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Exploratory Study on the Properties of Compact Three-Roving Yarn: Comparison The Properties of Compact Spun, Compact Siro-Spun and Compact Three-Roving Yarns

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ABSTRACT

This study presents the novel compact three-roving technology which developed on the working principle of siro-spun and compact spinning technologies. In the study, auxiliary parts of siro-spun and pneumatic compact spinning are newly designed for the production of compact three-roving yarns. The properties of new compact three-roving yarns were compared with compact spun and compact siro-spun yarns that produced at the same yarn count and at the same twist level from natural, synthetic and regenerated fibers. Besides, three-types of yarns were also used in the weft direction for the production of the woven fabric. Comparing yarn and fabric properties showed that, compact three-roving yarns have similar results to commercially used yarns such as compact and siro-spun yarns in general. In addition, it should also be noted that three-roving yarn can be also used for specific purposes owing to its composite structure.

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KEYWORDS

Compact yarn, three-roving yarn, compact three-roving yarn, siro-spun, woven fabric

1. INTRODUCTION

Recently, the continuous development of market demand, needs of yarn in different structures, and demand for producing yarn in a more economic way lead to the emergence of alternative spinning technologies [1]. During this period, developing technologies from ring spinning, which is the most widely used and also produces the optimum quality of yarn, provides the rapid spread of alternative technologies and better-quality yarn production. Compact spinning and siro-spun can be the example of the most widely used alternative spinning technologies that developed from ring spinning by adding some auxiliary parts.

The basis of the compact spinning technology is to reduce the spinning triangle that occurs after the front cylinder by negative air pressure and provides more fibers to join the yarn structure. Currently, there are number of available methods that the condensing zones are created with different auxiliary parts, such as perforated drum compacting, lattice apron compacting, and mechanical compacting. In the literature, many researchers underline the fact that taking advantage of compacting technology results in better yarn qualities than conventional systems. Compared the conventional yarns, compact yarns have better hairiness, packing densities, and unevenness [3-7]. In addition to the investigation of yarn properties, studies that compared fabric properties also showed that fabrics produced from compact yarns have better properties. Raja *et al.*[8] compared the fabric properties produced from ring, compact and ring-compacted folded yarns and claimed that fabrics produced from compact folded yarns have higher water and air permeability values. Akhtar *et al.*[9]

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compared the woven fabric properties that produced from ring, compact, rotor, and vortex yarns, and results showed that compact yarns and its fabrics have the highest tensile strength. Kim [10] investigated the properties of ring, compact, and vortex yarns and their knitted fabrics. Results showed that compact yarns have better irregularity and imperfection values than ring and vortex yarns and fabrics produced from compact yarns have the higher thermal conductivity than others. Kaynak and Celik [11] compared the ring, compact, siro spun yarns and thermophysiological comfort properties of the fabrics produced from those yarns. Results showed that compact yarns have better unevenness, imperfections and hairiness values than ring and siro-spun yarns. Comparing fabric properties showed that fabrics produced from compact and ring yarns have better abrasion resistance than siro-spun yarns.

Siro-spun is the other derivative spinning technology that developed from the conventional system and produces two-plied yarn structure in a single process. The basis of siro-spun technology is to feed two separate rovings into the drafting zone with the help of the roving funnel and delivery cylinder [12]. In siro-spun spinning, the structure of the spinning triangle, which occurs between the front cylinder and yarn formation point, is an important production parameter and directly related to roving space. Effects of the spinning triangle on siro-spun yarns have been investigated and researches pointed out that until the optimum level increasing roving space has a positive influence on yarn properties and after a certain level, greater roving space negatively affect yarn quality [13-18]. In the studies that compare the properties of siro-spun yarns with other spun technologies also showed that siro-spun yarns have better hairiness and unevenness values than conventional yarns [3,17,19,20]. In addition, compact siro-spun is the combination of the compact and siro-spun technologies and researches showed that compact siro-spun yarns are in more compact structure than compact yarns, have better hairiness values than siro-spun yarns and have better strength and evenness properties than ring yarns [21-22].

Three roving spinning has been the subject of many researches in recent years, due to its composite structure that allows more than one raw material in a single yarn structure, and also less production process than three-plied yarns that have a similar structure. In the literature, some researchers investigated the effects of fiber length, fiber fineness, distribution of the fibers in the yarn cross-section [23-25]. In the studies that compared three-roving and three-plied yarns showed that three-roving yarns have better hairiness, similar mechanical properties, but, imperfections and unevenness properties need to be improved [26-27]. In some studies, researchers also investigated the production parameters and the effects of roving space on the spinning triangle. In three-roving yarns, the structure of the spinning triangle is directly related to roving space and different spaces can cause more than one yarn formation point, eventually uneven yarn structure [28]. However, studies on three-roving spinnings are mostly focused on developing from conventional ring spinning [26-27 and 30]. There are also available studies about producing three roving yarns but these studies are mainly about producing core spun yarn structures [28-29].

It is seen from related literature that three-roving yarn technology is a promising spinning method that could provide superior yarn properties and economically competitive advantages. This study mainly presents the benefits of compacting effect and its application in three-roving yarn production to produce three roving yarns with better qualities. In the experimental part of the study, novel compact three-roving yarns were produced and compared with compact and compact siro-spun yarns in order to see the differences between compact three-roving and commercially used derivative yarns. For the production of compact three-roving yarns, auxiliary parts of pneumatic compact spinning with perforated drum and siro-spun technologies such as roving funnel, delivery cylinder, suction insert, and air-suction guides were redesigned. Newly designed auxiliary parts were assembled on pneumatic compact spun technology. Ne 50/1 compact spun, Ne 100/2 compact siro-spun, and Ne 150/3 compact three-rovings yarns were produced at the twist level α_e= 4.12. Later, these yarns were used for woven fabric production. Properties of the yarns and fabrics were measured and statistically analysed at the confidence level of 95%.

