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An analogical method for evaluating ring performance based on quality and production parameters

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ABSTRACT

This study was carried out to determine the best ring size for a certain yarn count. In a ring frame with three separate rings of varying sizes, 20s/1 kW yarn was created. The spinning method used the same ring speed, twist, ring traveller, and spacer but three distinct rings with diameters of 38 mm (Ring- A), 40 mm (Ring- B), and 42 mm (Ring- C). Then, under the same testing conditions, ten samples of each yarn were examined by Uster Evenness Tester (UT-6) and compared to determine the best one. The "Ring- C″ production yield was 0.22% and 1.34% greater than the "Ring- B″ and "Ring- A″ yields, respectively. Yarn breakage for "Ring- C″ was 47.78% and 200% greater than for "Ring- B″ and "Ring- A," respectively. Yarn unevenness for "Ring- C″ was found to be 4.15% and 4.14% higher than "Ring- B″ and "Ring- A," imperfection of yarn produced by "Ring- B″ was 18.54% and 3.47% lower than "Ring- C″ and "Ring- A," and tenacity of yarn produced by "Ring- B″ was 3.35% and 0.64% higher than "Ring- C″ and "Ring- A." "Ring- C″ yarn hairiness was 10.63% and 12.31% higher than "Ring- B″ and "Ring- A″ yarn hairiness, respectively. According to the study of the tested report, yarn generated from "Ring- B″ delivered optimized results in terms of both quality and output. Ring "Ring- B″ had a lower production loss than Ring "A" but a higher loss than Ring "C." Also, the hairiness of yarn made from "Ring- B″ was remarkably similar to yarn made from "Ring- A."

1. Introduction

According to the United States Department of Agriculture (USDA), cotton is the most significant natural fiber ever produced and produced 114.5 million bales in 2022–2023 [1]. Many spinning technologies have been devised to turn this fine-quality fiber into yarn. The ring-spinning system is the one that is most frequently utilized. Along with other important spinning technologies, including the air vortex, air jet, and rotor, the ring transforms staple fiber or filament into twisted yarn [2]. The ring-spinning method was developed by John Thorp in 1828 and is still the best in the spinning sector [3]. Even though it began approximately 200 years ago, the ring frame is still the world's most efficient and widely used spinning mechanism. More than 70% of the staple yarn produced globally is produced using this process [4]. The drafting, twisting, and winding movements in the ring-spinning system are accomplished simultaneously by the relative motion of the ring, ring traveller, and ring spindle [5].

The ring is a crucial part of the ring spinning system that influences key production factors, including machine effectiveness, yarn realization, production yield, and main quality metrics like U%, CVm%, hairiness, strength, and end breakage rate. Sayed et al. claimed

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that the ring breakage rate is a reliable indicator of cotton spinning performance [6]. Another study by Tyagi et al. showed the significant impact of various spinning parameters on the properties of yarn, including spindle speed, draught, twist factor, traveller weight, and yarn count [7]. Although efficiency is still a serious issue, ring spinning is currently the greatest spinning system for creating the highest-quality yarn [8]. Researchers are currently modifying the traditional ring frame in an effort to boost production and improve yarn quality.

To balance or minimize yarn residual torque in one step, Xu et al. added optional fiber separation devices and a fake twist device to the traditional ring spinning frame [9]. The delivery roller could prevent fibers from escaping from the twisting process in the spinning triangle and wrap most of them onto the stem of the yarn, according to research by Xia et al. who created yarn samples on an experimental ring frame with and without delivery rollers and examined yarn qualities [10]. Adding a fake twister mechanism to traditional ring-spinning machines has been the subject of numerous investigations [11,12]. Numerous experiments have also been done on changing the way the ring frame machine draughts. Cui et al. created the curve-shaped channel in the drafting zone of the ring-spinning machine using a flexible lattice apron and two magnetically fixed curved plates to control the movement of fibers [13]. The condensed yarn was produced by Murugan et al. using a mingling chamber installed in the front drafting zone of a traditional ring-spinning machine [14]. To improve performance, Ling et al. put three roving strands into a typical ring frame [15]. In a study on the temperatures of the traveller and ring during ring spinning, Wu et al. looked at the impact of the traveller's weight, yarn count, twist level, and spindle speed [16]. Different ring sizes, ring travellers, bobbin heights, and unique finishes are tested with various counts to produce yarn with the best quality and production specifications. Based on the ring size, traveller size, spindle speed, and yarn count, Siddiqua et al. demonstrated that the surface temperature of the ring and traveller could increase up to 220–300 °C [17]. The temperature issue can be reduced by applying a particular finish on the ring and traveller. Even with good finishing, larger rings with increased friction shorten the lifespan of ring travellers with high heat generation [18]. As the ring is attached to the traveller, the different ring sizes might affect the quality and production parameters and the mechanical and environmental states, such as the ring traveller's lifetime, heat generation, etc.

Finding the ideal ring size that completely satisfies quality and production requirements for a particular range of counts is crucial because ring frames are made to create a variety of yarn counts. A single-flange, smaller-size ring is highly recommended for finer counts, while double-flange or larger rings are said to be good for coarser counts. The paper explores an analytical investigation to determine the ideal ring size, considering both quality and production factors, eliminating significant production losses and super quality. Other elements, like average count, friction, etc., must be considered throughout the selection process. The article aims to identify a suitable ring that will yield the best quality and production information for 20s/1 kW yarn.

