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Comparative study of the effect of Lycra on Single Jersey and 1×1 Rib made from 100% Cotton and Cotton/Lycra Yarns

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Abstract
For an end consumer, the most significant factors are performance and comfort after a few aesthetic factors such as appearance and fashion appeal. For stretchable fabric, the fit related comfort lies the inability of the fabric to be stretched and recover when a repeated load is applied due to body movements without any permanent set. Lycra is one of the best yarn to use in a different field. In this study, the dimensional and physical properties of cotton/Lycra single jersey and rib fabrics are investigated in comparison with fabrics knitted from cotton alone. It is apparent that the presence of Lycra shows improved dimensional and physical properties in both knitted fabrics. Furthermore, it was found that Lycra-containing fabrics tended to have tighter structure, higher weight, thickness, bursting strength and elongation, but air permeability, tensile properties, pilling grade, and shrinkage are lower.

Key Words: Knitted Fabric, Lycra, Fabric Properties, 1×1 Rib, Shrinkage, Tensile Properties

1. Introduction

Stretch fiber, yarn, or fabric provides necessary elasticity for a garment to respond to every movement of the body and return to its original size and shape. The degree and direction of elasticity determine the end use of the stretch garment. The most important property requirements for stretch garment are in the order of body comfort fit, breathability, and durability.

Knitted fabrics are produced by interloping the yarn which can be made from natural, synthetic, or regenerated fibers. The raw material types and structures give different properties for the yarns used in knitting. The variation in yarn properties results in a variation of knitted fabrics properties such as dimensional, mechanical, comfort, and appearance. Mechanical properties, particularly strength and elongation, are the most important performance properties of knitted fabrics which govern the fabric performance in use by causing a change of dimensions of strained knitted fabrics (Eltahan 2016; Sarıoglu and Babaarslan 2017; Makhlouf 2015). A change of dimensions of strained knitted fabric can be defined by increasing dimension in one direction as a dimension in other directions is decreasing (Semnani 2013; Jinyun, Lam, and Xuyong 2010). In many cases, it is important to know how much the knit will deform in one or another direction. But it is known that, in various knitting structures, knitted fabrics are characterized in different extensibility (in a course and wale directions) and maximum force to rupture (Mikucioniene and Mickeviciene 2010; Man 2014). Processes of deformation of knitted fabrics are described in a concept of extensibility of knitted fabric, and the deformation can be determined and influenced by different factors.

As studied in different research results, dimensional and physical properties of knitted fabrics have been investigated by different scholars in relation to yarn types, yarn structure, and knit structures. Concerning the raw materials, the scholars do not yet investigate the comparative effect of Lycra yarn on dimensional and physical properties of single jersey and 1×1 rib knitted fabrics. In this paper, different dimensional and physical properties of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra blend (96/4 in percentage) is studied by conducting scientific tests and analysis.

2. Materials & Methods

2.1. Materials

Single jersey and 1×1 rib fabrics were knitted having 2.9 mm loop length: with 100% cotton and the other one as cotton/lycra (96%/4%) blended fabrics. Fabric Samples are produced in Mayer & Cie Single Jersey Circular Knitting Machine of 30 dia. & 24 gauge. 30/1 ring spun cotton yarn & 20 Denier Elastane were used in the experiment. An IRO MER2 system was used to feed the elastane, and yarn tension was 6 cN. The samples were subjected to the dyeing, washing, and finishing processes. Table 1 shows the sample specifications used to conduct this research.

Table 1. Sample specification

Sample	Fabric type	Stitch length (mm)	Cotton %	Lycra %
1	S/J	2.9	100%	0%
2	S/J (With Lycra)	2.9	96%	4%
3	Rib	2.9	100%	0%
4	Rib (With Lycra)	2.9	96%	4%

2.2. Methods

Table 2 shows the various testing methods and equipment's used for this experiment. All samples were tested 3 types, and the average was taken under consideration.