2. MATERIAL AND METHOD

2.1 Material

In this study, compact, compact siro-spun and compact three-roving yarns were produced from all main material groups and physical, mechanical, and structural properties were measured. Cotton, Modal (1.3 dtex and 38 mm), PES (1.3 mm dtex and 38 mm) were used from natural, regenerated and synthetic fiber groups, respectively. HVI results of cotton fibers are given in Table 1.

Table 1. Properties of cotton fibers (HVI results)

Fiber Properties	Averaged Value
Fineness (microner index)	4.0
Length (mm)	37.4
Tenacity (cN/tex)	45.5
Elongation (%)	5.7
SCI	214
Uniformity (%)	86.7
Maturity	4.6
SFI (%)	8.6

Ne 50/1 compact yarns, Ne 100/2 compact siro-spun yarns, Ne 150/3 compact three-roving yarns with α_e=4.12 twist multiplier were produced from 100% cotton, 100% Modal, 100% PES fibers. Experimental design of the yarn production is given in Table 2. In addition, these yarns were used in weft direction in plain weave structure of fabric production and structural details of fabrics are given in Table 3. Ne 50/1 compact combed cotton yarns were used in warp direction. All slivers used in the study were produced with Rieter B34 Bale opener, Rieter A81 UniBlend, Rieter A79 UniStore and Rieter C70. Rieter SBD-24 draw frame was used for drawing process. All yarns were produced with Rieter K 45 compact spinning machine simultaneously, therefore in order to obtain same count for all yarn types, Ne 1.2 rovings for compact spun yarns, Ne 2.4 rovings for compact siro-spun yarns and Ne 3.6 rovings for compact three-roving yarns were produced with Marzoli FTSDN roving frame. For compact three-roving yarn production, newly designed auxiliary parts were assembled on Rieter K 45 machine.

2.2 Method

2.2.1 Compact Three-Roving Yarn Production System

Compact three-roving yarn technology can be counted as the combination of compact spun and siro-spun technologies. From this point of view auxiliary parts of the both technologies were redesigned for compact three-roving yarn production. With the same principle of siro-spun, three individuals rovings were fed into the drafting zone simultaneously. In order to control roving space and roving movements into the drafting zone, three-roving funnel and three-grooved delivery cylinders were designed (Figure 1-2).

In order to create condensing zone for individual fiber strands, suction insert and air-suction guide, which are the essential parts of pneumatic compact technologies with perforated drum, were designed and assembled on the inner and outer surface of the perforated drum. In pneumatic compact spinning technology with perforated drum, the width of the condensing zone is restricted by the width of air-holes on the perforated drum. In Rieter K 45 compact technology, the width of the air-holes on the perforated drum is 12 mm, therefore, this restriction is taken into consideration for the design of new parts. For compact three-roving technology, roving space is set as 3 mm with using the three-grooved delivery cylinder. In addition, the new air suction guides and suction inserts are also designed to create a condensation zone for individual rovings within the width of the air hole zone, which is 12 mm on the perforated drum of the Rieter K 45 (Fig. 3-4). All auxiliary parts were produced with 3D printer and were assembled on Rieter K 45 pneumatic compact spinning machine (Figure 5). Figure 6 shows the successful condensing effect for three-rovings with redesigned auxiliary parts. All detailed paramters of designed parts were given in Demir and Demir *et al.* [31-32].

Table 2. Experimental design of the yarn production

Yarn Production Technology	Raw Material	Roving Count (Ne)	Yarn Count (Ne)	Twist of produced yarn (T/m)
Compact Spun	Cotton, Modal, PES	1.2	50/1	1150
Compact Siro-spun	Cotton, Modal, PES	2.4	100/2	1150
Compact Three-roving	Cotton, Modal, PES	3.6	150/3	1150

Table 3. Structural details of fabrics

Yarn	Raw Material	Yarn Count (Ne)	Weft density (cm^{-1})	Warp density (cm^{-1})
Compact Spun	Cotton, Modal, PES	50/1	32	54
Compact Siro-spun	Cotton, Modal, PES	100/2	32	54
Compact Three-roving	Cotton, Modal, PES	150/3	32	54

Figure 1. 3D printed three roving funnel a) front view b) back view

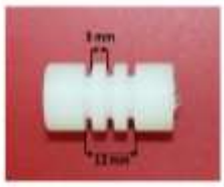


Figure 2. Three-grooved delivery cylinder

Figure 3. 3D printed air-suction guide for compact three-roving yarn a) front view b) back view c) side view

Figure 4. 3D printed suction-insert for compact three-roving yarn a) front view b) side view

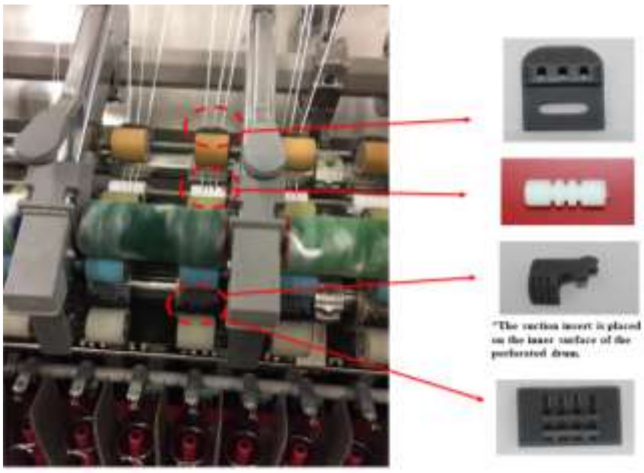


Figure 5. Compact three-roving spinning technology

Figure 6. Compacting three individual rovings

2.2.2 Experimental

To measure yarn properties, 5 packages of each yarn types were produced and tested. Hairiness, unevenness, imperfections, diameter, density, roughness and roundness values of yarns were measured with USTER Tester 6 S800 at 400 m/min production speed and each test were performed during 2.5 minutes. Breaking force and breaking elongation values of yarns were measured with Uster Tensorapid 4. Every test was performed at 400 m/min and 500 mm gauge length. Friction properties of yarns were measured with Lawson Hemphill CTT and input tensions were set for 12 cN for both friction types. Yarn-to-yarn friction tests were performed at 20 m/min test speed and 5 minutes test duration and yarn-to-metal frictions tests were performed at 100 m/min test speed. In addition, tensile strength according to the EN ISO 13934-1, tear strength according to the EN ISO 13937-2, seam slippage resistance according to the EN ISO 13936-1, abrasion resistance EN-ISO 12947-2 and pilling according to the EN ISO 12945-2 were performed for produced fabrics. All yarn samples were prepared for hard sectioning with Leica Historsin Kit and cross-section samples of the yarns were obtained with Leica Rotary microtome (RM2125RT) as described in Demir [29]. Olympus BX43 microscope was used for cross-section image acquisition at 100X zoom.