2. Materials and methods

2.1. Raw materials

The 20s/1 kW ring-spun yarn samples were produced using cotton fiber from two different origins: Burkina Faso and Togo. For Burkina Faso and Togo, the ratio was maintained at 65% and 35%, respectively. Two cotton varieties were selected to maintain optimal mixing costs and fiber spinning quality. The blending price per kilogram of yarn was $2.85 for cotton from Burkina Faso and $2.45 for cotton from Togo. Mixing with solely Togo cotton causes several issues, including low strength and unsatisfactory spinning results. On the other hand, Burkina cotton has a high level of contamination but a very good spinning consistency and great strength. These fibers are combined to maximize quality and reduce expenses.

2.2. Methodology

The experiment was conducted at a Bangladeshi spinning mill. With the help of three different ring sizes, "Ring- A" (38 mm), "Ring- B" (40 mm), and "Ring- C" (42 mm), this work creates three different forms of ring-spun yarns. The Advance Fibre Information System (AFIS) and High Volume Instrument (HVI) equipment were used to assess the raw material's quality parameters using standard sample weights (See Table 1). Then, various ring frame parameters are computed, including the cop's content, the number of doffs per day, the efficiency of the machine, the production per doff, the production per day, the production loss per day, the total machine stop time due to doffing, and the end breakage rate for all three rings. Lastly, Uster Evenness Tester 6 was used to evaluate yarn samples. According to the standard BS EN ISO 139:2005 + A1:2011 (Textiles), these tests were conducted in the testing facility under typical climatic circumstances (Temperature: 20 ± 2 °C, Relative Humidity: 65 ± 2%. Standard conditions for testing and conditioning) BSTI [19]. Fig. 1 depicts the workflow for three different ring-spun yarn samples.

Table 1
Properties of cotton fiber from different origins were used as raw materials for this experiment.

Country	SCI	Moist	Mic	Mat	UHML (mm)	UQL (mm)	UI (%)	SFI (%)	Elg%	Strength (gm/tex)	Rd	+b
Burkina Faso	126	6.20	4.16	0.87	28.91	29.7	81.33	11.1	4.10	29.1	74.1	9.2
Togo	130	5.90	4.21	0.86	28.03	29.6	82.54	8.60	6.20	29.7	75.2	9.3

SCI = Spinning Consistency Index; Moist = Moisture; Mic = Micronaire; Mat = Maturity Index; UHML = Upper Half Mean Length; UQL = Upper Quartile Length; UI = Uniformity Index; SFI = Short Fiber Index; Elg = Elongation; Rd = Reflectance; +b = Yellowness.

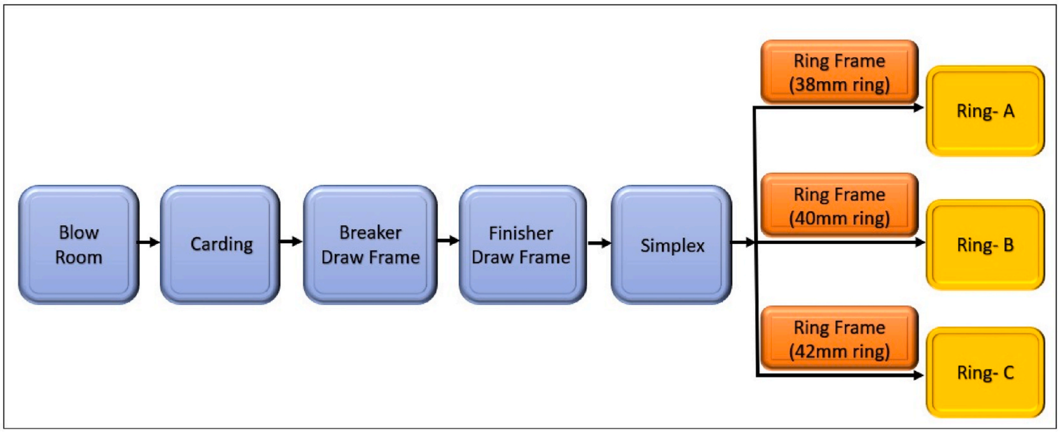

Fig. 1. Process sequence of three different ring-spun yarn produced by different ring size.

2.2.1. Machinery

The details of the equipment used to manufacture samples according to predetermined standards are listed in Table 2 and Table 3. The following Table 3 depicts the change in ring frame part that were made to produce three different ring-spun yarns.

2.2.2. Testing parameters

The Uster Tester 6, Mesdan Lab, and Mag Twist tester were used to test the quality attributes. In advance of the test, samples were prepared in standard climatic conditions. Each sample had ten readings collected from it. Table 4 contains a list of the testing parameters.

Table 2
Types of machinery and their set parameters employed to carry out the research work.

