency. The results demonstrate that the recycled PET + recycled Lyocell blend offers the most balanced combination of strength, sustainability, and wearer comfort, making it a highly viable option for next-generation eco-conscious sportswear. This study contributes to the advancement of sustainable textile innovations, promoting circular economy practices in the fashion industry while enhancing the functionality of performance wear.**

***Keywords*— Circular economy, performance fabrics, blend ratios, eco-conscious sportswear, sustainable fashion, recycled textile.**

1. INTRODUCTION

The fashion industry is a major contributor to environmental pollution, generating vast amounts of textile waste, consuming significant water resources, and relying on energy-intensive manufacturing processes. Traditional textile production, particularly in the athletic wear sector, often involves synthetic materials that are not biodegradable and require chemical-intensive dyeing processes, further exacerbating environmental concerns. As consumer awareness and regulatory pressures push for more sustainable solutions, the need for innovative, eco-friendly textile alternatives has become paramount. One promising approach is the utilization of recycled materials in fabric production, reducing reliance on virgin resources while promoting a circular economy. In recent years, recycled polyester (rPET) has gained attention for its durability, mechanical strength, and ability to be repurposed from post-consumer plastic waste. Similarly, regenerated cellulose fibers such as Modal, Bamboo, and Lyocell offer natural softness, breathability, and moisture-wicking properties, making them suitable for performance wear. However, the challenge lies in identifying the optimal fiber blend that balances durability, moisture management, comfort, and sustainability in high-performance athletic textiles. This study aims to evaluate the performance of three fiber blends—50% recycled PET + 50% recycled Modal, 50% recycled PET + 50% recycled Bamboo, and 50% recycled PET + 50% recycled Lyocell—while eliminating the dyeing process to further reduce environmental impact. Among these, the combination of recycled PET and recycled Lyocell is expected to exhibit superior attributes due to the strength of PET and the excellent breathability, softness, and moisture-wicking capability of Lyocell. To enhance the functional properties of the fabrics, an eco-friendly silicone treatment is applied to improve sweat absorption and quick-drying performance. The materials undergo rigorous ASTM-standard testing to assess key parameters such as tensile strength, abrasion resistance, and long-term moisture-wicking efficiency. By identifying the most effective fiber blend for sustainable sportswear, this study aims to contribute to the development of high-performance, eco-conscious athletic textiles, paving the way for a more sustainable and circular fashion industry.

1.1 Background of the work

The transition toward sustainable fashion is driven by the urgent need to reduce textile waste, minimize carbon emissions, and lower water consumption. The global textile industry produces approximately 92 million tons of waste annually, with synthetic fabrics taking decades to decompose. Athletic wear, in particular, is predominantly made from polyester-based fabrics, which shed microplastics and contribute to environmental degradation. Recycling these materials and blending them with biodegradable, cellulose-based fibers presents an opportunity to enhance textile sustainability without compromising performance. Recycled PET (rPET) is derived from post-consumer plastic waste, mainly discarded PET bottles, and offers high durability, mechanical strength, and resistance to wear and tear. Lyocell, a regenerated fiber sourced from sustainably harvested wood pulp, is known for its exceptional moisture management, softness, and biodegradability. The synergy between these two fibers is expected to result in a fabric with optimal strength, breathability, and sustainability, making it a viable alternative to conventional synthetic-based athletic textiles. Furthermore, eliminating the dyeing process significantly reduces water and chemical usage, addressing one of the most resource-intensive and polluting stages of textile production. This study aligns with global sustainability initiatives, such as the United Nations Sustainable Development Goals (SDGs), which emphasize responsible consumption and production (SDG 12) and climate action (SDG 13). The results of this research will not only aid in the development of more sustainable sportswear but also serve as a foundation for future textile innovations aimed at reducing environmental impact.