3. RESULTS AND DISCUSSION

In this section, physical, mechanical, and structural properties of novel compact three roving yarns were compared with compact spun and compact siro-spun yarns. Besides, the properties of fabrics produced from these yarns were also compared. All statistical analyses performed for α=0.05 significance level and confidence interval graphs were also given.

3.1 Yarn Properties

3.1.1. Physical and structural properties

Cross-section images of the compact spun, compact siro-spun and compact three roving Modal yarns are illustrated in Figure 7. It is seen from the figure that, novel compact three-roving yarn is in circular cross-sectional shape and all fibers are located in an assumed circular packing row. It is seen from Figure 7 that, compact three-roving yarns show similarities to compact spun yarns as each roving is placed in the yarn structure, while two different components of siro-spun yarns are more visible.

Hairiness parameters H (total length of protruding fibers of 1 cm of yarn length), sh (standrt deviation of H), S3 (number of protruding fibers greater than 3 mm along 100 m of yarn length) and S 1+2 (number of protruding fibers smaller than 3 mm along 100 m of yarn length) were measured. Mean values of the hairiness (H, sh, S1+2, S3) of produced yarns were given in Table 4 and the 95% confidence interval graphs of those values were given in Figure 8. Results showed that compact spun yarns have higher hairiness values for all hairiness types (H, sh, S1+2, S3) and compact siro-spun and compact three-roving yarns have similar values. Similar results are shown in some studies where siro-spun yarns have better hairiness values than single spun yarn [17, 20]. It can be explained by yarn formation trapping model that occurs while playing single rovings to folded structure in multi-strand spinning. In addition, rovings in the spinning triangle that occurs for compact siro-spun and compact three-roving, are exposed greater tension than single plied yarn and it results in better fiber orientation in the yarn structure. However, the positive relationship between the geometry of the spinning triangle and hairiness is restricted until a certain point. After that point, greater spinning triangle can cause fiber loss and uneven yarn structure [15, 18].

Unevenness (CVm%) and optical unevenness (CV2D8mm%) values of compact spun, compact siro-spun and compact three-roving yarns are given in Table 5 and 95% confidence interval of those values are given in Figure 9. Comparing results showed that compact siro-spun yarns have the better unevenness values, compact spun and compact three-roving yarns have similar unevenness values in general. The possible explanation of this situation could be related to the number of rovings that used for yarn production and fiber orientation in the yarn structure. The number of rovings in the yarn production may display similar effects with Poisson distribution like in the draw frame process. In the draw frame, the even number of slivers is doubled and drawn and the aim behind this process is to eliminate thin and thick places in the sliver with the possibility of covering each other. Similarly, in compact siro-spun where two rovings are used for yarn production, uneven structures of each roving can eliminate each other in the final yarn structure. However, the same effects can not be seen in the yarns that consist of an odd number of components like compact spun and compact three-roving.

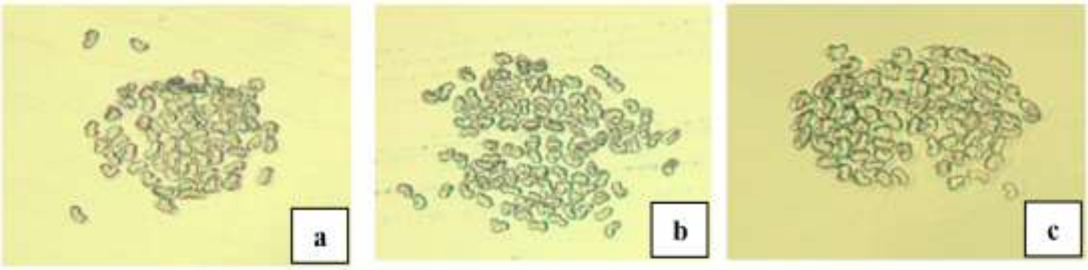
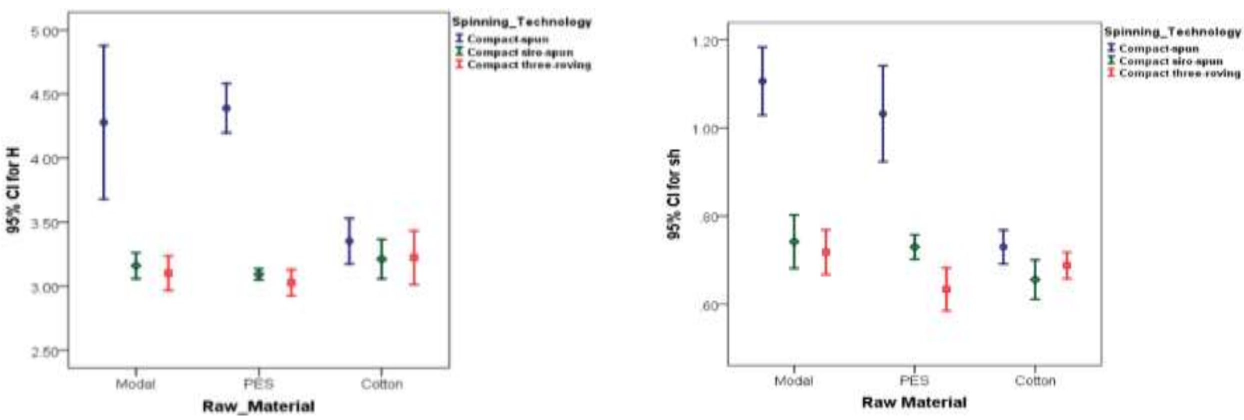


