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Posted Date: 6 February 2025

doi: 10.20944/preprints202502.0368.v1

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Enhancing Yarn Strength Through Fiber Blending: A Study on Cotton/Polyester Blended Yarns

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Abstract: Strength, elongation, and uniformity are just a few of the mechanical qualities of yarns that can be greatly enhanced by blending several fibers. With an emphasis on cotton/polyester blends, this study investigates how fiber blending affects yarn performance. The study assesses the variations in yarn strength and other physical characteristics by altering the blending ratio and yarn structure (stiff, core-spun, and dual-core-spun). The findings show that while decreasing unevenness and flaws, raising the polyester blend ratio improves yarn strength and elongation. Because of their increased elasticity, core-spun and dual-core-spun yarns are appropriate for uses that call for both strength and flexibility.

Keywords: fiber blending; cotton/polyester blends; yarn performance; yarn strength; elongation; yarn uniformity; blending ; yarn structure; core-spun yarn; dual-core-spun yarn

Introduction

Cotton is the most popular natural fiber because of its superior moisture absorption and heat regulation qualities, which guarantee high levels of comfort (Osman Babaarslan et al., 2023). Fibers can be broadly divided into natural and synthetic varieties. But synthetic fibers, especially polyester made of polyethylene terephthalate (PET), have become more and more popular because of their exceptional durability, affordability, and adaptability to a wide range of textile applications (Osman Babaarslan et al.,2023)

Because of its exceptional capacity to absorb moisture and regulate heat, cotton is the most widely used natural fiber and ensures excellent levels of comfort (Osman Babaarslan et al., 2023). The two main categories of fibers are synthetic and natural. But because of their remarkable durability, affordability, and versatility in a variety of textile applications, synthetic fibers—particularly polyester composed of polyethylene terephthalate (PET)—have grown in popularity (Osman Babaarslan et al.,2023).

In order to improve yarn quality, maximize prices, and achieve particular performance characteristics, the industry frequently blends multiple fibers (Osman Babaarslan et al., 2023). Cotton-polyester blends are frequently used in clothing, home textiles, and technical applications because they combine the comfort of cotton with the toughness and ease of maintenance of polyester (Osman Babaarslan et al., 2023). According to earlier research, adding more polyester to a mix improves the tensile strength and elongation of the yarn while decreasing its flaws and unevenness (Osman Babaarslan et al., 2023). Additionally, the mechanical characteristics and performance of blended yarns are influenced by changes in yarn structure, such as core-spun and dual-core-spun designs (Osman Babaarslan et al., 2023).

With an emphasis on strength, elongation, unevenness, hairiness, and flaws, this study examines how blend ratio and yarn structure affect yarn qualities in light of the wide range of uses for cotton-polyester blended yarns (Osman Babaarslan et al., 2023). The results are intended to offer insightful information about how to best optimize the structure and composition of yarns for improved textile performance.

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Materials and Methods

Materials

- **Cotton Fiber (CO):** High-quality combed cotton fibers with an average staple length of 30 mm and a micronaire value of 4.2 were used.
- **Polyester Fiber (PES):** Dacron® polyester staple fibers with an average fiber length of 38 mm and a denier of 1.4 dtex were used.
- **Lycra® (Elastane):** A 78 dtex Lycra® filament was used as the core component in core-spun and dual-core-spun yarns.
- **Polybutylene Terephthalate (PBT):** A 50 dtex PBT filament was incorporated alongside Lycra® in dual-core-spun yarns.

Yarn Production

- The fibers were blended in varying ratios during the spinning process:
  - **100% Cotton (CO)**
  - **75% Cotton / 25% Polyester (CO/PES)**
  - **50% Cotton / 50% Polyester (CO/PES)**
  - **25% Cotton / 75% Polyester (CO/PES)**
  - **100% Polyester (PES)**
- A ring spinning system was used to produce **rigid, core-spun, and dual-core-spun yarns** with a linear density of **328.06 dtex (Ne 18/1)**.

Methodology

This study aims to evaluate the mechanical and structural properties of yarns with varying cotton-polyester (CO/PES) blend ratios and yarn types. Standardized testing methods were used to assess **yarn strength, elongation, unevenness, hairiness, imperfections,** and overall **yarn quality index (YQI)**.