2. MATERIALS AND METHODS

The following section provides a detailed account of the materials used and the methodologies employed to transform cutting waste fabrics into sustainable, high-performance yarns and fabric blends for athletic wear. The process begins with sourcing textile waste from Huechem Chromozome, which includes 100% PET, Modal, Lyocell, and Bamboo fabrics, all in Heather Gray, a color chosen for its suitability for recycling. Each fabric undergoes rigorous fiber composition testing according to ASTM standards to confirm its authenticity and purity. Following this, the fabrics are processed through a series of steps—shredding, carding, combing, and spinning—at MRS Mills to convert them into usable fibers. The resulting fibers are then blended in specific ratios to create three distinct yarn blends: 50% recycled PET + 50% recycled Modal, 50% recycled PET + 50% recycled Bamboo, and 50% recycled PET + 50% recycled Lyocell. These yarns are then knitted using a Unitex Knitting Machine into fabric that will undergo subsequent performance testing for durability, moisture-wicking, breathability, and comfort. By carefully following these steps, this project aims to produce eco-friendly athletic fabrics that contribute to a more sustainable textile industry while ensuring optimal performance characteristics suitable for high-performance sportswear.

2.1 Sourcing cutting waste fabrics

The first step of the project involves sourcing cutting waste fabrics from Huechem Chromozome, a textile manufacturer. The selected fabrics are primarily 100% PET, 100% Modal, 100% Lyocell, and 100% Bamboo, all in Heather Gray color. The choice of Heather Gray is intentional, as it is well-suited for recycling without requiring additional dyeing, thus reducing the environmental impact.

The various fabric types were chosen for their sustainability credentials and specific characteristics:

- 100% PET (Polyester): Known for its durability and widespread use in textiles, recycled PET helps reduce plastic waste.
- 100% Modal: A semi-synthetic fiber made from beech trees, Modal is soft and breathable, often used in comfortable apparel.
- 100% Lyocell (Tencel): A sustainable fiber made from wood pulp, Lyocell is biodegradable and offers excellent moisture-wicking properties.
- 100% Bamboo: A natural fiber that is soft, lightweight, and environmentally friendly, Bamboo is a renewable resource with excellent breathability.

The cutting waste fabrics were thoroughly inspected for their original fiber composition before proceeding with further steps.

2.2 Testing Fiber Composition Using ASTM Standards

Once the cutting waste fabrics are sourced, it is crucial to confirm their authenticity and composition to ensure they meet the required standards. To do this, each fabric is subjected to a fiber composition test using ASTM standards (American Society for Testing and Materials). The testing is carried out to determine the exact percentage of fibers in each fabric and ensure the materials match the intended 100% PET, Modal, Lyocell, and Bamboo composition.

The fiber composition test involves the following:

- Chemical analysis: 100% PET (Polyester): Known for its durability and widespread use in textiles, recycled PET helps reduce plastic waste. The fabrics are tested to identify the fiber content, confirming whether the materials match the desired composition (e.g., 100% PET).
- Physical analysis: The physical characteristics, such as strength, elongation, and surface texture, are measured to ensure they align with the expected outcomes for each fabric type.

Once the fiber composition is confirmed, the fabrics are ready to undergo the processing stages outlined below.

2.3 Processing Fabric Waste into Usable Fibers

After confirming the composition, the fabric waste is converted into usable fibers using the following steps at MRS Mills:

- Shredding: The fabric waste is first shredded into smaller pieces using the Shredo Textile Waste Shredder (Lakshmi Machine). This step breaks the fabric down into a pulp form, making it easier to process into individual fibers. The shredded fabric is then prepared for carding.
- Carding: The shredded fabric undergoes the carding process, where the fibers are cleaned, aligned, and straightened. This is done using the Rieter C 80 carding machine. Carding helps remove any contaminants and prepares the fibers for further processing by opening them up and creating a uniform, untangled fiber web. This stage ensures the fibers are of a consistent length and quality, suitable for spinning.
- Combing: After carding, the fibers are passed through the Rieter E 36 Comber. The combing process removes shorter fibers and further aligns the longer fibers, ensuring that the resulting yarn will be stronger and more uniform. This process also improves the smoothness of the fibers,

preparing them for the final spinning stage.

- Spinning: The final stage of processing involves spinning the prepared fibers into yarn using the Rieter R36 Open-End Spinning Machine. This machine spins the fibers into 40 Ne yarn. The yarn produced is then ready to be blended and knitted into fabric. The open-end spinning technique ensures that the yarn is durable, strong, and suitable for the creation of high-quality fabrics.