Table 2. Testing methods and equipment's

Tests	Methods	Equipment's
Fabric weight	ISO 33071	GSM cutter, Electric balance
WPC & CPC	Manually	Magnifying glass, Needles
Stitch density	Manually	N/A
Pilling	ISO 12945-1:2000	ICI pilling test box
Shrinkage	ISO 6330	Wascator
Bursting	ISO 13938-2 1999	Tru Burst Machine
Spirality	AATCC 179	N/A
Air permeability	ISO 9237	Air permeability tester
Tensile properties	ASTM D5035- 95	MESDAN TENSO Tensile tester

3. Results & Discussion

3.1. Fabric Weight

Table 3. Comparison of GSM

Sample No	GSM (gm/m^2)	Standard deviation	CV%
Single Jersey (Without Lycra)	132.8	1.15	0.86
Single Jersey (With Lycra)	172.8	0.85	0.43
Rib (Without Lycra)	195.8	1.17	0.88
Rib (Lycra)	212.4	0.85	0.44

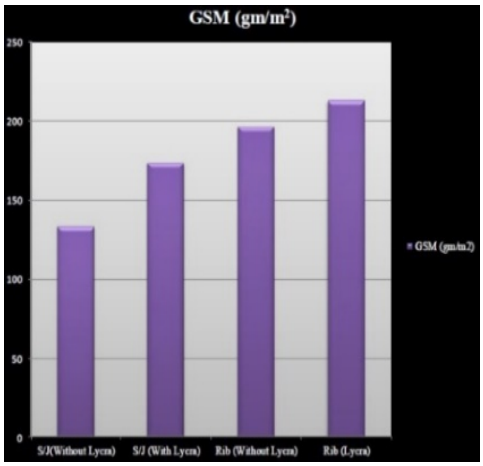

Figure 1. Effect of GSM in Single jersey & Rib (with or without Lycra) from table 3.

From figure 1, the GSM of the samples having 100% cotton is less than the samples which have 4% Lycra with cotton. This is because Lycra in the knitted fabric leads to compacting the fabric together. Lycra in the yarn tends to contract the loops to each other, which decreases loop length, and the amount of elastane increases, making tighter fabric**.** But since rib structure is naturally more compact and heavier than single jersey thus showing higher GSM.

3.2. Fabric Density: Wales / cm (WPC) & Course /cm (CPC)

Table 4. Comparison of Wales/cm and Course/cm

Sample no	Wales/cm	Course/cm
Single Jersey (Without Lycra)	37	52
Single Jersey (With Lycra)	35	59
Rib (Without Lycra)	15	23
Rib (Lycra)	14	26

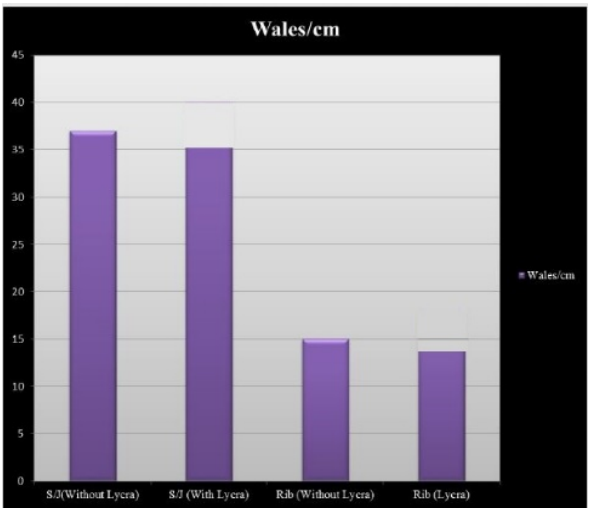

Figure 2. Effect of Wales per cm in Single jersey & Rib from table 4.