Process	Machine	Parameters and Value	Process	Machine	Parameters and Value
Blow Room (Trutzschler)	Blendomat	Take up depth: 5 mm Roller rpm: 680/690 Grid Bar Setting: 3°	Simplex	Marzoli (FT6-D)	Delivery Hank: 60 Ne TPI[a]/TM[a]: 1.10 and 1.42 Flyer Speed: (1100) Spacer: Black (5.5) Drafting System (4 over 4 rollers): Front, middle, back zone 42, 48 and 62.5 respectively Break Draft: 1.32 Total Draft: 6.116 DCP[a] and TCP[a]: 83 and 57
	Pre cleaner (CL-P)	Beater rpm (1st and 2nd): 650 and 680 Grid Bar Setting: 3°			
	Fine cleaner (CL- C3)	Roller rpm: 800, 1100, and 1400 for 1st, 2nd and 3rd rollers respectively			
Carding (Trutzschler)	Carding (TC-15)	Sliver (Grain/yards):85 Delivery Hank: (0.098) Delivery Speed: 96.5 kg/h Flat Speed: 320 mm/min Cylinder Speed: 850 rpm Grid Bar Setting: (12/14/18)			
Breaker Drawing (Trutzschler)	Breaker Drawing (TD-9)	Sliver (Grain/yards): (0.098) Delivery Hank: 0.098 Ne Delivery Speed: 680 m/min Doubling: 8 Drafting System (3 over 3 rollers): Front zone = 42 mm, Back zone = 50 mm Draft: 8 Back Draft: 1.35 Trumpet size: 4.5 mm			
Finisher Drawing (Trutzschler)	Finisher Drawing (TD-8)	Hank: 0.098 Ne Delivery Speed: 680 m/min Drafting System (4 over 4 rollers): Front zone = 41 mm, Back zone = 50 mm Draft: (8) Break Draft: 1.32 Trumpet size: 4.5 mm			

[a] TPI = Twist per Inch, TM = Twist Multiplier, DCP = Draft Change Pinion, TCP = Twist, RPM = Rotation per minute.

Table 3
Ring frame paratmeters to produce three different types of sample.

Process	Machine	Parameters	Ring- A	Ring- B	Ring- C
Ring Frame	Toyota RX-300	Count	20 Ne	20 Ne	20 Ne
		Spindle Speed	15,500 rpm	15,500 rpm	15,500 rpm
		TPI[a]	21.45	21.45	21.45
		TM[a]	4.78	4.78	4.78
		Traveller No.	N-1(k)	N-1(k)	N-1(k)
		Drafting System (3 over 3 rollers)	Front zone = 44 mm and Back zone = 60 mm	Front zone = 44 mm and Back zone = 60 mm	Front zone = 44 mm and Back zone = 60 mm
		Total draft	36.82	36.82	36.82
		Break draft	1.26	1.26	1.26
		Spacer	White (3 mm)	White (3 mm)	White (3 mm)
		Bobbing height	210 mm	210 mm	210 mm
		Ring Size (mm)	38	40	42

[a] TPI = Twist per Inch, TM = Twist Multiplier.

Table 4
Testing parameters with respective instrument list for the research work.

Machine	Tested Parameters	Operational Data	Testing standard
Uster Tester (UT-6)	U%, CVm%, Thin place, Thick place, Neps, and Hairiness	Testing velocity: 400 m/min; observing length: 400 m; test time: 1min	ISO 16549:2004
Mesdan Lab Strength Tester (Autodyn 300)	Breaking strength and elongation of single yarn	Sample length 500 mm; clamp speed1000 mm/min; and load cell ID/FS (kg) 3/12	ISO 8939:1988; ISO 2062: 2009
Mag twist tester (leTwist)	Twist per meter	Test length: 19.8 ″; test speed: 40 rpm	ASTM D1422

2.2.3. Production data collection method

The production data were collected for 7 days by weighting each cop of each doff. The time required for doffing, machine efficiency, number of doffs, and total production were collected from the machine monitor. The doffing time loss per day was collected by manual calculation.

3. Results

3.1. Production reports

According to the production data compiled in Table 5, the cops content in the weight and length categories are higher for ring “Ring- C″ than for “Ring- B″ and “Ring- A,” respectively, by 6.93% and 19.28%. Additionally, “Ring- C″ has 6.69% fewer doffs each day than “Ring- B″ and “Ring- A″ and 18.16% fewer than “Ring- B″ combined. The efficiency for “Ring- C″ is 0.20 and 0.65% greater than “Ring- B″ and “Ring- A″ due to the smallest amount of doffs and the resulting shorter stop time. Production per doff for “Ring- C″ is higher than that for “Ring- B″ and “Ring- A″ by 6.90% and 19.26%, respectively. “Ring- C″ produces more each day than “Ring- B″ and “Ring- A″ by 0.22% and 1.34%, respectively. In comparison to “Ring- B″ and “Ring- A,” the end breakage rate of yarn produced from “Ring- C″ is respectively 47.78% and 200% greater. While retaining the same weight loss or corrosion, “Ring- C″s ring traveller lifespan is 14.28% and 29.41% less than “Ring- B″ and “Ring- A″ accordingly.

3.2. Yarn quality testing reports

From the data summary from Table 6, it can be seen that the unevenness% for ring “Ring- C″ is 4.15% and 4.14% higher than “Ring- B″ and “Ring- A″, respectively. As the unevenness is high, the coefficient of variation is 4.17% and 3.82% higher for “Ring- C″ over “Ring- B″ and “Ring- A”. Hairiness for “Ring- C″ is 9.60% and 10.96% higher than compared to “Ring- B″ and “Ring- A”. “Ring- C″ has the lowest yield and is 2.90% and 4.36% lower compared to “Ring-B″ and “Ring- A″ respectively. For elongation, “Ring- B″ produces maximum yields and is 3.33% and 1.63% higher than “Ring- C″ and “Ring- A”. Tenacity of yarn produced from “Ring- B″ is 3.35% and 0.64% higher compared to “Ring- C″ and “Ring- A”.