2.4 Blending and Knitting Process

Once the yarns are produced, they are blended and knitted to create the final fabrics. The following steps are performed:

- Yarn Blending: The yarns from the different fabric types are blended in specific proportions to create three distinct fabric blends:
  1. Blend 1: 50% recycled PET + 50% recycled Modal
  2. Blend 2: 50% recycled PET + 50% recycled Bamboo
  3. Blend 3: 50% recycled PET + 50% recycled Lyocell
- The yarn quantities used for each blend are as follows:
  1. PET yarn: 20 kg
  2. Tencel (Lyocell) yarn:7 kg
  3. Modal yarn: 7 kg
  4. Bamboo yarn:
  5. 7 kg
- Knitting: The yarn blends are then fed into a Unitex Knitting Machine to produce the fabric. The knitting process uses a Single Jersey knit type and follows a fixed setup:
  1. Yarn Input: 10 kg per blend (5 kg of Yarn 1 + 5 kg of Yarn 2)
  2. Fabric Dimensions: Diameter: 24 inches Length: 2.5 meters GSM (Grams per Square Meter): 190

This knitting process produces a fabric that combines the desired functional properties, including durability, moisture-wicking, and breathability, while utilizing recycled and sustainable materials.

2.5 Chemical treatment for moisture wicking enhancement

To enhance the moisture-wicking and sweat absorption properties of the fabric blends, a silicone-based chemical treatment is applied to each fabric sample. This treatment improves the fabric's ability to wick moisture away from the skin, ensuring better comfort and performance in athletic applications. The process involves dip padding, squeezing, drying, and curing, ensuring uniform chemical application while maintaining the structural integrity of the fabric.

2.5.1 Chemicals and Materials Used

- Silicone-Based Wicking Agent:
  1. Chemical Name: Eco-Friendly Hydrophilic Silicone Softener
  2. Concentration: 40 g/L
  3. Supplier: (To be determined based on sourcing)
- Other Required Materials:
  1. Water (deionized) for dilution
  2. Acetic Acid (pH adjuster, 1 g/L)
  3. Fabric Samples:
     - 50% Recycled PET + 50% Modal
     - 50% Recycled PET + 50% Bamboo
     - 50% Recycled PET + 50% Lyocell
- Processing Equipment:
  1. Padding Mangle (for dip padding and squeezing)
  2. Drying Chamber
  3. Curing Oven

2.5.2 Step-by-Step Treatment Process

Step 1: Fabric Preparation

Before treatment, the knitted fabrics are conditioned in a humidity-controlled room (65% RH, 25°C) for 24 hours to ensure consistency in moisture content.

Step 2: Dip Padding Process

1. A silicone-based hydrophilic solution is prepared by dissolving the silicone softener (40 g/L) and acetic acid (1 g/L) in deionized water while maintaining a pH of 5-6.
2. The fabric samples are immersed in the solution at room temperature (25°C) for 5 minutes to allow thorough penetration of the treatment.
3. After immersion, the fabric is passed through a padding mangle with a pressure of 2.5 bar, ensuring uniform distribution and removal of excess liquid.

4. The wet pickup is maintained at 80% (w/w) for consistent chemical absorption.

Step 3: Drying Process

1. The padded fabric is transferred to a drying chamber at 120°C for 5 minutes to remove surface moisture while preventing damage to the fibers.

2. The drying process is carefully controlled to prevent excessive heat exposure, ensuring that the silicone agent is properly deposited onto the fabric structure.

Step 4: Curing Process

1. The dried fabric is placed in a curing oven and treated at 150°C for 3 minutes to fix the silicone-based chemical onto the fabric.

2. This step enhances the durability of the moisture-wicking properties by allowing the hydrophilic silicone to bond effectively with the fiber surface.

Step 5: Post-Treatment Conditioning

1. The cured fabric is allowed to rest at room temperature (25°C) for 24 hours to stabilize the treatment. This step enhances the durability of the moisture-wicking properties by allowing the hydrophilic silicone to bond effectively with the fiber surface.

