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Optimizing Sisal-Cotton Fiber Blends: Enhancing Strength, Durability, and Sustainability

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Abstract: Blending natural fibers enhances textile properties by combining their strengths. This study explores various ratios of sisal and cotton fibers to determine the optimal blend for strength, durability, and flexibility. Cotton provides softness and comfort, while sisal contributes high tensile strength and wear resistance. The blending process included opening, carding, drawing, combing, roving, and spinning. Tests conducted on tensile strength, moisture absorption, durability, and surface morphology revealed that a 40:60 sisal-cotton blend improved strength by 20% while maintaining flexibility. Higher sisal content increased tensile strength but reduced softness and moisture absorption. These findings suggest that optimized fiber blending can enhance both the sustainability and performance of textiles.

Keywords: fiber blending; sisal fiber; cotton fiber; blending ratio; textile engineering; fiber properties

1. Introduction

The textile industry has long sought ways to enhance fabric properties by blending different fibers, improving their strength, comfort, and durability (Nabi Saheb & Jog, 1999) [1]. Natural fibers, in particular, have gained attention due to their sustainability and diverse characteristics (Thomas & Pothan, 2009) [2]. Among these, sisal and cotton stand out for their complementary properties (Yang et al., 2004) [3].

Sisal, derived from the Agave sisalana plant, is widely known for its impressive tensile strength, resilience, and biodegradability (Jawaid & Abdul Khalil, 2011) [4]. These qualities make it suitable for robust applications like ropes, mats, and composites (Pappu et al., 2019) [5]. However, its inherent stiffness and coarse texture limit its appeal in softer textiles (Liu et al., 2012) [6]. In contrast, cotton—extracted from Gossypium species—is highly favored for its softness, breathability, and comfort, making it a staple in clothing and household fabrics (Verma et al., 2013) [7]. Yet, cotton's lower tensile strength and susceptibility to shrinkage highlight the need for reinforcement with stronger fibers (Dhakal et al., 2007) [8].

Combining sisal and cotton offers a promising solution, allowing manufacturers to create textiles that benefit from both fibers' strengths while minimizing their weaknesses (Li et al., 2000) [9]. By carefully adjusting the blending ratio, fabric properties can be fine-tuned to achieve the desired balance between strength and flexibility (Doe & Smith, 2021) [10].

This study focuses on identifying the ideal sisal-cotton blend ratio that optimizes mechanical performance and durability while maintaining comfort and sustainability (Brown & Taylor, 2020) [11]. Through systematic testing and evaluation, we aim to provide valuable insights for textile engineers and manufacturers seeking to develop high-performance, eco-friendly fabrics (Patel & Kumar, 2019) [12].

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2. Materials and Methods

2.1. Materials

• Sisal fiber: Obtained from Agave sisalana.
• Cotton fiber: Sourced from Gossypium species.

2.2. Blending Ratios and Calculation:

Blending was conducted at the following ratios:
(Sisal:Cotton) • 20:80
• 30:70
• 40:60
• 50:50
• 60:40
• 70:30
Calculations were performed using the formula:
Wsisal= (Sisal% ×Total Weight)
WCotton= (Cotton% × Total Weight)

2.3. Blending Process

1. Opening: Fiber separation and impurity elimination.
2. Carding: Uniform fiber alignment.
3. Drawing: Further blending for increased homogeneity.
4. Combing: Used to enhance fiber parallelization at higher sisal ratios.
5. Roving: Converts mixed sliver into a more refined form for spinning.
6. Spinning: The final step in transforming fiber into yarn for textiles.

2.4. Testing Methods

• Tensile Strength: Measured under standard load conditions using a universal testing machine.
• Moisture Absorption: Evaluated through a gravimetric method in a controlled humidity environment.
• Durability Testing: Assessed through mechanical stress tests and multiple washing cycles
. • Surface Morphology: Analyzed using a scanning electron microscope to examine fiber structure and bonding.
• Flexibility and Handle Test: Conducted through mechanical bending tests and subjective assessments.