4. Discussion

4.1. Production data calculation of sample yarns

4.1.1. Cops content (weight) and cops content (length)

The quantity of yarn wrapped on ring cops is known as the cops content. Fig. 2(a) and (b) display the cops content for “Ring- A″, “Ring- B″, and “Ring- C". As illustrated in Fig. 2, the ring diameter causes the cops content for Ring-C to be at its highest. The lifting stroke can be shortened with a larger ring diameter, increasing the number of wrappings or layers on a ring bobbin. The cop weighs as

Table 5
Production reports for three different sing-spun yarns.

Parameters	Ring - C	Ring - B	Ring - A
Ring size(mm)	42	40	38
Cops content (gm)	71.86	66.88	58
Cops content (m)	2490	2318	2010
Time required for automatic doffing (minute)	4	4	4
No. Of doff per day	10.32	11.06	12.61
Efficiency (%)	97.13	96.93	96.50
Production per doff (kg)	86.20	80.25	69.59
Production per day (kg)	889.54	887.56	877.56
Loss per day (minute)	41.28	44.24	50.44
Loss per day (kg)	28.60	30.58	40.58
Loss difference per day (kg)	0.00	−1.98	−11.98
End Breakage % (per 100 spindle/hour)	3.00	2.03	1.00
Ring traveller lifetime (days)	12	14	17

Table 6
Yarn quality reports fot three different ring spun yarn.

Parameters	Ring - C	Ring - B	Ring - A
Unevenness (U %)	11.30	10.83	10.84
Co-efficient of variation of mass (CVm %)	14.37	13.77	13.82
Thin −50%	3	0	1
Thick +50%	139	105	119
Neps +200%	109	97	110
IPI (−)	248	202	230
Hairiness (−)	6.66	6.02	5.93
TPI	20.85	21.20	21.30
Breaking Force (cN)	583.36	600.84	609.94
Elongation (%)	6.55	4.85	4.66
Tenacity(cN/tex)	19.67	20.33	20.20

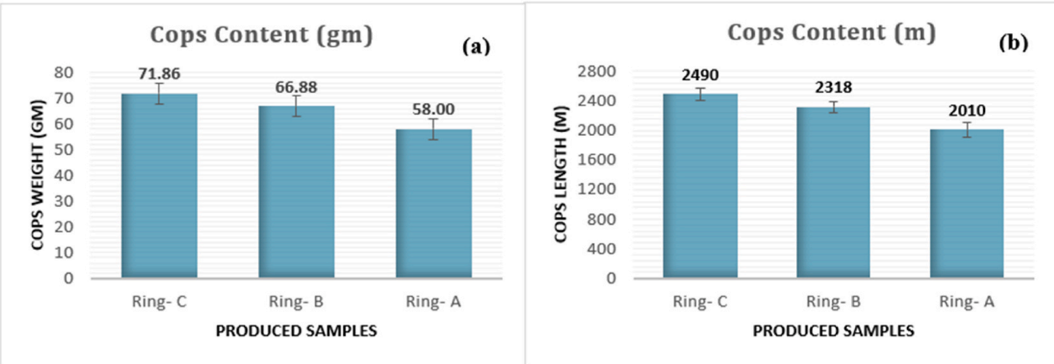

Fig. 2. Cops content of three different ring-spun yarn. (a) Cops content in wight (b) cops content in length.

much as the covering does. Additionally, the ring's diameter affects how much yarn is inside. A higher weight indicates a higher length content of the yarn because the yarn count is the same, as seen in Fig. 2.

4.1.2. Production per doff, number of doff per day, and efficiency

As can be shown from Fig. 2, "Ring- C″ has the highest cops content and hence the highest production per doff. The production was determined to be 86.20 kg for "Ring-C," 80.25 kg, and 69.59 kg for "Ring- B″ and "Ring-A," respectively, as indicated in Fig. 3 (a), with each machine having 1200 spindles. The time required to complete one doff for "Ring- C" (136 min) was the longest due to the higher production, whereas "Ring- A" (110 min) had the shortest production while maintaining the same ring speed. The "Ring- B″ doffing period lasted 126 min.

Fig. 3(a)–(b) show that "Ring-C″ had the highest production and doffing time, which resulted in the fewest doffs each day. Fig. 2 (b) displays the daily average for doffings. The machine had to be stopped for 4 min to discharge the material and enter a new bobbin. Therefore, multiplying the total number of doffs by four will give us the total stop time. Because fewer doffs result in shorter stop times and shorter stop times result in higher efficiency, "Ring- C″ had the highest efficiency (see Fig. 4). The efficiency of "Ring- B″ is higher