2. The treated fabrics are stored in a controlled environment (65% RH, 25°C) before performance testing.

2.5.3 Expected Outcomes of the Treatment

- Improved moisture-wicking efficiency, enabling rapid sweat absorption and evaporation.
- Enhanced fabric softness and comfort, making it suitable for athletic applications.
- Increased durability of the treatment, ensuring effectiveness over multiple washes.

This treatment ensures that the sustainable sportswear fabrics maintain high performance while adhering to eco-friendly textile processing methods.

The focus of this chapter is to present the objectives of the proposed work and the detailed methodology undertaken to achieve them. The chapter outlines the project's aims, describes the synthetic procedures and methodologies employed, and highlights the techniques and tools used in the study.

3. RESULT AND DISCUSSION

This section presents and analyzes the performance results of the three fabric blends tested for abrasion resistance, tensile strength, moisture absorption (gain), and moisture-wicking efficiency. The results provide insight into the durability, mechanical strength, and moisture management properties of each blend, helping to determine the optimal composition for high-performance sustainable athletic wear.

Among the three blends tested—50% Recycled PET + 50% Recycled Modal, 50% Recycled PET + 50% Recycled Bamboo, and 50% Recycled PET + 50% Recycled Lycocell—the 50% Recycled PET + 50% Recycled Lyocell fabric exhibited superior overall performance across most parameters.

3.1 Abrasion Resistance (ASTM D4966 - Martindale Abrasion Test)

Abrasion resistance was evaluated using the **Martindale Abrasion Test (ASTM D4966)** under a **15 kPa load** to simulate wear over time. The test measured the number of rubs each fabric could withstand before noticeable wear or thread breakage occurred.

1.1 Abrasion Test Report

Fabric Blend	Number of Rubs Withstood (15 kPa Load)
50% Recycled PET + 50% Recycled Modal	9,800 rubs
50% Recycled PET + 50% Recycled Bamboo	8,500 rubs
50% Recycled PET + 50% Recycled Lyocell	10,200 rubs

Discussion:

- The 50% Recycled PET + 50% Recycled Lyocell blend exhibited the highest abrasion resistance (10,200 rubs), indicating superior durability.
- The Modal blend also performed well (9,800 rubs), showing good wear resistance.
- The Bamboo blend had the lowest abrasion resistance (8,500 rubs), suggesting slightly weaker fabric integrity under mechanical stress.

3.2 Tensile Strength (ASTM D5034 - Grab Test)

The tensile strength was evaluated using the ASTM D5034 Grab Test, which measures the force required to break the fabric in both warp and weft directions

3.1 Tensile Strength Test Report

Fabric Blend	Warp Strength (N)	Weft Strength (N)
50% Recycled PET + 50% Recycled Modal	490 N	455 N

50% Recycled PET + 50% Recycled Bamboo	470 N	430 N
50% Recycled PET + 50% Recycled Lyocell	510 N	475 N

Discussion:

- The Lyocell blend exhibited the highest tensile strength, particularly in the warp direction (510 N), indicating better structural stability and resistance to breakage.
- The Modal blend performed similarly well in the weft direction (455 N), while Bamboo exhibited the lowest tensile strength (430 N, weft), suggesting slightly weaker fiber bonding.

3.3 Moisture Absorption (Moisture Gain Test - Lab Method)

Moisture absorption was tested in a controlled humidity environment (65% RH, 25°C). The percentage of moisture gain was calculated by measuring the weight difference before and after exposure to humid conditions.

3.3 Moisture Absorption Efficiency

Fabric Blend	Moisture Absorption (%)
50% Recycled PET + 50% Recycled Modal	.2%
50% Recycled PET + 50% Recycled Bamboo	68.5%
50% Recycled PET + 50% Recycled Lyocell	10.1%

Discussion:

- The Lyocell blend showed the highest moisture absorption (10.1%), making it the best choice for sweat management and moisture regulation.
- The Bamboo blend also absorbed a significant amount of moisture (8.5%), making it a good alternative for natural breathability.
- The Modal blend absorbed the least moisture (6.2%), suggesting that it may provide a drier feel under high-sweat conditions.

3.4 Moisture-Wicking Efficiency

The moisture-wicking performance was measured by placing a 0.1 mL water droplet on the fabric and recording the time taken for complete absorption and spreading.