Figure 7. Cross section images of Modal yarns **a)** compact spun **b)** compact siro-spun **c)** compact three-roving

Table 4. Hairiness values (H, sh, S1+2, S3) of compact spun, compact siro-spun, and compact three-roving yarns

Spinning Technology	Raw Material	H	sh	S3	S 1+2
Compact spun	Modal	4.28	1.11	5167.40	14817.00
	PES	4.39	1.03	3986.60	13895.80
	Cotton	3.35	0.73	2544.20	12899.20
Compact siro-spun	Modal	3.16	0.74	2217.40	7464.80
	PES	3.09	0.73	2224.20	7696.20
	Cotton	3.21	0.66	1774.00	10773.60
Compact three-roving	Modal	3.10	0.72	1858.40	7339.20
	PES	3.03	0.63	1280.00	5942.60
	Cotton	3.22	0.69	2270.80	11781.00



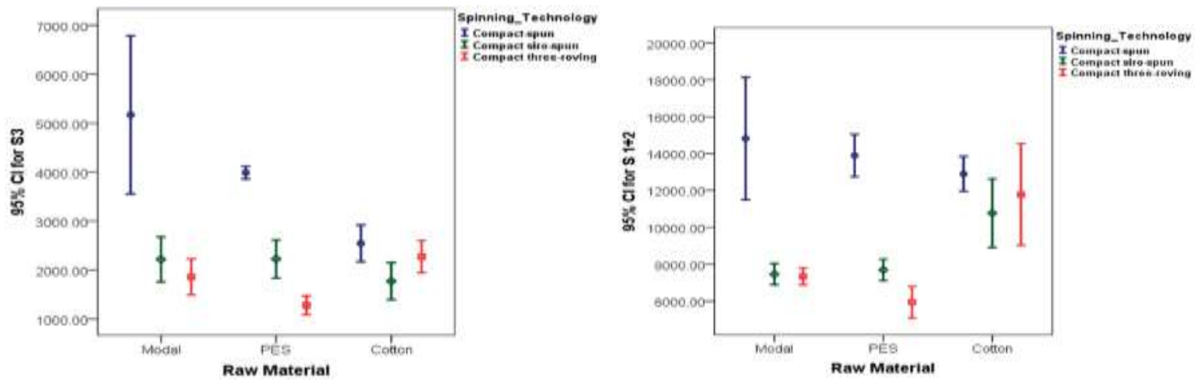


Figure 8. 95% confidence interval graphs for hairiness values of compact spun, compact siro-spun and compact three-roving yarns

On the other hand, although the yarn unevenness is defined and related to the number of the fibers in the yarn cross-section [33-34], there are also studies that pointed out the relation between unevenness and fiber position in the yarn structure [35-36]. For a better understanding of fiber orientation in the yarn structure for compact siro-spun and compact three-roving, the spinning triangle and its effects of yarn structure should be analyzed. When the fiber bundle leaves the front cylinder's nip point and starts to twist into the yarn form, a triangle occurs between the front cylinder and yarn formation point. For the same yarn production conditions, the structure of the triangles is related to the width of the fiber bundle for single spun yarn, and roving space for the multi-strand spun yarn [15,37]. The tension of the fiber is related to its path in the spinning triangle and effects the fiber position in the yarn structure. Fibers at the edge of the triangle follow a longer path hence exposed to greater tension, while fibers at the middle of the bundle follow a shorter path and hence exposed lower tension [3]. For the compact spun yarn, the triangle is reduced by the negative air-pressure and it can be assumed to be eliminated. In siro-spun, the spinning triangle consists of two components and a greater geometry of triangle occurs. A greater spinning triangle means greater tension on the fibers and better fiber orientation in the yarn structure until a certain point. The significant point for the spinning triangle that should be kept on the eye is that fluctuation on the nip point of the spinning triangle changes the length of each roving hence the tension. However, for the two components of the spinning triangle like the one in siro-spun, changes in the length of each roving could be assumed to the similar, and owing to plied structure, uneven structures of the single roving can be tolerated (|R1-R1ˈ| ≈ |R2-R2ˈ|) (Figure 10a). For the three-roving spinning, changes on both edge of the spinning triangle are not equal due to the third component in the middle. In any time of fluctuation during the yarn production, two of the rovings are closer than the other one, and displacements of the location of each roving are not been equal. Therefore, uneven structures of single roving can not be tolerated with the plying structure (|R1-R1ˈ| ≠ |R2-R2ˈ|) ≠ |R3-R3ˈ|) (Figure 10b).

Imperfection values of produced yarns are given in Table 6 and 95% confidence interval graphs of those values are illustrated in Figure 11. Results of imperfection values are mostly related with yarn preparation process and compact three-roving yarns show similar results with commercially used yarns in general.

Diameter (2DØ mm), density (D g/cm3), roughness (%CV FS) and roundness (shape) values of compact spun, compact siro-spun and compact three-roving yarns are given in Table 7 and 95% confidence interval graphs are given in Figure 12. Results showed that, there is no statistically significant difference between three types of yarns in general ($p>0.05$). In the other words, similar structures of compact three-roving yarns with compact spun and compact siro-spun were successfully produced.

