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Article

Comparative study on the quality parameters of ring and rotor spun yarn: A case study

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Abstract

This study presents a comparative analysis of the quality parameters of ring spun and rotor spun yarns, both produced from the same raw material, 100% Brazilian cotton fibers, and prepared into 20 Ne (carded) yarns. The yarns were produced using identical sliver preparation, with drawing before being fed into the ring spinning frame (through simplex) for ring spun yarn and directly into the rotor spinning frame for rotor spun yarn. Key yarn quality properties such as mass variation, imperfections, hairiness, and tensile properties (e.g., count strength product (CSP), breaking force, breaking length, tenacity, work of rupture, and breaking elongation) were compared between the two spinning systems. The findings indicate that ring spun yarn exhibited superior tensile properties including higher CSP, breaking force, and tenacity, while rotor spun yarn demonstrated better uniformity, lower imperfections, and reduced hairiness. The study provides valuable insights into the strengths and limitations of each yarn type and offers recommendations for selecting the appropriate yarn for specific textile applications based on the required properties for fabric performance.

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Ring spinning; rotor spinning; yarn quality; tensile properties; imperfections

Introduction

The spinning process involves the transformation of fibers into yarn by twisting or binding them together. The main steps in yarn spinning include drafting (drawing out the fibers), twisting, and winding. During the process, fibers are initially drafted to a thinner form using rollers. Afterward, twist is inserted into the fibers to bind them together and form a continuous yarn. The twist can be inserted using different mechanisms, such as rotating spindles or other twisting devices. Once the twist is inserted, the yarn is wound onto a spindle or bobbin, creating a yarn package that can be further processed for weaving or knitting. In traditional spinning methods like ring spinning, twisting and winding occur simultaneously, whereas in newer techniques, these actions are separated, allowing for higher production speeds and larger yarn packages. Various spinning systems, such as ring spinning, rotor spinning, and air-jet spinning, offer different benefits in terms of yarn quality, speed, and flexibility for different fiber types and yarn structures (Lawrence, 2010).

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The principle of ring spinning involves assembling and twisting fibers to form a continuous yarn. The process starts with drafting the fibers, which are thinned by a series of rollers to form a fiber strand. This strand is then twisted using a spindle and a rotating traveler, which inserts the twist into the fiber strand. As the twist propagates, the fibers consolidate into a yarn. The yarn is then wound onto a bobbin as it is formed. The twist insertion, governed by the rotation of the traveler around the ring, helps provide strength to the yarn by increasing the inter-fiber friction. The process also involves a "spinning triangle" that governs the flow of twist, ensuring that the yarn is formed with the desired characteristics. The system requires careful control of parameters such as tension, twist rate, and balloon formation to produce consistent and high-quality yarn (Rengasamy, 2010).