3.4 Moisture-Wicking Efficiency

Fabric Blend	Wicking Time (Seconds)
50% Recycled PET + 50% Recycled Modal	47 sec
50% Recycled PET + 50% Recycled Bamboo	39 sec
50% Recycled PET + 50% Recycled Lyocell	33 sec

Discussion:

- The Lyocell blend exhibited the fastest wicking time (33 sec), proving to be the best for moisture management, allowing sweat to disperse quickly.
- The Bamboo blend performed well (39 sec) due to its natural capillary action.
- The Modal blend had the slowest wicking time (47 sec), suggesting lower hydrophilic properties compared to Lyocell and Bamboo.

3.5 Overall Comparison and Selection of the Best Blend

Based on the tested properties, the 50% Recycled PET + 50% Recycled Lyocell fabric performed best in abrasion resistance, tensile strength, moisture absorption, and moisture-wicking efficiency.

3.5 Blend Comparison

Fabric Blend	**Abrasion Resistance (Rubs)**	**Tensile Strength (Warp/Weft, N)**	**Moisture Absorption (%)**	**Wicking Time (Sec)**
50% Recycled PET + 50% Recycled Modal	9,800	490 / 455	6.2%	47
50% Recycled PET + 50% Recycled Bamboo	8,500	470 / 430	8.5%	39
50% Recycled PET + 50% Recycled Lyocell	10,200	510 / 475	10.1%	33

3.6 Comparison of Recycled PET + Recycled Lyocell with Commercialized 50% Polyester + 50% Cotton Athletic Wear

To further assess the effectiveness of the 50% Recycled PET + 50% Recycled Lyocell blend, its performance was

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compared with an existing commercialized 50% Polyester + 50% Cotton (PET+Cotton) athletic fabric, which is widely used in sportswear. The key properties compared include abrasion resistance, tensile strength, moisture absorption, and moisture-wicking efficiency.

3.6 Comparative Performance Analysis

Property	50% Recycled PET + 50% Recycled Lyocell	50% Polyester + 50% Cotton (Commercial Fabric)
Abrasion Resistance (ASTM D4966, 15 kPa Load)	10,200 rubs (Excellent)	8,900 rubs (Good)
Tensile Strength (Warp/Weft, N) (ASTM D5034)	510 / 475 N	490 / 440 N
Moisture Absorption (%)	10.1% (Superior)	7.8% (Average)
Moisture-Wicking Time (Seconds)	33 sec (Fastest)	48 sec (Slower)
Breathability (Air Permeability, mm/s)	85 mm/s	70 mm/s
Durability After 30 Washes	Retains 92% Strength	Retains 85% Strength

3.6.1 Insights and Justification for Superiority of Recycled PET + Lyocell

1. Abrasion Resistance – Higher Durability for Long-Term Use

- The Recycled PET + Lyocell blend outperformed the PET + Cotton blend by withstanding 10,200 rubs compared to 8,900 rubs under the same conditions.
- This indicates that the Lyocell-PET blend offers superior durability, making it ideal for sportswear designed for high-performance activities.

2. Tensile Strength – Stronger Fabric for Performance Wear

- The Lyocell-PET blend had a higher tensile strength (510 N warp, 475 N weft) compared to the Polyester-Cotton blend (490 N warp, 440 N weft).This indicates that the Lyocell-PET blend offers superior durability, making it ideal for sportswear designed for high-performance activities.
- Lyocell's natural high-tenacity fibers enhance structural integrity, making it more resistant to tearing and stretching under tension.

3. Moisture Absorption – Superior Sweat Management

- The Recycled PET + Lyocell blend absorbed 10.1% moisture, which is significantly higher than Polyester-Cotton (7.8%).
  - Lyocell has excellent hydrophilic properties, allowing it to absorb and retain sweat more effectively than cotton, ensuring better dryness and comfort during workouts.

1. Moisture-Wicking Efficiency – Faster Sweat Evaporation

- The Lyocell-PET blend wicked moisture in just 33 seconds, whereas the Polyester-Cotton fabric took 48 seconds to absorb and spread moisture.
- This proves that Lyocell's capillary action is more efficient than Cotton, leading to quicker evaporation and a drier feel.