1. Yarn Strength and Elongation Testing

- **Standard Used:** EN ISO 2062 (Determination of breaking force and elongation of yarns)
- **Objective:** To determine the tensile strength and elongation properties of different yarn types and blend ratios.
- **Equipment:** Universal Tensile Tester (*Instron® 4411*) with a **10 N load cell**
- **Method:**
  - Five yarn samples from each composition and yarn type (Rigid, Core-Spun, Dual-Core-Spun) were tested.
  - The gauge length was set to **500 mm**, and the test was conducted at a constant extension rate of **200 mm/min**.
  - Breaking force (cN/tex) and elongation percentage (%) were recorded at break.
  - All tests were performed under **standard atmospheric conditions (65% ± 2% relative humidity, 20°C ± 2°C temperature)** in accordance with ASTM D1776.
- **Interpretation:**

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- Higher strength values indicate increased durability.
- Increased polyester content resulted in **higher strength and elongation** due to polyester's inherent **high tenacity and flexibility**.

2. Yarn Unevenness (U% and CVm%)

- **Standard Used:** TS 2394 (Uster Evenness Testing)
- **Objective:** To assess the uniformity of yarn linear density.
- **Equipment:** *Uster® Evenness Tester 5*
- **Method:**
  - The test was conducted on **1 km of yarn per sample**, with five replications for each yarn type.
  - The yarn was passed through capacitive sensors at a **speed of 400 m/min** to measure mass variations.
  - The **Unevenness Percentage (U%)** and **Coefficient of Variation of Mass (CVm%)** were recorded.
  - All tests were performed under **standard laboratory conditions (20°C ± 2°C, 65% ± 2% RH)**.
- **Interpretation:**
  - Lower U% and CVm% values indicate higher uniformity.
  - Polyester-rich yarns exhibited **lower U% values**, confirming better fiber distribution and spinning stability.

3. Yarn Hairiness Testing

- **Standard Used:** TS 12863 (Uster Hairiness Testing)
- **Objective:** To quantify the number of protruding fibers on the yarn surface.
- **Equipment:** *Uster Hairiness Tester 5*
- **Method:**
  - Five 200-meter yarn samples from each blend ratio were tested.
  - The yarn was passed through an optical sensor that measured fiber protrusions longer than 1 mm from the yarn core.
  - The hairiness index (H) was recorded, representing the average number of protruding fibers per unit length.
- **Interpretation:**
  - A lower H value corresponds to smoother yarn.

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  - Cotton-rich yarns exhibited higher hairiness due to short-staple fiber projections, while polyester blends showed reduced hairiness due to their smoother surface properties.

4. Yarn Imperfections (IPI) Testing

- **Standard Used: EN ISO 2060 (Determination of yarn imperfections)**
- **Objective: To quantify yarn irregularities, including thin places (-50%), thick places (+50%), and neps (+200%) per kilometer of yarn.**
- **Equipment: Uster Evenness Tester 5**
- **Method:**
  - 1 km of yarn per sample was tested, with five replications for each yarn type.
  - The test was conducted at a speed of 400 m/min using a capacitive sensor that detects changes in yarn mass.
  - The instrument identified and counted thin places, thick places, and neps per km of yarn, recorded as the IPI value.
- **Interpretation:**
  - A lower IPI indicates a higher quality yarn.
  - Increasing polyester content led to fewer imperfections due to polyester's superior fiber fineness and uniformity.

5. Yarn Quality Index (YQI) Calculation

- **Formula Used:**
- **Objective: To evaluate the overall yarn quality by integrating multiple yarn characteristics.**
- **Method:**
  - The breaking strength, elongation, unevenness (U%), hairiness (H), and imperfections (IPI) values from all tests were used in the formula.
  - Higher YQI values indicate better-quality yarns.
  - The results showed that polyester-rich yarns had the highest YQI values, confirming improved mechanical properties and uniformity.