Table 5. Unevenness (CVm%) and optical unevenness (CV2D8mm%) values of compact spun, compact siro-spun, and compact three-roving yarns

Spinning Technology	Raw Material	CVm (%)	CV2D 8mm (%)
Compact spun	Modal	12.26	9.13
	PES	14.47	10.34
	Cotton	11.03	8.17
Compact siro-spun	Modal	11.15	7.65
	PES	11.10	7.52
	Cotton	10.68	7.83
Compact three-roving	Modal	12.02	8.44
	PES	13.62	9.21
	Cotton	11.38	8.37

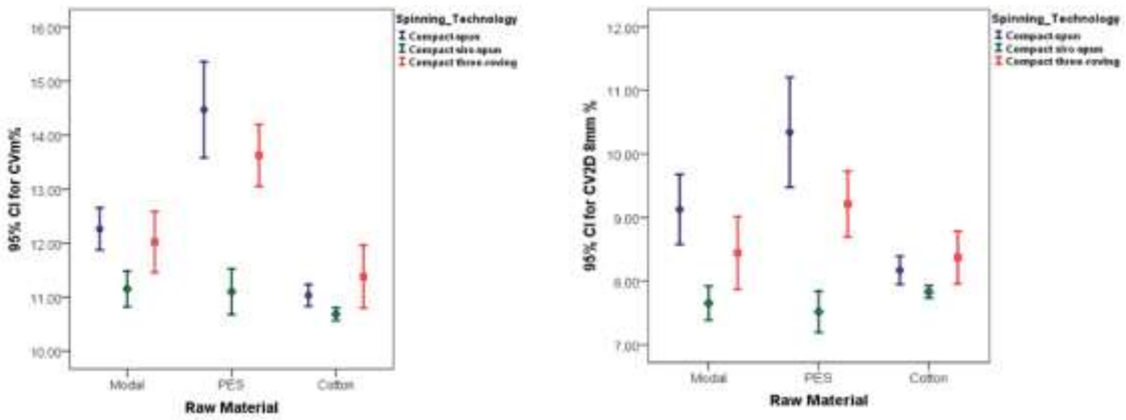


Figure 9. 95% confidence interval graphs for unevenness (CVm%) and optical unevenness (CV2D8mm%) values of compact spun, compact siro-spun and compact three-roving yarns

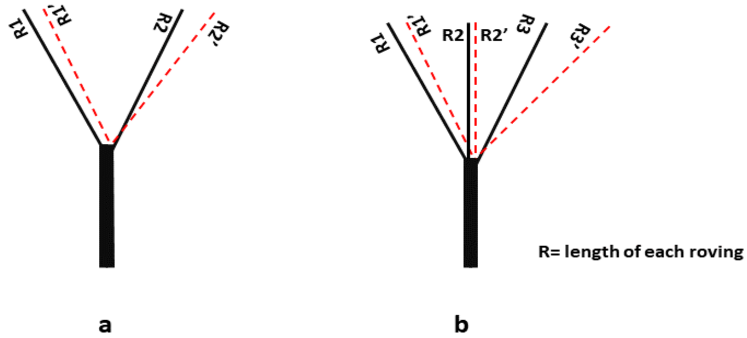
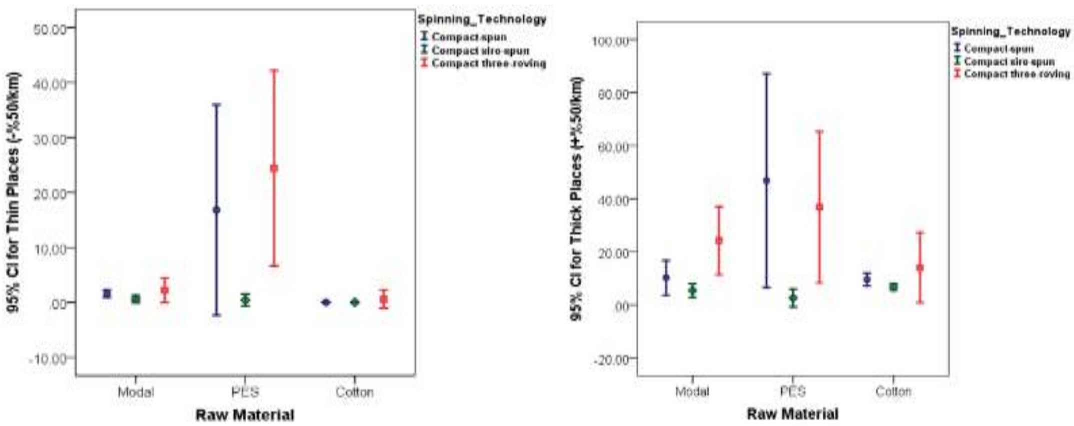


Figure 10. Geometrical changes of spinning triangles in siro-spun and three-roving yarns

Table 6. Imperfections values of compact spun, compact siro-spun, and compact three-roving yarns

Spinning Technology	Raw Material	Thin Places (-50%/km)	Thick Places (+50%/km)	Neps (+200 %/km)
Compact spun	Modal	1.60	10.20	59.60
	PES	16.80	46.80	15.20
	Cotton	0.00	9.60	41.40
Compact siro-spun	Modal	0.60	5.40	16.40
	PES	0.40	2.60	12.40
	Cotton	0.00	6.80	46.40
Compact three-roving	Modal	2.20	24.20	37.80
	PES	24.40	36.80	21.60
	Cotton	0.60	14.00	62.20



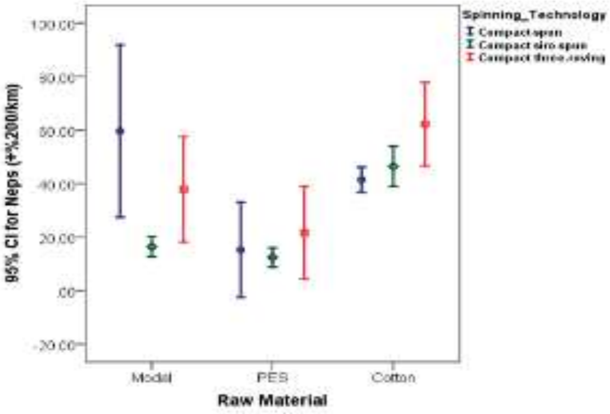


Figure 11. 95% confidence interval graphs for imperfections values of compact spun, compact siro-spun, and compact three-roving yarns

Table 8 shows the yarn-to-yarn and yarn-to-metal friction coefficients of three types of yarns and Figure 13 illustrates the 95% confidence interval of those values. Both of the friction coefficients are related to the yarn surface structures [38-39]. Since all three-types of yarns show similar surface characteristics, there are no statistically significant differences for friction properties in general.