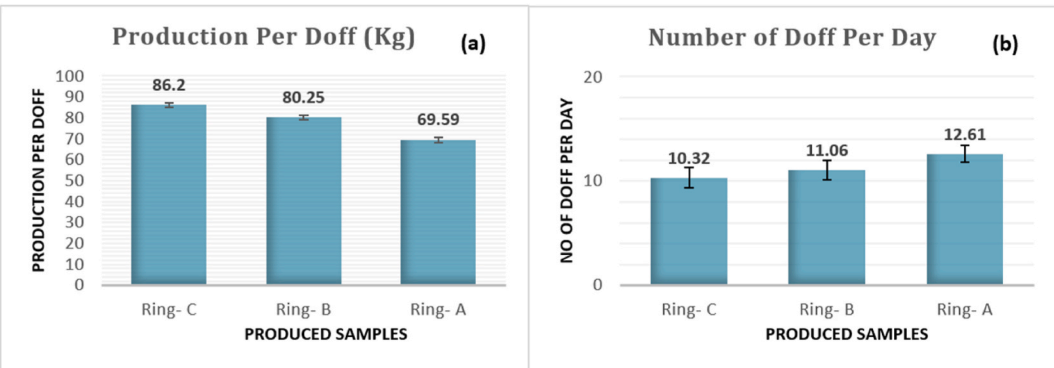

Fig. 3. (a) Production per doff of three different types of ring-spun yarn. (b) Number of doff per day of three different types of ring-spun yarn.

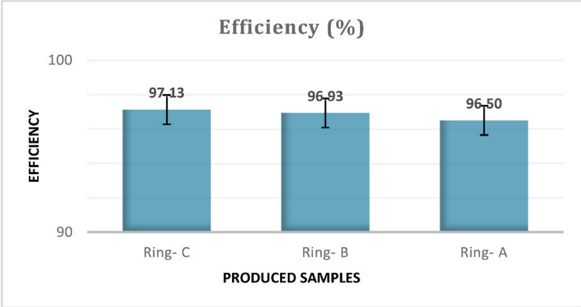

Fig. 4. Efficiency of ring frame for three different types of ring size.

than "Ring- A″ and lower than "Ring- C″ because it performs more doffs each day and stops sooner than "Ring- A″ and "Ring- C," respectively.

4.1.3. Production calculation per day

Production per day is determined and displayed in Fig. 5(a) by multiplying total production per doff (see Fig. 3(a)), number of doff per day (see Fig. 3(b)), machine efficiency (see Figure (4)), and also from physical data (by manual weighting). Given that "Ring- C″ had the fewest doffs and the highest efficiency, its manufacturing yield is at its peak. The production yield was lowest for "Ring- A″ because the quantity of doffs was highest and efficiency was lowest. With production and efficiency lower than "Ring- C″ and higher than "Ring- A," "Ring- B″ continues to be in between "Ring- C″ and "Ring- A." The stop minutes for "Ring- C″ were lowest, resulting in greater production, and the stop minutes for "Ring- A″ were highest, resulting in less production, as the number of doffs for "Ring- C″ was lowest and "Ring- A″ was greatest. The production and stop time stay in the middle because "Ring- B″ has the number of doffs between "Ring- A″ and "Ring- C," as shown in Fig. 5(b).

4.1.4. Ring traveller lifetime and end breakage

The length of the ring traveller's journey depends on how far it travels overall and how much friction there is between the ring and the traveller. The distance covered by a ring traveller can be calculated using equation number (1).

$$S = \pi \times d \times N \tag{1}$$

where,

d = Diameter of the ring.

N = RPM of the traveller.

S = Covered distance.

It is obvious from equation (1) that the circumference and ring diameter are proportionate at the same RPM. Therefore, a larger ring size indicates that a greater distance must be travelled for each twist, as well as an increased friction force. Since the twist was the same for all experiments, Fig. 6(a) shows that the traveller for "Ring- C″ wore out more quickly than others due to the traveller's greater distance travelled, which resulted in the lifetime being the lowest; in contrast, the lifetime for "Ring- A″ was highest due to the traveller's lesser distance travelled. "Ring- B″ is between "Ring- A″ and "Ring- C".

Ring breakage depends on many factors; ring traveller age and balloon size are some of them. A worn-out ring traveller leads to more breakage as the movement of the ring traveller on the ring becomes uneven and causes more friction due to the deterioration of

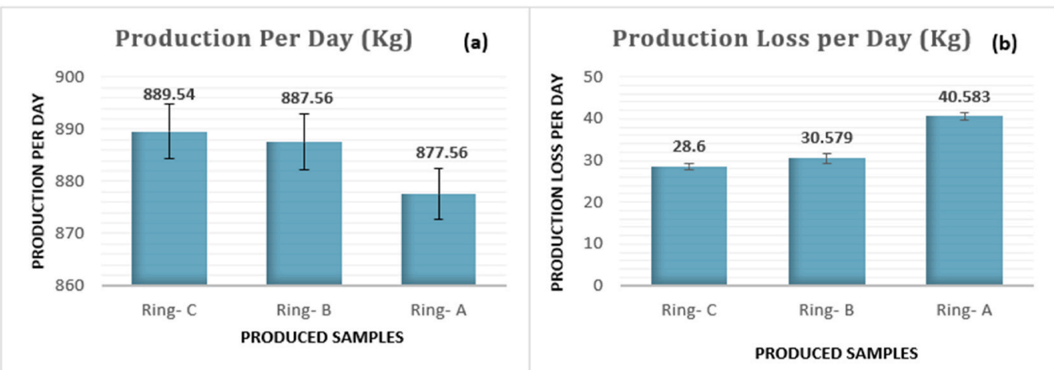

Fig. 5. Production calculation for three different types of ring-spun yarn. (a) Production per day in kg, (b) production loss per day in kg.