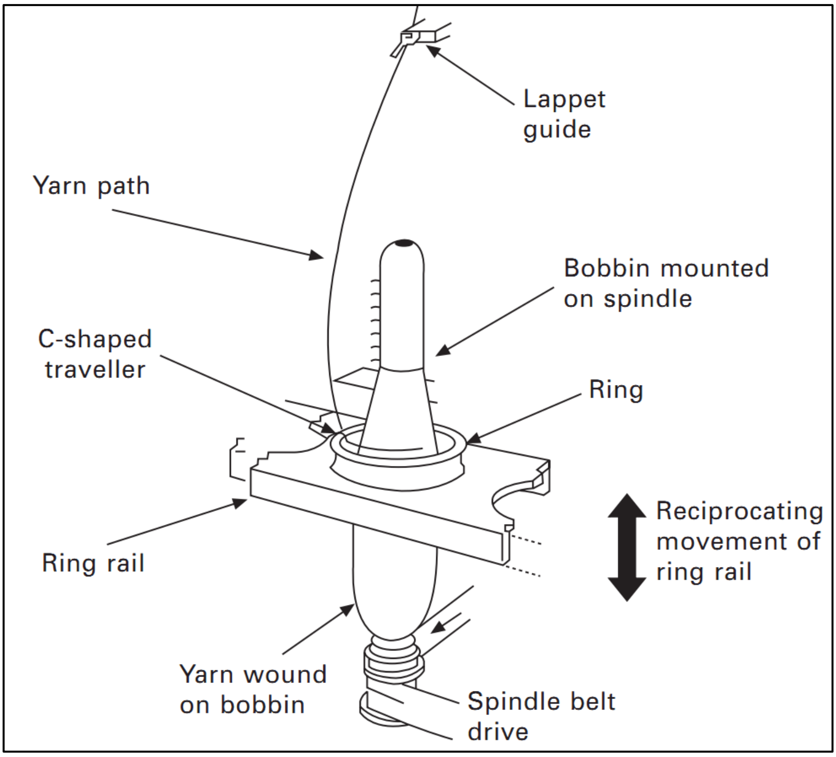

Figure 1. Principle of yarn formation in ring spinning

The principle of yarn formation in rotor spinning begins with the presentation of sliver, which is fed into the system by the feed roller. The opening roller then separates the fibers, and the individual fibers are transported through a tapered tube toward the rotor. Once inside the rotor, the fibers are accumulated on the rotor's inner wall to form a fiber ribbon. This ribbon is then twisted as it enters the rotor groove, where centrifugal forces and air drag pull the fiber ribbon into the spinning process. The twist propagates as the yarn is continuously pulled out by the delivery rollers, and the fibers are bound together to form yarn. This process is efficient because twisting and winding occur simultaneously, and rotor spinning eliminates the need for roving, making it faster and more automated than traditional ring spinning. However, rotor spun yarns are typically coarser and less strong compared to ring spun yarns due to the random alignment of the fibers (Das & Alagirusamy, 2010).

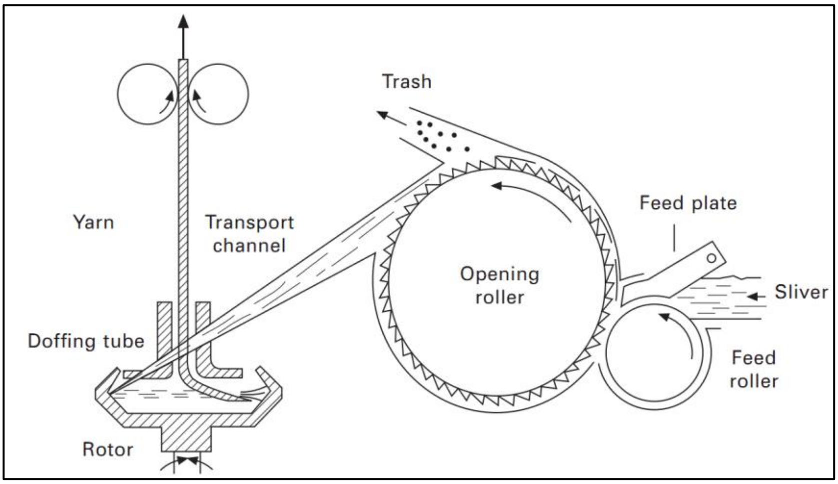

Figure 2. Principle of yarn formation in rotor spinning

The properties of raw cotton provide a comprehensive understanding of its quality and suitability for textile processing. The Uniformity Index (UI) measures the consistency of fiber length, while the Spinning Consistency Index (SFI) reflects how uniform the fibers are for spinning. The Maturity Index (Mat1) indicates the developmental stage of the fibers. The Upper Half Mean Length (UHML) shows the average length of the longer fibers, and the Micronaire value (Mic) combines fiber fineness and maturity. Fiber Strength (Str) is measured in grams per tex, representing how much force the fiber can withstand, while Short Fibre (SF) percentage indicates the portion of shorter fibers that may affect yarn quality. Elongation (Elg) measures how much the fiber can stretch before breaking, and Moisture Content (Mst) shows the amount of water in the fibers. Reflectance (Rd) and Yellowness (+b) assess the brightness and color tone, respectively. The Color Grade (CGrd) is an overall color assessment of upland cotton. Trash-related properties such as Trash Count (TrCnt), Trash Area (TrAr), and Trash or Leaf Grade (TrID) measure the amount and size of impurities. Nep characteristics, including Total Nep Counts, Fiber Nep Count, and Seed Coat Nep Count, along with their mean sizes, indicate the presence of entangled fiber clusters. Length properties like Mean Length by Weight (L(w)), its variation (CV%), and Short Fiber Content by Weight (SFC (w)) help in understanding the fiber distribution, while equivalent measurements by number (L(n), CV%, and short fiber content) provide a count-based perspective. The 5% Length by Number gives the length below which 5% of fibers fall. Lastly, Fineness measured in millitex, Maturity Ratio, and Immature Fiber Content give further insight into fiber quality and development, all of which together influence the spinning performance and final textile quality (Zhenzhen & Fang, 2024).

Yarn quality plays a crucial role in textile manufacturing as it directly influences the performance, appearance, and durability of the final fabric. High-quality yarn ensures uniformity in texture, strength, and elasticity, which are essential for producing fabrics with consistent properties. The quality of yarn affects key characteristics such as fabric smoothness, strength, shrinkage, and colorfastness. Furthermore, yarn quality impacts the efficiency of subsequent processes like weaving, knitting, and dyeing, as poor-quality yarns can lead to increased breakage, defects, and wastage, thereby reducing productivity and increasing costs. In addition, yarn quality is critical in meeting the specific requirements of end-use applications, such as in apparel, upholstery, or technical textiles, where factors like softness, resilience, and resistance to abrasion are vital. Therefore, maintaining high yarn quality is fundamental to achieving cost-effective production and ensuring that the final textile products meet the desired standards for their intended applications ("Appendix 4 - Advanced topics II: Testing of textile materials," 2003; Lord, 2003).