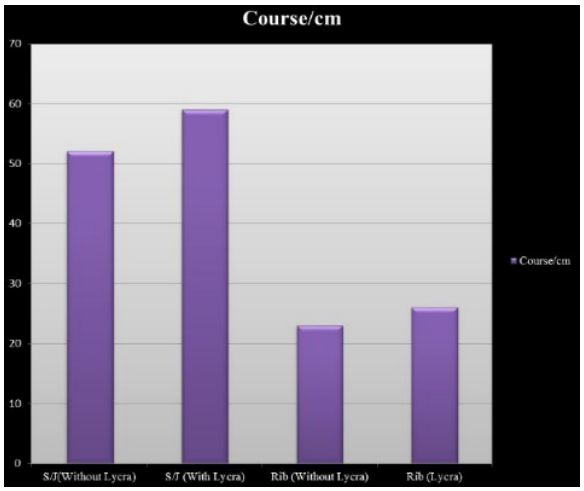

Figure 3. Effect of Courses per cm in Single jersey & Rib from table 4.

From Figure 2, the wales/cm decreases due to the presence of Lycra in the fabric. This is because Lycra in the yarn tends to contract the loops to each other. From Figure 3, by adding Lycra in the knitted fabrics, the course density increases. This is already very clear since Lycra tends to contract the loops to each other, causing less number of wales/cm, which in turn increases the course/cm of the fabric containing Lycra. Due to the compact structure of rib fabric, it shows less number of course and wales per cm than that of the single jersey.

3.3 Loop shape factor

Table 5. Comparison of the loop shape factor

Serial no	Kc	Kw	Loop shape factor
Single Jersey (Without Lycra)	4.9	3.36	1.45
Single Jersey (With Lycra)	6.72	4.56	1.47
Rib (Without Lycra)	3.84	2.88	1.33
Rib (Lycra)	6.24	3.84	1.62

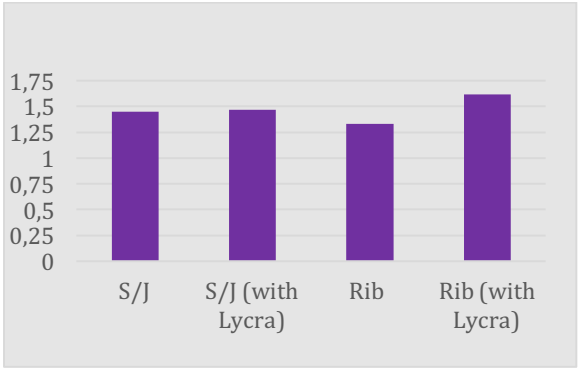

Figure 4. Effect of loop shape factor in Single jersey & Rib from table 5.

From figure 4, Loop shape factor increases as loop length decrease. The effect of Lycra on loop shape factor is similar to the effect on the course and wales density. As the Lycra tends to contract the loops to each other, the loop shape factor Kc/Kw increases for fabric containing Lycra.

3.4 Stitch Density

Table 6. Comparison of stitch density

Sample no	Wales/cm	Course/cm	Stitch density=WPCXCPC
Single Jersey (Without Lycra)	37	52	1924
Single Jersey (With Lycra)	35	59	2065
Rib (Without Lycra)	15	23	345
Rib (Lycra)	14	26	364

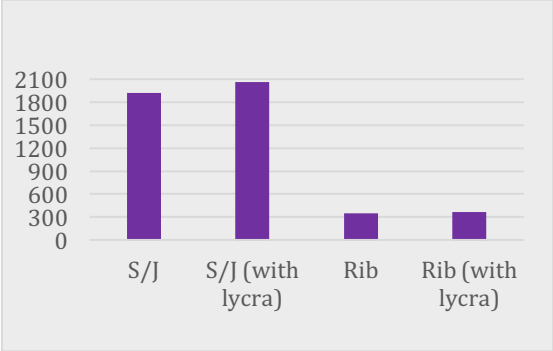

Figure 5. Effect of stitch density in Single jersey & Rib from table 6.

From the figure 5, stitch density of fabrics containing Lycra is higher than 100% cotton-containing fabric as the courses/cm increases with the decreases of wales/cm as the Lycra tends to contract the loops to each other. Due to the compact structure of rib fabric, it shows less stitch density than single jersey.