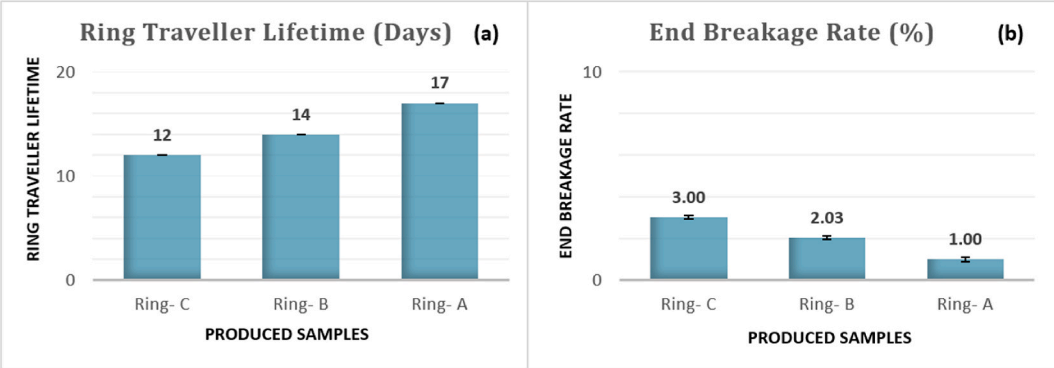

Fig. 6. (a) Ring traveller lifetime of three different ring-spun yarn. (b) End breakage rate for three different ring-spun yarn.

surface smoothness. More tension is put on the yarn as a result of this friction, which increases yarn breaking. Conversely, a bigger ring size results in a bigger balloon size, which increases air resistance, friction, or force. Additionally, friction increases yarn breaking. The ring breakage for "Ring- C″ was the highest, "Ring- A″ was the lowest, and "Ring- B″ fell in between "Ring- C″ and "Ring- A," as can be seen in Fig. 6(b).

4.2. *Quality parameter analysis of sample yarns*

4.2.1. *Evenness properties of sample yarn*

The evenness of the yarn is assessed using quality metrics such unevenness (U%), coefficient of variation of mass (CVm%), thick place, thin place, neps, and hairiness [20]. Unevenness is a unit of weight or irregularity variation per unit length. Fig. 7(a) demonstrates that "Ring- C″ has a larger U% than "Ring- A″ and "Ring- B″ by 4.15% and 4.14%, respectively. Because "Ring-C″ had a 42 mm diameter, inserting a twist required additional friction between the yarn and the traveller. More air friction between the yarn and the ballon arises from a greater ring diameter. "Ring- B″ and "Ring- A″ yield comparable outcomes. Since "Ring- C″ had the largest degree of unevenness, it also had the highest coefficient of variation, which was determined from Fig. 7(b) to be 4.35% and 3.97% higher than "Ring- B″ and "Ring- A". The amount of fibres branching out from the yarn structure is a measure of hairiness [21]. Fig. 7(c) shows that "Ring- C″ creates more hairiness of 10.63% and 12.31% than "Ring- B″ and "Ring- A," respectively. This is because increased friction and air drag from a bigger ring size result in increased fibre breakage and poor fiber migration. The ring traveller is soon worn out due to the increased friction, which is also the reason for the increased hairiness of the yarn.

As can be seen from Fig. 7(d), the thin place (−50%) was higher for "Ring- C″ due to the ring travellers' rapid wear and tear, which results in an uneven rotational speed on the ring. This suggests that "Ring-A″ should have the lowest thin spot, yet the data show it only has one. It occurs because, when winding is done in the base position, a smaller ring creates a little balloon, which touches the bobbin tip. It has been discovered that ring "Ring-B″ creates the ideal amount of friction and balloon size to prevent uneven rotation and bobbin tip and yarn contact.

Fig. 7 (e) revealed that "Ring- B‴s thick place was 24.46% and 11.76% lower than "Ring- C″ and "Ring- A″, respectively. Neps is typically brought on by fiber or seed coat coagulation. Besides, high ring breakage, incorrect clearer gauge setup, poor fiber migration, and fly production on the ring frame, ring frame factors have relatively little impact on the neps. Fig. 7(f) demonstrates that the variation in neps across all samples is remarkably minimal. Even though the neps is not statistically significant when combined with thin place and thick place, it results in a statistically significant difference in the imperfection index.

4.2.2. *Tensile properties of sample yarns*

According to Fig. 7, "Ring- A″ and "Ring- C″ exhibit greater thick-thin regions and imperfection indices. The number of weak spots is, therefore, greater for "Ring C″ and "Ring- A″ than for "Ring- B″ for both rings. Fig. 8(c) demonstrates that "Ring- B″ had the greatest tenacity and that it was 3.35% and 0.64% greater than "Ring- C″ and "Ring- A″ in comparison.

The force needed to break a specimen is expressed in terms of breaking force. It is often described as the fiber's maximum breaking force (in cN-force units). The fiber parameter and the yarn parameter both affect the breaking force. Higher breaking force and minimal elongation are provided by an even and straight distribution of fiber in the yarn cross-section. This is because straight fiber has fewer air pockets and is more compact in its twisted structure. More fiber-to-fiber friction is created by this compact structure, which helps to prevent slippage [22]. However, because the fiber is already in the extension stage, straight fiber offers less elongation. Fig. 7 (a) demonstrates that "Ring-C″ has the highest unevenness, corresponding to the lowest fiber orientation. As a result, "Ring- C″ has a breaking force that is 4.57% and 2.90% less than "Ring A″ and "Ring B″, respectively (see Fig. 8(a)). An alternative outcome is shown in Fig. 8(b) that the elongation, which reveals that "Ring- C″ is longer than "Ring- B″ and "Ring- A″ by 35.1% and 40.6%, respectively.