Unevenness (U%) measures the variation in yarn thickness along its length, indicating how irregular the yarn is. The Coefficient of Variation (CVm) % reflects the variability in yarn mass relative to the mean, showing consistency. Thin places (-50%) count the number of spots per kilometer where the yarn diameter is reduced by 50%, representing areas of thinning defects, while thick places (+50%) similarly count spots where the diameter increases by those percentages, indicating thick defects. Neps (+200%) represent small fiber knots or entanglements per kilometer that increase mass by 200%, affecting smoothness. The imperfection index (IPI) is the sum of yarn thin places/ km (-50%), thick places/km (+50%) and neps/km (+200%) per kilometer of tested yarn. Hairiness (H) is defined as the total length of protruding fibers divided by the length of the sensor (1 cm). It is a unitless figure that quantifies the amount of fiber protrusion on the yarn's surface. This measurement plays an essential role in evaluating the quality of yarn because high hairiness can negatively impact the smoothness of the yarn and the resulting fabric, with the standard deviation of hairiness (Sh) showing variation along the length. The Count Strength Product (CSP) combines yarn count (in Ne) and strength (in pound) to evaluate overall quality. Mechanical properties include Breaking Force (cN), which is the force needed to break the yarn; Breaking Length or RKm (Km), indicating the length of yarn that can support its own weight before breaking; Tenacity (cN/tex), which is the breaking force per unit linear density; Work of Rupture or Breaking Work (cN.cm), the energy absorbed before yarn breaks; and Breaking elongation (%), the extent the yarn stretches before breaking, showing its elasticity. Together, these parameters give a comprehensive understanding of yarn quality and performance. Mathematical equations of some quality paraments are given below (Equation 1-8):

$$1.\ \text{Uneveness, U\%} = \text{Percent Mean Deviation(PMD)} = \frac{\text{Mean deviation}}{\text{mean}} \times 100 = \frac{1}{\bar{x}} \sum |x - \bar{x}| \times 100 \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

Here,

- x is the individual data point
- $\bar{x}$ is mean

$$2.\ \text{Breaking length (in Km)} = \text{RKm value} = \frac{\text{Single yarn strength (in g)}}{\text{Yarn linear density (in tex)}} \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

$$3.\ \text{Work of rupture (in cN.cm)} = \int_0^{\text{break}} F \times dl \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

Here,

- F is the applied force (cN)

- dl is the incremental change in length due to force (cm)

4. $\text{Tenacity (cN/tex)} = \frac{\text{Force required to break (cN)}}{\text{Linear density (tex)}}$ ....(4)

5. $\text{Standard Deviation, } \sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$ ....(5)

6. $\text{Coefficient of Variation, CV\%} = \frac{\sigma}{\bar{x}} \times 100 = 1.25 \times \text{PMD}$ ....(6)

7. $\text{Breaking elongation (\%)} = \frac{\text{Elongation at break}}{\text{Original length of specimen}} \times 100$ ....(7)

8. $\text{Shape Factor} = \frac{\text{Diameter equivalent from perimeter}}{\text{Diameter equivalent from area}}$ ....(8)

9. C.S.P = Strength of yarn in pound x Count in English system. ....(9)

Deshdeepak et al. (2016) compared ring, rotor, and vortex spinning systems. They found that while vortex spun yarns exhibited lower tenacity and breaking elongation compared to ring spun yarns, they showed better evenness and fewer imperfections such as thin places and thick places. The study emphasized that ring spun yarns had the highest hairiness and imperfection index but were superior in terms of tensile strength, making them more suitable for high-performance applications where durability is essential (Varshney, 2016). In the study conducted by Nakib-Ul-Hasan et al. (2016), a comparative analysis between ring spun and rotor spun yarns was carried out on 100% cotton yarns. The authors found that ring spun yarns had significantly higher strength, but rotor spun yarns displayed better uniformity, with fewer imperfections such as thin places and neps. The rotor spun yarn also had lower hairiness, indicating that it might be more suitable for smoother fabrics, although the tenacity of rotor spun yarns was found to be 36.36% lower than that of ring spun yarns (Ul-Hasan et al., 2014). Furthermore, Zahidul Islam et al. (2019) compared ring, rotor, and compact spun yarns and found that compact spun yarns exhibited the highest strength and elongation while having less hairiness and mass irregularity than both ring and rotor spun yarns. They concluded that compact spinning offers a better balance of quality by improving strength, elongation, and reducing imperfections (Islam, 2019). Ahmed et al. (2015) also examined ring, rotor, and air-jet spun yarns. They found that although ring spinning produced the highest quality yarn in terms of strength, rotor spinning provided lower imperfections and better evenness. The air-jet yarns, while being highly efficient in terms of production speed, showed inferior performance compared to ring and rotor spun yarns in terms of strength and imperfections (Ahmed et al., 2015).