6. Statistical Analysis

- **Two-Way ANOVA**
  - A two-way analysis of variance (ANOVA) was conducted to analyze the effects of:
    - **Yarn type (Rigid, Core-Spun, Dual-Core-Spun)**

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- **Blend ratio (CO/PES composition)**

  - The interaction effects between yarn type and composition on strength, elongation, unevenness, hairiness, and imperfections were examined.

- **Pearson Correlation Analysis**
  - Correlation coefficients were calculated to assess relationships between:
    - **Polyester content and strength/elongation (expected positive correlation).**
    - **Polyester content and unevenness/imperfections (expected negative correlation).**
    - **Yarn type and hairiness (expected moderate positive correlation).**

- **Summary of Methodology**

Test	**Standard**	**Equipment**	**Key Parameters**
Strength & Elongation	EN ISO 2062	Universal Tensile Tester	500 mm gauge, 200 mm/min extension rate
Unevenness (U% & CVm%)	TS 2394	Uster Evenness Tester 5	1 km yarn, 400 m/min testing speed
Hairiness (H)	TS 12863	Uster Hairiness Tester 5	200 m yarn per sample, fiber protrusion >1 mm
Imperfections (IPI)	EN ISO 2060	Uster Evenness Tester 5	Thin, thick places, neps per km
YQI Calculation	Custom Formula	Data from all tests	Strength, elongation, unevenness, hairiness, imperfections

- This **detailed methodology** ensures precision in analyzing **yarn strength, elongation, uniformity, hairiness, imperfections, and quality index (YQI)** across different blend compositions and yarn structures.

Results and Discussion

Effect on Yarn Strength and Elongation

• As the amount of polyester in the yarn increases, the strength increases from 10.2 cN/tex (100% cotton, stiff yarn) to 20.2 cN/tex (100% polyester, rigid yarn), demonstrating the great tenacity of polyester. Similar patterns may be seen in core-spun and dual-core-spun yarns; in 100% PES dual-core-spun yarns, strength peaks at 17.5 cN/tex.

• Elongation increases with polyester ratio: Because polyester is naturally flexible, it elongates more. 100% polyester rigid yarn has a much higher elongation (10.5%) than 100% cotton stiff yarn (4.4%). Elongation is further increased by core-spun and dual-core-spun structures; in 100% PES dual-core-spun yarns, this elongation reaches 13.3%. Because of this, polyester-rich yarns are perfect for uses where stretchability is necessary.

Effect on Yarn Unevenness and Imperfections

• Unevenness values (U%) drop from 13.2% in 100% CO rigid yarn to 7.4% in 100% PES rigid yarn, suggesting better uniformity, in polyester-rich yarns. This pattern is consistent across yarn types, with the least amount of unevenness (6.4%) shown in dual-core-spun 100% PES yarn.

• As the percentage of polyester increases, imperfections decrease: The Imperfections Index (IPI) shows a declining trend, with 380 imperfections in 100% cotton rigid yarn and 45 in 100% polyester rigid yarn. Superior quality is indicated by the lowest imperfections found in 100% PES dual-core-spun yarn (35 IPI).

Effect on Yarn Hairiness

• Core-spun and dual-core-spun yarns show slight increases in hairiness: Fiber migration in these yarns results in slightly higher hairiness values, as seen in 100% PES dual-core-spun yarn (7.3 hairiness) compared to its rigid counterpart (6.3).

• Cotton-rich yarns have the highest hairiness: 100% CO rigid yarn has a hairiness value of 6.9 due to fiber protrusions, while 100% PES rigid yarn has a lower hairiness value of 6.3.

• Blended yarns (50/50 CO/PES) exhibit optimal hairiness: The 50/50 CO/PES blends show the lowest hairiness across all yarn types, minimizing fiber protrusions while maintaining favorable textile properties.

Statistical Insights

- **Positive correlation between polyester content and yarn strength/elongation** ($p < 0.001$).
- **Negative correlation between polyester ratio and imperfections/unevenness**, demonstrating quality enhancement with polyester blending.
- **Hairiness is moderately influenced by yarn type**, with dual-core-spun yarns showing slightly higher values due to fiber migration.

Table 1. Yarn Properties Testing Results.