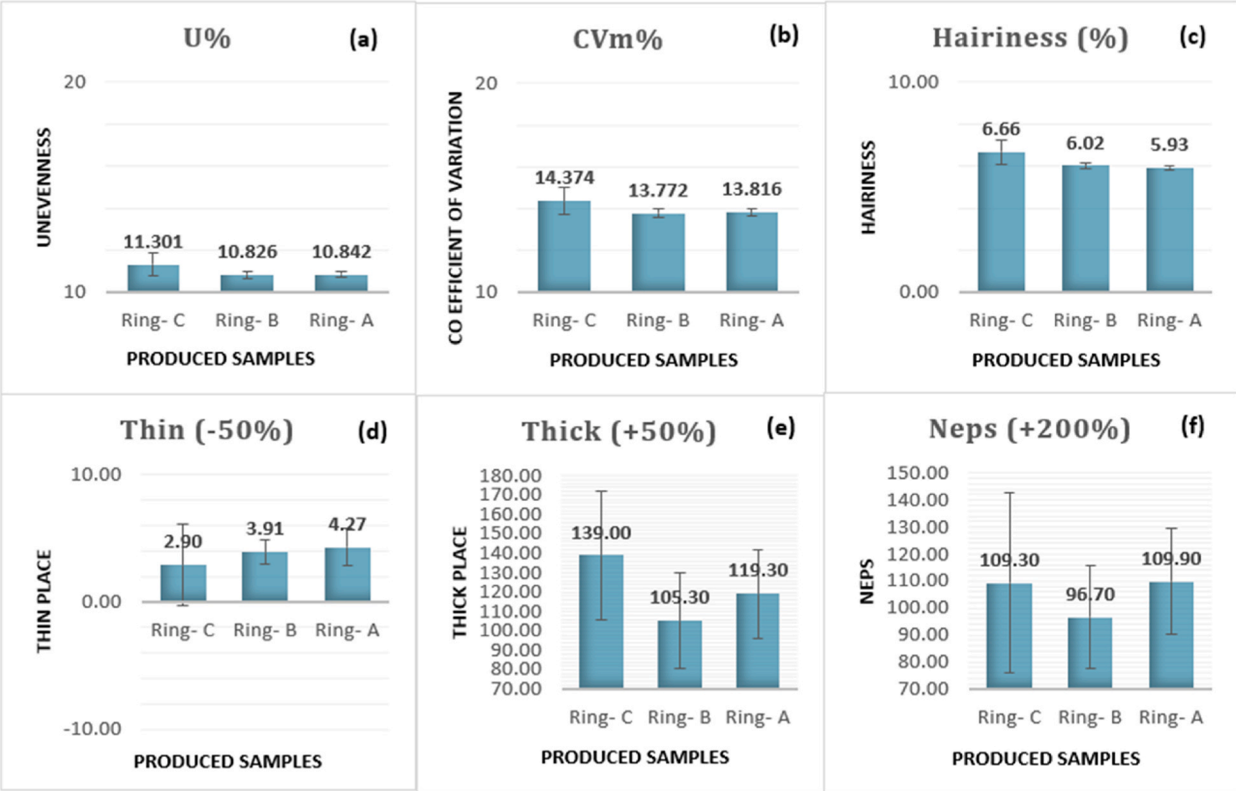

Fig. 7. Different quality parameters of three different types of ring-spun yarn. (a) Unevenness %, (b) co-efficient of variation %, (c) hairiness % (d) thin place (e) thinck place (f) neps.

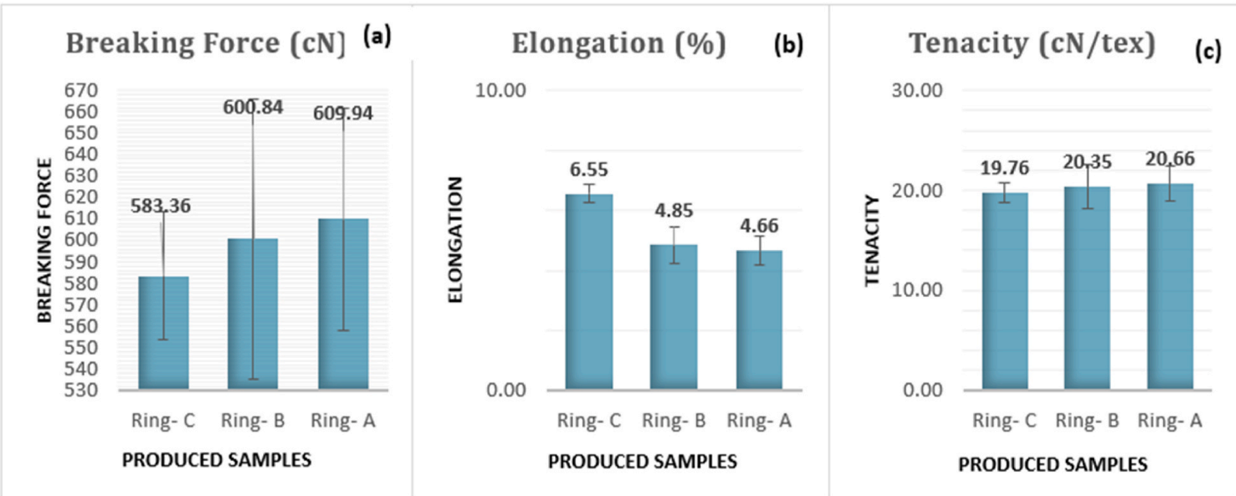

Fig. 8. Tensile properties of three different ring-spun yarn. (a) Breaking force of sample yarns (b) Elongation of sample yarns (c) Tenacity of sample yarns.