While previous studies have compared ring spun and rotor spun yarns, there is a lack of research that uses the same raw material (100% Brazilian cotton fiber) to produce yarns for both spinning methods under identical conditions. Many studies do not account for the potential variability in fiber lot or sliver preparation, which can significantly affect the final yarn quality. Additionally, while imperfections, strength, and uniformity have been analyzed in individual spinning methods, there is insufficient research on directly comparing the yarn properties—such as mass variation, hairiness, and tenacity—produced from the same sliver in both spinning systems. Most comparisons focus on just one or two yarn qualities, leaving a gap in understanding how different spinning methods affect all aspects of yarn performance when the fiber quality and sliver preparation are kept consistent. Furthermore, limited studies have comprehensively analyzed the impact of sliver preparation and fiber alignment on yarn characteristics across both ring and rotor spinning.

This research will fill the gap by using 100% Brazilian cotton fibers from the same raw material lot, ensuring consistent sliver preparation for both ring spinning and rotor spinning. By maintaining identical fiber and sliver processing conditions, the study will provide a direct comparison between the two spinning methods. The analysis will focus on multiple key yarn quality parameters, including imperfections, hairiness, mass variation, strength, tenacity, and elongation. This comprehensive approach will offer new insights into the true impact of the spinning method on yarn quality and performance, eliminating the variability that comes from differences in fiber lots or sliver preparation.

Materials and Methods

Materials

In this study, 100% Brazilian cotton fibers were used as the raw material for producing both ring spun and rotor spun yarns. The cotton fibers were sourced from a single lot to ensure uniformity and consistency throughout the experiment. The research was conducted at Abul Kalam Spinning Mills Limited, Sonargaon, Narayangonj, 1440, Bangladesh, where both ring and rotor spinning facilities are available. The cotton was characterized using High Volume Instrument (HVI) and Advanced Fiber Information System (AFIS), which provided detailed information about its properties. The cotton's specifications are summarized in Table 1.

Table 1. Specification of Raw cotton

Sl	Testing Instrument	Properties of raw cotton	Unit	Value
1.	High Volume Instrument (HVI)	Uniformity index (UI)	%	81.6
2.		Spinning consistency index (SFI)	-	118
3.		Maturity index (Mat1)	-	0.86
4.		Upper half mean length (UHML)	inch	1.190
5.		Micronaire value(Mic)	-	4.65
6.		Strength (Str)	g/tex	29.5
7.		Short Fibre(SF)	%	8.9
8.		Elongation (Elg)	%	7.0
9.		Moisture content (Mst)	%	6.4
10.		Reflectance (Rd)	-	75.9
11.		Yellowness (+b)	-	9.8
12.		Color Grade, upland (CGrd)	-	22-2
13.		Trash Count (TrCnt)	-	35
14.		Trash Area (TrAr)	%	0.34
15.		Trash or leaf grade (TrID)	-	3
16.	Advanced Fiber Information System	Total nep countS	Count/g	69
17.		Total nep mean size	µm	603
18.		Fiber nep count	Count/g	65

Sl	Testing Instrument	Properties of raw cotton	Unit	Value
19.	(AFIS)	Fiber nep mean size	µm	588
20.		Seed Coat Nep count	Count/g	4
21.		Seed Coat Nep mean size	µm	986
22.		Mean Length by Weight, L(w)	mm	25.0
23.		Length Variation by weight, L(w), CV%	%	34.8
24.		Short Fiber Content by weight, SFC (w)	%<12.7 mm	8.8%
25.		Upper Quartile Length by weight, UQL (w)	mm	31.2
26.		Mean Length by Number, L(n)	mm	20.4
27.		Length Variation by number , L(n) CV%	%	47.8
28.		Short Fiber Content by number	%<12.7 mm	24.1
29.		5% Length by number	mm	35.2
30.		Fineness	millitex	161
31.		Maturity Ratio	-	0.89
32.		Immature Fiber Content	%	6.8

Machine Description

Table 1 lists the various machines involved in the yarn production process, including Blow Room, Carding, Drawing, Simplex, Ring Frame, Rotor Spinning Machine, Uster Testers, Lea Making, and Strength Tester, along with their respective manufacturers, model numbers, and origins.