2. Breathability – Increased Airflow for Enhanced Comfort

- The Lyocell-PET blend had an air permeability of 85 mm/s, making it significantly more breathable than the Polyester-Cotton fabric (70 mm/s).
- Lyocell fibers have a unique nanostructure, allowing better air circulation and reducing heat buildup, making it ideal for athletic activities.

3. Durability After Washing – Longer Fabric Lifespan

- After 30 washing cycles, the Recycled PET + Lyocell fabric retained 92% of its tensile strength, compared to 85% in Polyester-Cotton blends.
- Lyocell's natural resistance to fiber degradation ensures longer-lasting performance, reducing the need for frequent replacement and contributing to sustainability.

4. Sustainability – A Fully Eco-Friendly Alternative

- The Recycled PET + Lyocell blend is made entirely from recycled fibers, making it a fully sustainable fabric choice.
- In contrast, commercial Polyester-Cotton blends are only partially sustainable, as only the polyester component is recyclable, while cotton requires extensive water and chemical usage.

3.6.2 Key Takeaways: Why Recycled PET + Lyocell is the Best Choice

1. **Higher abrasion resistance** →Longer lifespan for activewear.
2. **Greater tensile strength** → More durable for intense movement and stretching.
3. **Superior moisture absorption & wicking** → Keeps athletes dry and comfortable.
4. **Enhanced breathability** → Reduces heat buildup during physical activity.

5. **Better wash durability** → Extends garment life cycle, reducing waste.
6. **Fully sustainable** → 100% recycled fibers contribute to an eco-conscious future.

4. CONCLUSION

This study successfully developed and evaluated three sustainable fabric blends using recycled fibers, aiming to create high-performance athletic wear with minimized environmental impact. By recycling cutting waste fabrics and processing them into high-quality yarns and textiles, this project contributes to sustainable textile innovations. Among the three blends analyzed—50% recycled PET + 50% recycled Lyocell, 50% recycled PET + 50% recycled Modal, and 50% recycled PET + 50% recycled Bamboo—the 50% recycled PET + 50% recycled Lyocell blend demonstrated the most superior properties in terms of durability, breathability, moisture absorption, and moisture-wicking efficiency.

The 50% recycled PET + 50% recycled Lyocell fabric exhibited the highest abrasion resistance, withstanding over 10,200 rubs under a 15 kPa load, outperforming the other blends. It also demonstrated superior tensile strength (510 N) and breathability (85 mm/s), making it highly suitable for sportswear applications. Furthermore, its moisture-wicking time was recorded at 33 seconds, significantly faster than the other blends, ensuring better comfort for athletes. Compared to the commercially available 50% polyester + 50% cotton blend used in athletic wear, the recycled PET-Lyocell fabric demonstrated superior moisture management, durability, and sustainability, reinforcing its potential as an eco-friendly alternative.

The chemical treatment process with eco-friendly silicone further enhanced moisture-wicking performance, proving that sustainable methods can produce high-quality functional textiles. These findings highlight the potential of incorporating recycled fibers in performance textiles, reducing reliance on virgin materials while maintaining or exceeding industry standards. Future research can explore alternative fiber ratios, advanced chemical treatments, and large-scale production feasibility to optimize the application of these sustainable fabric blends in commercial textile manufacturing.

6.1 Suggestions for Future Work

1. Advanced Fiber Blends – Investigate alternative fiber ratios and additional recycled materials to further optimize durability, moisture-wicking, and breathability. Eco-Friendly Treatments.
2. Develop and test sustainable chemical treatments to enhance moisture management and antibacterial properties without compromising environmental safety. Life Cycle & Environmental Impact
3. Conduct a comprehensive life cycle assessment (LCA) to quantify the environmental benefits of recycled PET-Lyocell athletic wear compared to conventional fabrics. Industrial Scalability
4. Explore large-scale manufacturing feasibility, cost- effectiveness, and potential challenges in commercializing these sustainable fabric blends. Consumer Acceptance & Performance Testing
5. Perform real-world wear trials and consumer surveys to assess comfort, durability, and market potential for sustainable athletic apparel.

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