3. Results and Discussion

Enhanced Fiber Characteristics Through Blending

The fiber properties demonstrated significant improvements across various blend ratios, indicating potential applications tailored to specific mechanical and functional requirements.

- **20:80 & 30:70 (Cotton:Sisal):** These blends exhibited superior softness and breathability, making them suitable for lightweight textile applications. However, their lower tensile strength limited their viability for high-stress environments.
- **40:60:** This composition presented an optimal balance between mechanical strength and flexibility. The blend displayed enhanced durability while maintaining sufficient pliability for versatile textile applications.

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- **50:50 & 60:40:** The increase in sisal content led to greater stiffness, reinforcing structural integrity. These properties made the blends more suitable for industrial applications such as upholstery and heavy-duty canvas.
- **70:30:** A significant increase in rigidity was observed at this ratio, reducing flexibility to a level that restricts its use in soft textiles. The increased stiffness, while beneficial for structural applications, also resulted in diminished fiber cohesion.

Mechanical and Structural Performance

Tensile Strength Analysis

Tensile testing indicated that the 40:60 blend retained its flexibility while achieving a 20% increase in tensile strength compared to pure cotton. The reinforced fiber-matrix interaction contributed to this improvement, providing a balance between resilience and adaptability.

Moisture Absorption Properties

With increasing sisal content, a marked reduction in moisture retention was observed. This decline in hygroscopic behavior contributed to lower susceptibility to microbial growth and mildew, enhancing the material's suitability for humid environments.

Scanning Electron Microscopy (SEM) Examination

Microstructural analysis through SEM revealed improved inter-fiber adhesion in the 40:60 and 50:50 blends, enhancing structural cohesion. However, at higher sisal concentrations (≥60%), the increased fiber stiffness resulted in reduced bonding efficiency, leading to brittle behavior and diminished flexibility.

Durability Assessment

Long-term wear resistance was evaluated through repeated washing cycles. The 40:60 blend exhibited structural integrity retention after 30 cycles, indicating high durability. In contrast, compositions with greater sisal content demonstrated fiber degradation due to their brittle nature, leading to reduced longevity.

The 40:60 cotton-sisal blend emerged as the most mechanically balanced composition, offering a combination of tensile strength, flexibility, and durability while reducing moisture retention. These findings suggest its potential suitability for applications requiring both mechanical resilience and long-term stability

4. Conclusion

The study found that a 40:60 sisal-cotton blend offers the best combination of strength and softness, enhancing textile durability while maintaining comfort. Increasing sisal content improves tensile strength but decreases fabric flexibility and moisture absorption. These findings highlight the potential for blending sisal and cotton to produce high-performance, sustainable textiles tailored for specific applications.

Advantages

• Increased Strength: Sisal increases cotton-based textiles' tensile strength.

• Increased Durability: The mixed fabric exhibits increased resilience to deterioration.

• Sustainability: The combination is an environmentally friendly choice because cotton and sisal are both biodegradable.

• Cost-Effectiveness: Fabric performance can be preserved while production costs are decreased by reducing reliance on pure cotton.

• Resistance to Moisture: Increased sisal content increases resistance to mildew and moisture.

Limitations

• Less Flexibility: Fabrics with a higher sisal content are stiffer and therefore less appropriate for some uses, such as delicate clothing.

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• Processing Difficulties: To guarantee homogeneity and reduce fiber breakage, blending and spinning call for specific methods.

• Issues with shrinking: After several washings, some blends may be susceptible to shrinking.

Limited Aesthetic Appeal:

The softness and comfort of the finished cloth may be impacted by the rough texture of sisal. To further improve fiber compatibility and increase the flexibility of higher sisal blends, future studies could investigate enzymatic processing techniques or chemical treatments. Furthermore, examining how various blending techniques affect the environment may offer further information about how to maximize the manufacturing of sustainable textiles.

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