Table 7. Diameter (2DØ mm), density (D g/cm3), roughness (%CV FS) and roundness (shape) values of compact spun, compact siro-spun and compact three-roving yarns

Spinning Technology	Raw Material	Diameter (mm)	Density (g/cm^3)	Roughness (CV FS%)	Roundness
Compact spun	Modal	0.140	0.760	9.21	0.844
	PES	0.141	0.752	8.79	0.866
	Cotton	0.147	0.698	7.84	0.854
Compact siro-spun	Modal	0.140	0.766	6.93	0.848
	PES	0.141	0.760	6.74	0.846
	Cotton	0.149	0.682	7.97	0.840
Compact three-roving	Modal	0.139	0.776	6.89	0.850
	PES	0.140	0.750	6.55	0.874
	Cotton	0.147	0.696	7.92	0.844

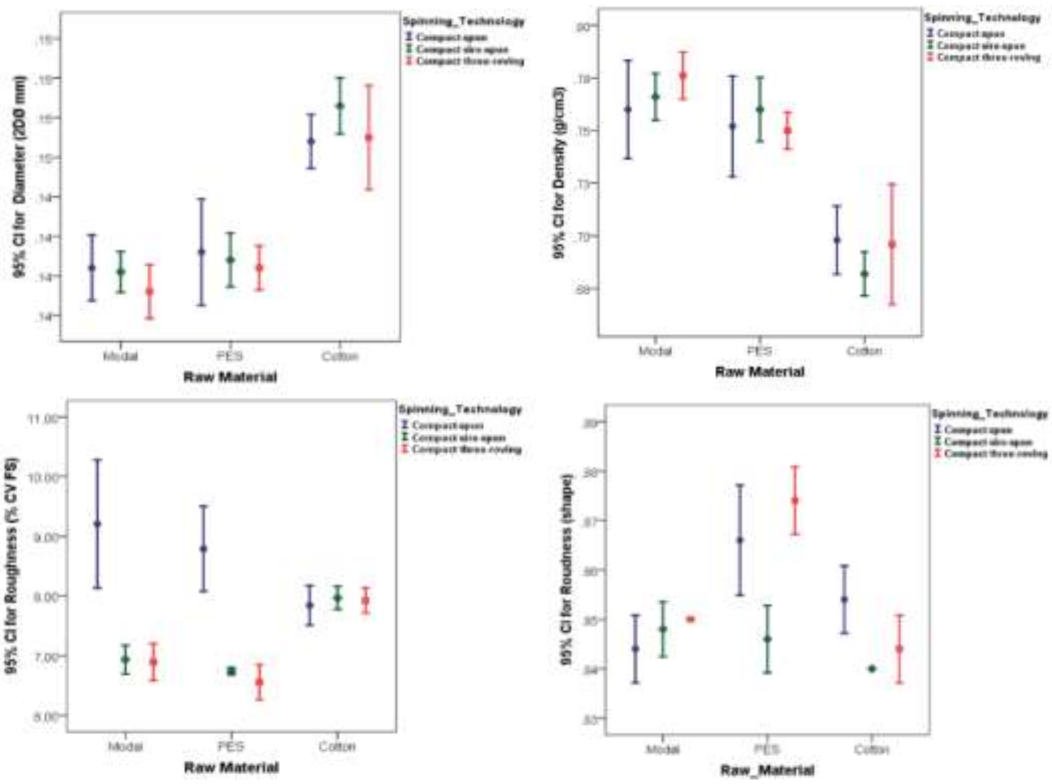


Figure 12. 95% confidence interval graphs for diameter (2DØ mm), density (D g/cm3), roughness (%CV FS) and roundness (shape) values of compact spun, compact siro-spun and compact three-roving yarns

Table 8. Yarn-to-yarn and yarn-to-metal friction coefficients of compact spun, compact siro-spun and compact three-roving yarns

Spinning Technology	Raw Material	yarn-to-yarn	yarn-to-metal
Compact spun	Modal	0.1480	0.2977
	PES	0.1718	0.2556
	Cotton	0.1640	0.2578
Compact siro-spun	Modal	0.1456	0.3072
	PES	0.1692	0.2642
	Cotton	0.1646	0.2588
Compact three-roving	Modal	0.1429	0.3001
	PES	0.1698	0.2359
	Cotton	0.1602	0.2584

3.1.2 Mechanical Properties

Breaking force (cN/tex) and breaking elongation (%) values of compact spun, compact siro-spun, and compact three-roving yarns are given in Table 9 and 95% confidence interval graphs are shown in Figure 14. Results showed that for all raw material, results of novel compact three-roving yarns are similar with compact spun and compact siro-spun yarns. Comparing the breaking force and breaking elongation of the yarns that produced at the same twist level and same yarn count, the number of the fibers in the yarn cross-section is decisive for those properties. According to the results, it can be said that compact three-roving yarns are successfully produced with proposed new method in terms of mechanical properties.

3.2 Fabric Properties

In this section, tensile strength, tear strength, seam slippage resistance, pilling and abrasion resistance of the fabrics produced from compact spun, compact siro-spun and compact three-roving yarns were compared. For fabric production, produced yarns were only used in the weft direction. Therefore, fabric properties in weft directions were investigated.