3.5 ICI Pilling Test Report

Table 7. 100% cotton single jersey 30 Ne

Serial no.	No. of cycles	Rating in Wales direction	Avg. rating in Wales direction	Course direction	Avg. rating in Course direction
1.	14400	4	4	4	4
2.	14400	4		4	

Table 8. 30/1 cotton (96%) and 20D Lycra (4%) S/J

Serial no.	No. of cycles	Rating in Wales direction	Avg. rating in Wales direction	Course direction	Avg. rating in Course direction
1.	14400	4	4	4	4
2.	14400	4		4	

Table 9. 100% cotton Rib 30 Ne

Serial no.	No. of cycles	Rating in Wales direction	Avg. rating in Wales direction	Course direction	Avg. rating in Course direction
1.	14400	3	3	3	3
2.	14400	3		3	

Table 10. 30/1 cotton (96%) and 20D Lycra (4%) Rib

Serial no.	No. of cycles	Rating in Wales direction	Avg. rating in Wales direction	Course direction	Avg. rating in Course direction
1.	14400	3	3	3	3
2.	14400	3		3	

Tables 7-10, show the differences between pilling of single jersey and rib fabric containing Lycra with that of 100% cotton is too insignificant. But there exists a difference between S/J and rib fabrics. Generally, fabric tends to pill a little more along the wales than courses. Moreover, the plain knitted fabric generally produced flatter pills lying closer to the fabric surface as well as having less abrasion effect compared to the 1x1 rib fabric whose pills were also fluffy due to having a higher abrasion effect.

Table 11. Observation of shrinkage percentage

Sample no.	Shrinkage in length direction	Shrinkage in width direction
Single Jersey (Without Lycra)	-5.1	-4.6
Single Jersey (With Lycra)	-4.0	-2.0
Rib (Without Lycra)	-3.5	-2.5
Rib (Lycra)	-2.0	-1.6

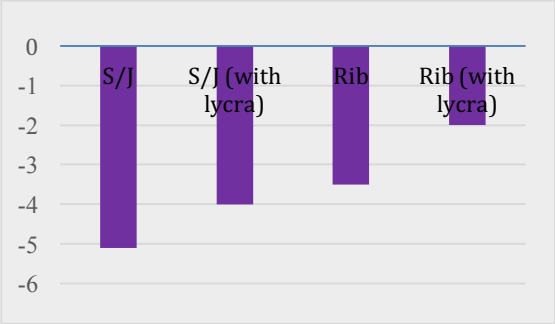

Figure 6. Effect of Shrinkage Percentage in a lengthwise direction from table 11.

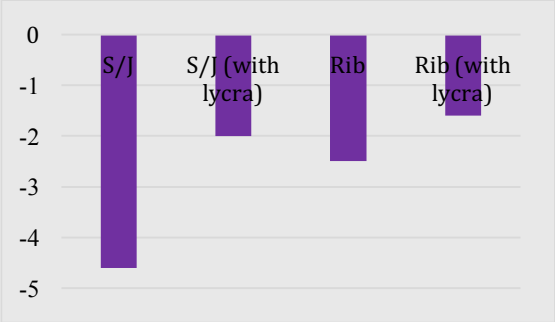

Figure 7. Effect of Shrinkage Percentage in widthwise direction from table 11.

From figure 6 & 7, shrinkage percentage of cotton/lycra fabrics is less than that of 100% cotton fabrics. Because Lycra containing yarn helps to retain the fabric's original dimension as far as possible after washing. On the other hand, since rib fabric is more compact and tightly held balanced structure than that of single jersey, so it shows lower shrinkage.

3.7. Bursting Strength Test

Table 12. Comparison between these samples

Sample no.	Bursting strength (KN/m^2)	CV% of bursting strength
Single Jersey (Without Lycra)	124.1	6.45
Single Jersey (With Lycra)	154.3	2.91
Rib (Without Lycra)	162.1	5.45
Rib (Lycra)	176.1	2.88