Table 2. Machinery Details used in the study

Machine Type	Name	Manufacturer	Model No	Origin
Blow Room	Uniflock	Rieter	A-10	Switzerland
	Uniclean	Rieter	B-10	Switzerland
	Unimix	Rieter	B-60	Switzerland
	Uniflex	Rieter	B-70	Switzerland
Carding	Carding	Rieter	C-51 Hi Per	Switzerland
Drawing	Breaker Drawing(1st)	Rieter	RSBD-30	Switzerland
	Finisher Drawing (2nd)	Rieter	RSBD-30	Switzerland
Simplex	Simplex	Rieter	F 40	Switzerland
Ring Frame	Ring Frame	Rieter	G-32	Switzerland
Rotor Spinning	Rotor Spinning Machine	Rieter	R66	Switzerland
Uster Tester	Uster Tester 6	Uster	-	Switzerland
Uster Tensorapid	Uster Tensorapid 5	Uster	-	Switzerland
Lea making	Wrap reel Machine	TESTEX	TY360B	China
Strength Tester	Lea strength tester	Apple	AFT	India

Methods

For ring spinning, the process begins with the Blow Room, followed by Carding to separate and align the fibers. The fibers then go through two stages of Drawing (1st and 2nd Drawing machine), where they are further aligned and blended. After drawing, the fiber is processed in the Simplex machine, which prepares the sliver for spinning. Finally, the sliver is fed into the Ring Frame, where the yarn is spun.

For rotor spinning, the process is quite similar but ends at the Rotor instead of the ring frame. Starting again with the Blow Room and Carding, followed by the 1st and 2nd Drawing machine, the prepared sliver is then fed directly into the Rotor, where the spinning process occurs. Flow charts illustrating the yarn production process are shown in Figure 3.

After the yarn production, various quality parameters such as imperfections, strength, elongation, and hairiness were measured using Uster Tester 6, Uster Tensorapid 5, and other machinery as mentioned in Table 2 at Textile Testing and Consultation Services (TTCS), Bangladesh University of Textiles, Dhaka. These instruments were used to evaluate the yarn's performance, including its count strength product (CSP), breaking force, and breaking elongation, ensuring that the yarns produced from both spinning systems meet the desired quality standards.

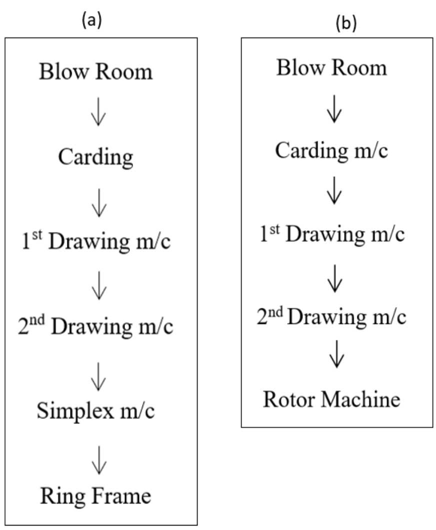

Figure 3. Flow charts illustrating the yarn production process: (a) Ring Spinning Process, (b) Rotor Spinning Process

Results and Discussion

This section presents a comparative analysis of the yarn quality parameters of ring spun and rotor spun yarns produced from 100% Brazilian cotton fibers. The results of the various tests conducted on both yarn types, including mass variation, imperfections, hairiness, and tensile properties, are presented and discussed. The data provided in Table 3 shows the ring spun yarn and rotor spun yarn for key quality parameters. This Uster analysis is based on five test specimen (5000m yarn) from a single cone.

Table 3. Experimental findings of various quality parameters

Sl	Quality Parameters		Ring spun yarn	Rotor spun yarn
1.	Mass Variation	Unevenness (U%)	9.52	9.63
2.		Coefficient of variation (CVm) %	12.05	12.12
3.	Imperfection	Thin places (−50%)/km	0	1
4.		Thick places (+50%)/km	28	8
5.		Neps (+200%)/km (Ring), Neps (+280%)/km (Rotor)	15	14
6.		Imperfection Index (IPI)	43	23
7.	Hairiness	Hairiness (H)	6.44	4.77
8.		Standard deviation of hairiness (Sh)	1.28	1.1
9.	Tensile Properties	Count strength product (CSP)	2242.5	1621.5
10.		Breaking force (cN)	441.52	319.16
11.		Breaking length or RKm value (Km)	15.24	11.02
12.		Tenacity (cN/tex)	14.95	10.81
13.		Work of rupture or Breaking Work (cN.cm)	520.09	585.08
14.		Breaking Elongation (%)	4.25	6.84
15.	Shape factor	Shape factor	0.80	0.69

Comparative Study of Mass Variation of Ring Spun and Rotor Spun Yarn

The unevenness (U%) in ring spun yarn is 9.52%, slightly lower than 9.63% in rotor spun yarn, with a 1.14% higher unevenness in rotor spun yarn. A comparative analysis of yarn unevenness (U%) across different studies reveals noteworthy discrepancies. Zahidul Islam (2019) reported higher unevenness in ring-spun yarn (10.26%) compared to rotor-spun yarn (8.57%), a trend also observed by Ahmed et al. (2015), who recorded U% values of 11.03% for ring yarn and 10.17% for rotor yarn. In contrast, the present study observed a marginally lower U% in ring yarn (9.52%) relative to rotor yarn (9.63%) (Ahmed et al., 2015; Islam, 2019)

This deviation from established findings may be attributed to several factors. Firstly, raw material quality likely played a significant role; the present study utilized high-uniformity Brazilian cotton (UI = 81.6%), whereas prior studies employed Uzbek cotton of comparatively lower uniformity. Secondly, process consistency—particularly the use of identical sliver preparation for both yarn types—may have contributed to the improved evenness of ring yarn. Thirdly, testing precision is also a consideration, as this study employed the advanced Uster Tester 6, which offers greater accuracy compared to older models used in earlier research.