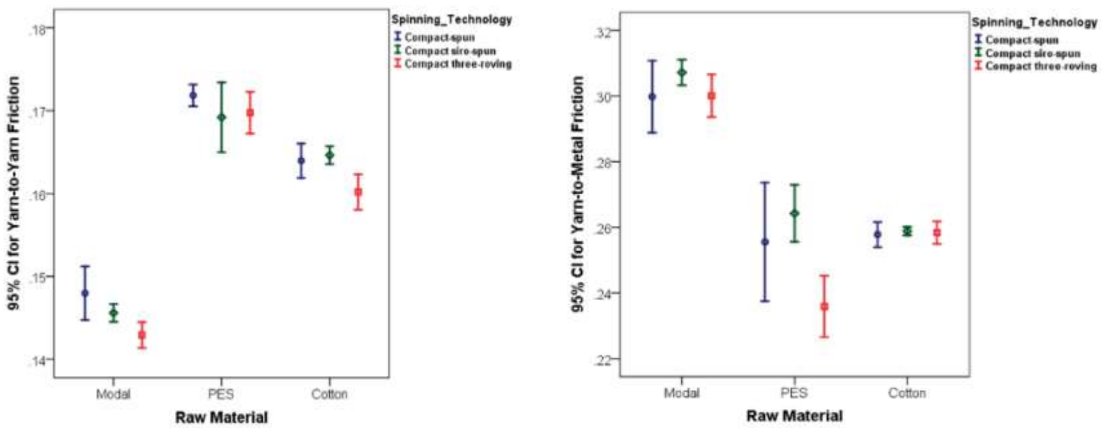
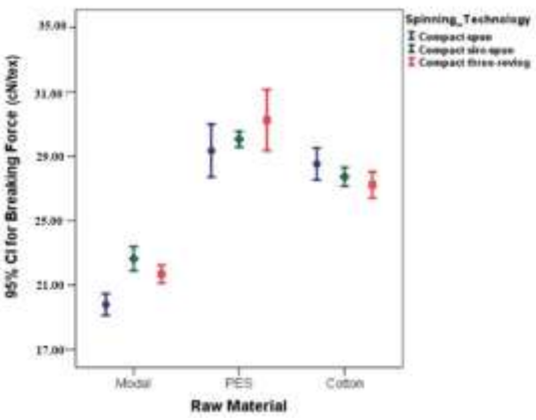


Figure 13. 95% confidence interval graphs for yarn-to-yarn and yarn-to-metal friction coefficients of compact spun, compact siro-spun and compact three-roving yarns

Table 9. Breaking force and breaking elongation values of compact spun, compact siro-spun, and compact three-roving yarns

Spinning Technology	Raw Material	Breaking Force (cN/tex)	Breaking Elongation (%)
Compact spun	Modal	19.89	8.13
	PES	22.81	9.42
	Cotton	21.89	9.23
Compact siro-spun	Modal	30.05	10.22
	PES	30.76	9.34
	Cotton	32.01	10.01
Compact three-roving	Modal	29.13	5.49
	PES	28.29	5.22
	Cotton	27.75	4.98



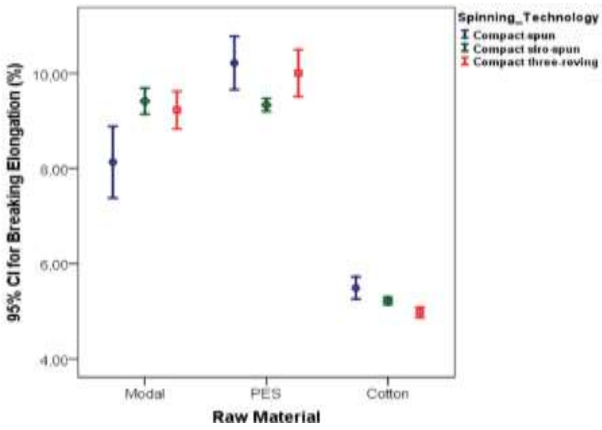


Figure 14. 95% confidence interval graphs for breaking force and breaking elongation values of compact spun, compact siro-spun and compact three-roving yarns

3.2.1 Mechanical Properties

Tensile Strength

Tensile strength (N) of the fabrics produced from three types of yarns are given in Table 10 and 95% confidence interval graph of those values are given in Figure 15. Results showed that, there is no statistically significant difference between all fabrics for all material groups ($p>0.05$). This is an expected result for the produced fabrics, since the tensile strength of the fabrics with similar woven structure is mostly related to yarn tenacity [40].

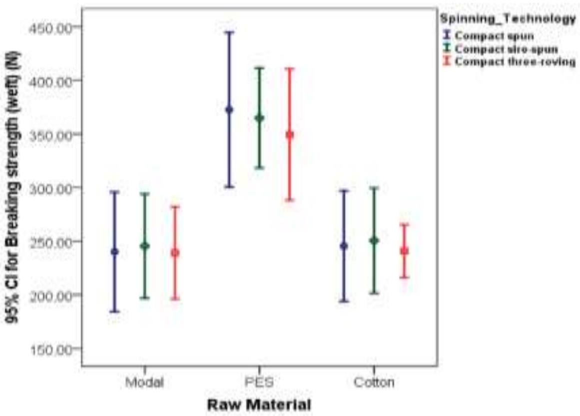


Figure 15. 95% confidence interval graphs for breaking strength values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

Tear Strength

Tear strength (N) values of the produced fabrics are given in Table 11 and Figure 16 illustrates the 95% confidence interval of those values. Results showed that there is no statistically significant difference for tear strength values in weft direction in general. From the same reason of tensile strength, similar results were obtained for tear strength.