4.3. Statistical analysis

Table 7 summarizes the results of a single-factor ANOVA test performed in Microsoft Excel 2019 to determine the significant difference between groups. The test was run with a 0.05 alpha level.

From the statistical table, Table 8, it can be seen that a significant difference is found in all quality and production parameters

Table 7
Statistical table for produced sample.

Statistical testing parameter	P Value
CVm%	0.001*
Imperfection index(−)	0.040*
Hairiness (−)	0.00*
Tenacity (CN/Tex)	0.509
Breaking Force (cN)	0.515
Elongation %	0.00*
Cops content (gm)	0.00*
Production/day (Kg)	0.00*
Loss/day (Kg)	0.00*
End breakage rate (%)	0.00*
Ring Traveller lifetime (day)	0.00*

Table 8
Post hoc analysis: T-Test-two samples assuming equal variance.

Yarn properties	Paired ring	P Value (T=<t) two tail	Production Parameters	Paired ring	P Value (T=<t) two tail	Ring parameters	Paired ring	P Value (T=<t) two tail
CVm%	A & B	0.440	Cops Content (gm)	A & B	0.00*	Ring Traveller lifetime (day)	A & B	0.00*
	A & C	0.004*		A & C	0.00*		A & C	0.00*
	B & C	0.002*		B & C	0.00*		B & C	0.00*
Imperfection Index (−)	A & B	0.088	Production/day (Kg)	A & B	0.00*	Breaking Force (cN)	A & B	0.770
	A & C	0.406		A & C	0.00*		A & C	0.111
	B & C	0.055		B & C	0.10		B & C	0.468
Hairiness(−)	A & B	0.043	Loss/day (Kg)	A & B	0.00*	Elongation (%)	A & B	0.515
	A & C	0.001*		A & C	0.00*		A & C	0.00*
	B & C	0.005*		B & C	0.002*		B & C	0.00*
Tenacity (cN/Tex)	A & B	0.867	End Breakage Rate (%)	A & B	0.00*			
	A & C	0.472		A & C	0.00*			
	B & C	0.452		B & C	0.00*			

except tenacity and breaking force, as the P value is less than 0.05, marked in *.

4.3.1. Post-hoc analysis

After the ANOVA test, which compares three or more groups together, a post-hoc test is crucial to determine precisely which groups differ from one another. For each group of parameters, there were three pairwise comparisons with an alpha level of 0.05. As a result, the alpha level for post hoc analysis was maintained at (0.05/3) 0.0167 in accordance with the Bonferroni Correction. Table 8 provides a summary of the test results, and statistically significant pairs are denoted with a *.

According to Table 8, there is no significant difference between the imperfection index and tenacity. However, "Ring- B″ yields superior results for both parameters. There is a significant difference between "Ring- A and C″ and "Ring- B and "Ring- C″ for CVm% and hairiness. However, "Ring- A″ and "Ring- B″ do not differ significantly. In the case of CVm%, "Ring- B″ provides a superior outcome, whereas "Ring- A″ provides a superior result for hairiness. All pairings have statistically significant cop content, ring traveller lifetime, and end breakage rate. The daily production is significantly different between "Ring- A and "Ring- C″ and "Ring- A and "Ring- B″ but not between "Ring- B and "Ring- C." Thus, the production loss in "Ring- B″ is less than in "Ring- C." "Ring- A″ and "Ring- B″ lose significantly more per day than "Ring- C″, but "Ring- B″ loses significantly less per day. A significant difference is found in terms of elongation between "Ring-A and Ring-C″ and "Ring-B and Ring-C"; however, no statistically significant difference is found between "Ring-A and Ring-B".

5. Conclusion

From the preceding discussion and statistical analysis, it can be concluded that "Ring- C″ only produces high yields that are not significantly greater than "Ring- B″ and result in less production loss. "Ring- A″ possesses less hairiness and has a maximal ring traveller lifetime where hairiness is insignificantly greater than "Ring- B." In contrast, "Ring- B″ yields the finest results regarding the mass variation coefficient (CVm%), imperfection index, and yarn tenacity. Overall, one can conclude that "Ring- A″ generates the highest quality yarn with the lowest output. Ring "C" generates the lowest quality with the greatest output. Ring "Ring- B″ produces yarn quality comparable to ring "Ring- A″, which is the maximum, and production yield comparable to "Ring- C″, which is also the maximum. Based on the discussion and statistical analysis, it might be concluded that "Ring- B″ or 40 mm is superior for 20s/1 kW yarn production.

Author contribution statement

Towfik Aziz Kanon: Conceived and designed the experiments; Performed the experiments; Wrote the paper. Md. Ehsanur Rashid: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Md. Atikul Islam: Contributed reagents, materials, analysis tools or data.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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