The superior evenness of ring-spun yarn observed in this study is likely due to enhanced fiber alignment, optimized drafting conditions, and reduced short-fiber content, which together minimized mass variation. These advantages appear to have outweighed the inherent evenness benefit typically associated with the back-doubling effect of rotor spinning. These findings highlight the critical influence of fiber quality and process optimization on yarn performance, and suggest that traditional assumptions regarding yarn evenness may not always hold under controlled conditions. Further investigation with standardized fiber-length distributions is recommended to better elucidate the interplay between material properties and spinning techniques.

Similarly, the Coefficient of Variation (CVm) % in rotor spun yarn is 0.57% higher than in ring spun yarn, with rotor spun yarn at 12.12% and ring spun yarn at 12.05%. This slight increase in CVm reflects greater variation in mass distribution in rotor spun yarn. Rotor spinning, being less controlled, results in a more variable distribution of fibers, leading to small inconsistencies in yarn thickness. Ring spinning's more controlled drafting process allows the fibers to be more evenly distributed, thereby reducing variation in the yarn's mass and resulting in a lower CVm.

Comparative Study of Imperfections of Ring Spun and Rotor Spun Yarn

For thin places (-50%) per km, ring spun yarn has no thin places, while rotor spun yarn has 1 thin place per kilometer. The reason for this slight increase in thin places in rotor spun yarn is the less efficient fiber packing and lower tension in the rotor spinning process. Rotor spun yarn has a looser fiber structure, which can create weak spots or thinner sections in the yarn. On the other hand, the more controlled tension and drafting in ring spinning result in better fiber adhesion and stronger, more uniform yarn, reducing the occurrence of thin places.

In terms of thick places (+50%) per km, ring spun yarn has 28 thick places, significantly more than the 8 in rotor spun yarn, showing a 71.42% higher occurrence of thick places in ring spun yarn. The cause of this difference is the non-uniform fiber distribution in the ring spinning process, where the fibers can be unevenly aligned and packed, leading to thicker sections in the yarn. Rotor spinning, which involves a more controlled fiber distribution and back doubling process, leads to a more uniform yarn structure, resulting in fewer thick spots.

For neps (+200%) per km, ring spun yarn has 15 neps per kilometer, while rotor spun yarn has 14. Although the difference is minimal, the slight increase in neps in ring spun yarn can be attributed to the higher drafting tension and the greater fiber entanglement during the spinning process. In ring spinning, as the fibers are pulled and twisted under higher tension, they are more likely to form tangles, leading to more neps. In contrast, rotor spinning uses a more controlled spinning mechanism that reduces fiber entangling and the formation of neps, resulting in a smoother yarn.

The Imperfection Index (IPI), which is the sum of thin places (-50%), thick places (+50%), and neps (+200%) per kilometer, is 46.51% higher in ring spun yarn (43) compared to rotor spun yarn (23). The higher IPI in ring spun yarn is primarily due to the greater number of thick places and neps, which indicates that the ring spinning process creates more irregularities in the yarn. The increased fiber entangling, non-uniform fiber alignment, and higher tension in ring spinning contribute to these imperfections. Rotor spinning, on the other hand, benefits from back doubling and more controlled fiber insertion, leading to a smoother, more uniform yarn with fewer imperfections overall.

Comparative Study of Hairiness of Ring Spun and Rotor Spun Yarn

The hairiness of the yarn, indicated by the Hairiness Index (H), is significantly higher for ring spun yarn compared to rotor spun yarn. From table 3, it is found that, the ring spun yarn exhibits a hairiness value of 6.44, which is 25.93% higher than the 4.77 value of rotor spun yarn. The higher hairiness in ring spun yarn can be attributed to its structural characteristics. Ring spinning produces a higher number of free fiber ends, especially at the outer layers of the yarn, which are not fully adhered to the body of the yarn. These loose fibers contribute to a rougher texture and greater protrusion. Additionally, the uncontrolled passage of edge fibers during the ring spinning process, especially in the balloon region, leads to more fiber ends being exposed on the surface of the yarn. The larger spinning triangle in ring spinning allows more fiber to escape and protrude, thus contributing to higher hairiness.