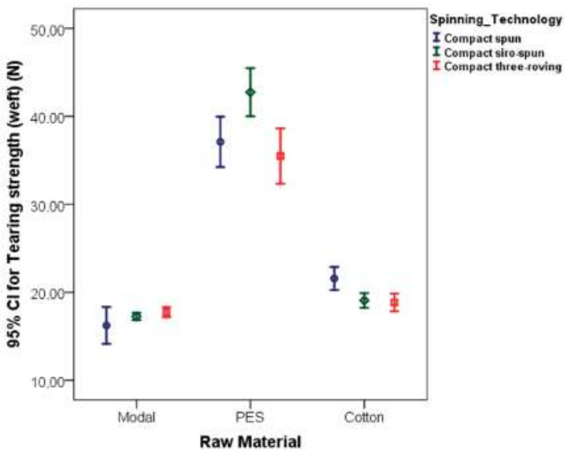


Figure 16. 95% confidence interval graphs for tear strength values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

Seam Slippage Resistance

Results of seam slippage resistance (N) of produced fabrics are given in Table 12 and 95% confidence interval graphs for those results are given in Figure 17. It can be seen from the results that there is no statistically significant difference between three types of fabrics in general. Seam slippage results of fabrics produced from PES yarns are relatively high, however, greater confidence intervals are observed, particularly for siro-spun yarns.

Table 10. Breaking strength (N) values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

Spinning Technology	Raw Material	Breaking Strength (N)
Compact spun	Modal	240.1
	PES	372.5
	Cotton	245.4
Compact siro-spun	Modal	245.4
	PES	364.8

	Cotton	250.5
Compact three-roving	Modal	239.1
	PES	349.4
	Cotton	240.8

Table 11 Tear strength (N) values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

Spinning Technology	Raw Material	Tearing Strength (N)
Compact spun	Modal	16.2
	PES	37.1
	Cotton	21.6
Compact siro-spun	Modal	17.3
	PES	42.7
	Cotton	19.1
Compact three-roving	Modal	17.7
	PES	35.5
	Cotton	18.9

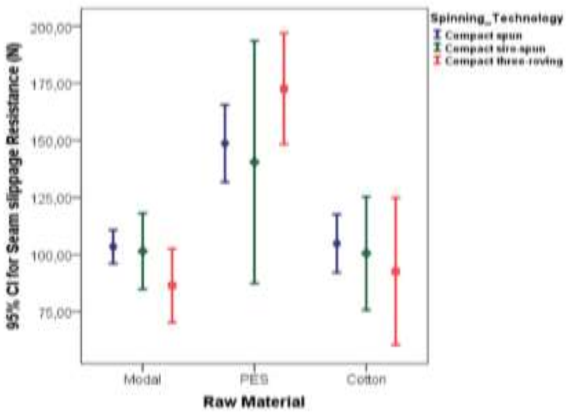


Figure 17. 95% confidence interval graphs for slippage resistance values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

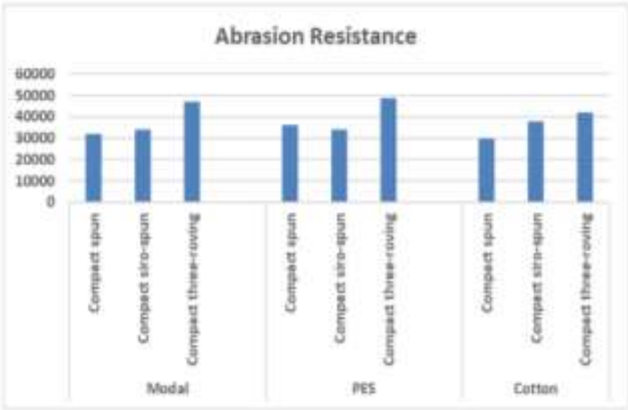


Figure 18. Abrasion resistance values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

3.2.2 Surface Properties

Pilling and Abrasion Resistance

The results of the pilling tests are given in Table 13 and the results of the abrasion resistance are given in Figure 18. It's seen from the table that pilling results of the fabrics that produced from compact siro-spun and compact three-roving yarns are similar and better than compact-spun yarns. Pilling tests results are parallel to the hairiness values of three types of yarns. For the abrasion resistance according to the specimen breakdown, it is clearly seen that compact three-roving yarns have better values for all raw materials owing to the three-component structures.

4. CONCLUSION

This study presents the novel compact three-roving yarn production and investigates the physical, mechanical, and structural properties of the compact three-roving yarn. For the production of three-roving yarn, auxiliary parts of compact and siro-spun yarn production technologies were redesigned and assembled on a pneumatic compact spinning machine. For a better assessment, commercially used yarn technologies compact spun and compact siro-spun yarns were also produced at the same yarn count and twist multiplier. Results showed that, compact three-roving have better hairiness and similar unevenness values than compact-spun yarns. Mechanical and other structural parameters of the yarns also show similar values. Three-types of yarns were used for fabric production, and the mechanical and surface properties of the fabrics were also compared. Similar mechanical and better surface properties were obtained for fabrics produced from three-roving yarns. In overall assessment, it can be concluded that novel compact three-roving technology is successful method for yarn production. In addition, it should also be noted that beside being an alternative of commercially used yarns, three-roving yarns can be also used for specific purposes owing to its composite structure that enables to feed different raw materials into the yarn structure.

Table 12. Seam slippage resistance (N) values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

Spinning Technology	Raw Material	Seam slippage Resistance (N)
Compact spun	Modal	103.4
	PES	148.7
	Cotton	104.8
Compact siro-spun	Modal	101.5
	PES	140.5
	Cotton	100.6
Compact three-roving	Modal	86.4
	PES	172.6
	Cotton	92.6

Table 13. Pilling values of fabrics produced from compact spun, compact siro-spun and compact three-roving yarns

Spinning Technology	Raw Material	Pilling					
		125	500	1000	2000	5000	7000
Compact spun	Modal	4-5	2-3	2-3	2	1-2	1-2
	PES	4-5	2-3	2-3	2	2	1-2
	Cotton	4-5	2-3	2-3	2	2	1-2
Compact siro-spun	Modal	4-5	3-4	3-4	2-3	2	1-2
	PES	4-5	4	3-4	2-3	2	1-2
	Cotton	4-5	4	3-4	2-3	2	1-2
Compact three-roving	Modal	4-5	3-4	3	2-3	2	1-2
	PES	4-5	3	3	2-3	2	1-2
	Cotton	4-5	3-4	3	2-3	2-3	2

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