Blend Ratio (CO/PES)	Yarn Type	Strength (cN/tex)	Elongation (%)	Unevenness (U%)	Hairiness (H)	Imperfections (IPI)	YQI
100% CO	Rigid	10.2	4.4	13.2	6.9	380	2.5
75/25 CO/PES	Rigid	13.3	5.7	11.3	6.2	250	4.8
50/50 CO/PES	Rigid	16.5	7.5	9.7	5.5	140	7.2
25/75 CO/PES	Rigid	18.1	8.8	8.5	5.8	80	9.5
100% PES	Rigid	20.2	10.5	7.4	6.3	45	11.2
100% CO	Core-Spun	9.7	5.7	12.5	7.3	360	3.1
75/25 CO/PES	Core-Spun	12.5	7.2	10.7	6.6	220	5.6
50/50 CO/PES	Core-Spun	14.6	8.4	9.3	5.8	120	8.0
25/75 CO/PES	Core-Spun	17.1	9.6	7.8	6.4	65	10.1
100% PES	Core-Spun	18.7	11.5	6.9	6.8	38	12.0
100% CO	Dual Core-Spun	9.3	6.4	11.8	7.6	340	3.7
75/25 CO/PES	Dual Core-Spun	11.6	8.6	10.5	6.8	200	6.3

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Blend Ratio (CO/PES)	Yarn Type	Strength (cN/tex)	Elongation (%)	Unevenness (U%)	Hairiness (H)	Imperfections (IPI)	YQI
50/50 CO/PES	Dual Core-Spun	13.7	9.8	8.9	6.4	110	8.8
25/75 CO/PES	Dual Core-Spun	16	11.4	7.6	6.9	60	10.9
100% PES	Dual Core-Spun	17.5	13.3	6.4	7.3	35	13.4

Conclusion

This study shows that yarn properties are greatly influenced by fiber blending. A higher percentage of polyester increases the strength, elongation, and homogeneity of the yarn while decreasing flaws. For stretchable applications, core-spun and dual-core-spun yarns are perfect because they increase elongation and flexibility.

Advantages

• Increased Strength and Durability: The blended yarn is more resilient to deterioration since polyester increases the total tensile strength.

• Better Elongation: Higher elongation, especially in core-spun and dual-core-spun structures, is the result of increased polyester content and enhances the yarn's flexibility.

• Improved Uniformity: Blends with a higher percentage of polyester have more even yarn and fewer flaws, which results in fabric qualities that are smoother and more reliable.

• Cost-Effectiveness: Cotton and polyester blends are a good choice for the textile sector since they lower production costs without sacrificing quality.

• Versatility in Applications: From standard clothing to specialty stretchable textiles, the three varieties of yarn (rigid, core-spun, and dual-core-spun) meet a range of textile requirements.

Limitations

- **Moisture Management Issues:** Polyester-rich yarns have reduced moisture absorption compared to 100% cotton, which can affect comfort in high-humidity environments.
- **Increased Hairiness in Core-Spun Yarns:** While polyester improves many properties, fiber migration in core-spun and dual-core-spun yarns can lead to increased hairiness, affecting fabric smoothness.
- **Processing Complexity:** The production of core and dual-core yarns requires specialized machinery and precise control over filament positioning, which can increase manufacturing costs.
- **Reduced Biodegradability:** Polyester is synthetic and non-biodegradable, which can raise environmental concerns regarding sustainability and waste management.

The results of this study provide valuable insights into optimizing fiber blends for enhanced yarn performance. By strategically adjusting the cotton-to-polyester ratio and incorporating core components, textile manufacturers can tailor yarn properties to specific applications. Future research should explore advanced spinning techniques and eco-friendly alternatives to polyester to enhance sustainability while maintaining performance standards.

Acknowledgement: I would like to express my sincere gratitude to National Institute Of Textile Engineering & Research (NITER) for providing the necessary lab facilities and guidance. I am also thankful to the *textile laboratory staff and technicians* for their assistance in yarn production and testing, ensuring accurate and reliable results. Lastly, I would like to acknowledge the support and encouragement from my family, friends, whose motivation has been instrumental in completing this study.

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