In contrast, rotor spun yarn has a significantly lower hairiness due to its unique spinning process. The rotor spinning method helps bind the loose fiber ends with wrapping fibers that wind crosswise around the yarn. This wrapping action reduces the amount of free fiber ends that are exposed, resulting in less hairiness. The structure of rotor spun yarn, with fewer protruding fibers, leads to smoother yarn, which is beneficial in applications where low pilling and abrasion resistance are important.

The standard deviation of hairiness (Sh) is also higher for ring spun yarn (1.28) compared to rotor spun yarn (1.1), indicating that the variation in fiber protrusion is greater in ring spun yarn. This variability is due to the more complex fiber migration and alignment process in ring spinning, which produces a less uniform yarn surface. Rotor spun yarn, with its more controlled process, has less variation in hairiness.

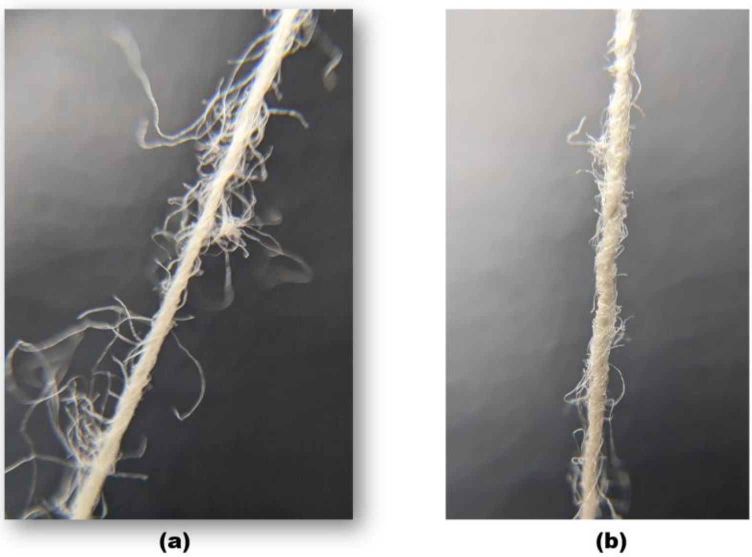

Figure 4: Photography of (a) Ring yarn and (b) Rotor Yarn

The images of ring spun yarn (Figure 4a) and rotor spun yarn (Figure 4b) provide visual confirmation of the key differences in yarn structure between the two spinning systems. The ring spun yarn exhibits a visibly hairier and more irregular surface, corresponding to its higher measured hairiness index (H=6.44), imperfection index (IPI=43), and shape factor (0.80). This higher shape factor indicates a more elliptical cross-section compared to the rotor yarn's rounder profile (shape factor=0.69), contributing to ring yarn's greater bending rigidity and stiffness. The rotor spun yarn displays a smoother, more uniform surface texture, consistent with its lower hairiness (H=4.77), fewer imperfections (IPI=23), and more circular cross-section (shape factor=0.69), which enhances its flexibility and drape characteristics. These structural differences, quantified by both shape factors and other quality parameters, demonstrate how ring spinning produces yarns with greater strength (CSP=2242.5) but higher mass variation, while rotor spinning yields more even yarns with superior elongation (6.84% vs 4.25%). The photographs effectively complement the empirical data by illustrating how the distinct spinning mechanisms and resulting cross-sectional geometries produce yarns with characteristic properties that determine their suitability for different textile applications.

Comparative Study of Tensile Properties of Ring Spun and Rotor Spun Yarn

Tenacity, the force required to break the yarn per unit of its linear density (tex), is another critical parameter for understanding yarn strength. From table 3, it has been found that, the tenacity of ring spun yarn (14.95 cN/tex) is 27.69% higher than that of rotor spun yarn (10.81 cN/tex). This difference again reflects the superior strength of ring spun yarn, which can better withstand forces relative to its thickness. The higher tenacity in ring spun yarn is due to its structural properties—aligned fibers, high migration levels, and greater packing density—which contribute to better fiber-to-yarn strength translation. Rotor spun yarn, with its lower packing density and disordered fiber structure, exhibits lower tenacity and is therefore weaker relative to its linear density.

Breaking force of ring spun yarn (441.52 cN) is stronger than rotor spun yarn (319.16 cN) by 27.69%. The higher breaking force of the ring spun yarn further confirms its superior strength and resistance to breakage. This is due to the unique structural combination in ring spun yarn, which involves a greater proportion of straight and parallel fibers, along with better fiber packing and migration. These features ensure that the yarn can withstand higher stress before breaking. In contrast, rotor spun yarn's lower breaking force results from the more disordered and folded fibers within its structure, which are less capable of sharing load efficiently compared to the aligned fibers of ring spun yarn.

The Count Strength Product (CSP) is a crucial measure that combines the yarn's strength and fineness. In this comparison from the table 3, the CSP of ring spun yarn (2242.5) is significantly higher than that of rotor spun yarn (1621.5) by 27.69%. This difference indicates that the ring spun yarn has better overall strength and finer texture, making it more durable. The superior CSP in ring spun yarn can be attributed to its structural features, which include a higher level of straight and parallel fibers, better fiber migration, and greater packing density. These factors lead to more efficient translation of fiber-to-yarn strength, which is why ring spun yarn performs better in terms of strength and durability. On the other hand, rotor spun yarn's lower CSP suggests a relatively lower tensile strength and finer structure, making it less suitable for applications where high durability is required.

The breaking length (RKm value) is another measure of yarn strength, indicating how much length of yarn can be suspended before breaking. Ring spun yarn (15.24 Km) exhibits a higher breaking length than rotor spun yarn (11.02 Km) by 27.69%. The superior breaking length of ring spun yarn is attributed to its stronger and more consistent structure, which allows it to resist breakage over longer lengths. As mentioned in the provided text, the higher proportion of straight and parallel fibers in ring spun yarn, along with high packing density, results in greater strength-to-length conversion. Rotor spun yarn, with its disordered and less packed fibers, is not as resistant to breakage, leading to a shorter breaking length.

Work of rupture (or breaking work) measures the energy required to break the yarn, indicated by the area under the force-elongation curve. Here, rotor spun yarn (585.08 cN.cm) has a higher breaking work than ring spun yarn (520.09 cN.cm) by 11.10%. This suggests that rotor spun yarn can withstand more deformation before breaking, reflecting its higher elasticity and extensibility. As discussed in the provided text, rotor spun yarn contains more disordered fibers, which, although resulting in lower tensile strength (tenacity), contribute to increased stretchability and better work of rupture. The lower tension used during the spinning of rotor spun yarn allows for a more extensible structure, which can absorb more energy before breaking compared to the more rigid and structured ring spun yarn.

Breaking elongation measures the percentage increase in length before the yarn breaks. Rotor spun yarn (6.84%) shows a 37.86% higher elongation than ring spun yarn (4.25%). The higher elongation of rotor spun yarn is due to its structural composition, which includes a higher proportion of disordered fibers in the sheath and a lower spinning tension. These factors make the rotor spun yarn more flexible and capable of stretching more before breaking. In contrast, ring spun yarn, with its more tightly packed and aligned fibers, tends to be less extensible and has a lower breaking elongation. The relatively lower elongation in ring spun yarn makes it suitable for applications requiring higher strength and lower stretch, while rotor spun yarn's higher elongation is more beneficial in applications that require flexibility and stretchability.

Conclusion

This study presents a comprehensive comparative analysis of ring spun and rotor spun yarns produced from 100% Brazilian cotton fibers. The yarns were produced using identical sliver preparation to ensure consistency and minimize external variability. The key quality parameters, including mass variation, imperfections, hairiness, and tensile properties, were measured and compared between the two spinning methods. The results show that ring spun yarn exhibits superior strength properties, with higher count strength product (CSP) and breaking force, suggesting greater durability. However, rotor spun yarn demonstrated a more uniform structure, with fewer imperfections, lower hairiness, and better breaking elongation, making it more flexible and elastic. The imperfection index (IPI) was significantly higher in ring spun yarn, indicating more imperfections, while rotor spun yarn proved to be more consistent and uniform in quality. These findings highlight the strengths and trade-offs of each spinning method, making them suitable for different textile applications based on the required yarn properties.

Limitations

While the study provides valuable insights into the comparative yarn quality of ring spun and rotor spun yarns (20 Ne), certain limitations must be acknowledged. First, the research focused on 100% Brazilian cotton and does not account for the impact of different fiber types or blends. Yarn quality may vary significantly with other raw materials, which limits the generalizability of the findings to all types of cotton or synthetic fibers. Additionally, although identical sliver preparation was used, external factors such as humidity, machine maintenance, and slight variations in machine performance could have influenced the results. Furthermore, the study was conducted within a single spinning mill, which may not fully represent the diversity of industrial conditions in other mills.

Further Work

Future research could extend this study by exploring the impact of different fiber blends (e.g., cotton-polyester blends) on the quality of ring spun and rotor spun yarns. Additionally, a broader comparison that includes other spinning technologies, such as air-jet spinning, could provide more comprehensive insights into the performance of yarns produced by different methods. Investigating the economic and environmental aspects of each spinning process, such as energy consumption, material waste, and overall cost efficiency, would also offer valuable information for the textile industry. Moreover, the long-term performance of yarns produced by both methods in real-world applications, including abrasion resistance and pilling, would provide further insights into the practical advantages of each spinning system. Finally, incorporating advanced testing techniques like microstructural analysis could help in understanding the fiber arrangement and the influence of spinning method on yarn structure in greater detail.

Declarations

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