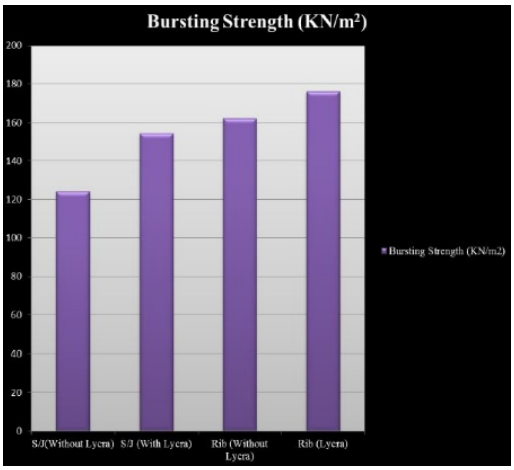

Figure 8. Effect of bursting strength (KN/m2) in Single jersey & Rib from table 12.

Figure 8 shows that the bursting strength of cotton/lycra fabric is higher than the 100% cotton s/j and rib because the use of Lycra yarn causes the increase of the strength of the fabric which results in higher compactness of the fabric structure thus resisting the bursting force.

3.8. Air Permeability Test

Table 13. Air permeability test results

Sample	Air Permeability (l/m²/s)
Single Jersey(Without Lycra)	556
Single Jersey(With Lycra)	30.6
Rib (Without Lycra)	633
Rib (With Lycra)	89.7

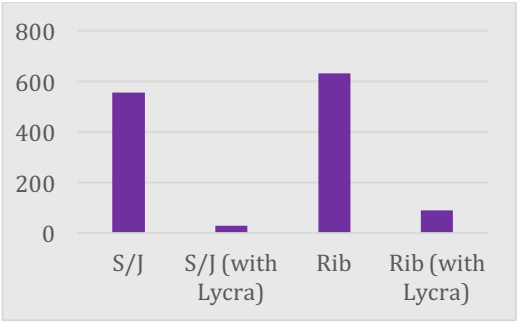

Figure 9. Bar chart showing the air permeability from table 13.

Figure 9 shows, fabric porosity, has a reflection on the air permeability, that is, as the porosity of the fabric increases the air permeability of fabric also increases (Prakash 2010). As shown in Figures 9, the air permeability of a single jersey is lower than the rib. This is because rib1x1 is more stable fabric from shrinkage as compared to single jersey and the air is applied at the face and reverse stitches equally. The other reason for the two fabrics having different air permeability is rib fabrics have high resistance to robbing back of yarn during knitting. This resistance helps the needles to obtain long yarn during knitting (Sitotaw 2016). Instead, fabrics containing Lycra shows more compact structure due to elastic property Lycra, which in turn decreases the air permeability.

3.9. Spirality Test

Table 14. Comparison between these samples

Sample	Spirality (%)
Single Jersey(Without Lycra)	2.5
Single Jersey(With Lycra)	2.0
Rib (Without Lycra)	1.9
Rib (With Lycra)	1

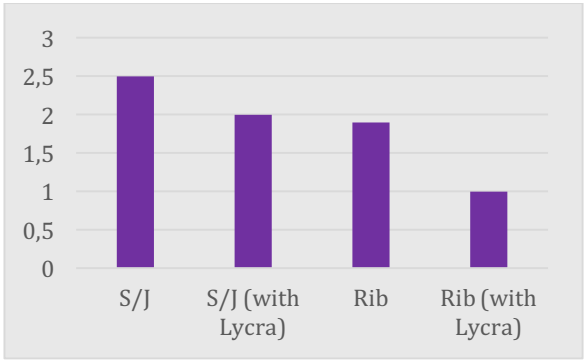

Figure 10. Effect of Spirality in Single jersey & Rib from table 14.

Figure 10 shows that Spirality of single jersey fabric made of 100% cotton is higher than rib fabric this is because single jersey fabric is open knitted structure thus the yarn has a higher tendency to rotate inside the fabric after relaxation while in a closed knitted structure the movement of a knitted loop is restricted, and thus the Spirality is reduced in rib fabric. Since a single jersey structure is highly unbalanced. The forces created by interlacing loops are substantially different on the technical face and technical back due to the fact that loops are continuously formed in one direction only (Spencer 2001). This creates different forms and levels of forces on the two fabric faces. The main reason for achieving lower values of distortion in 1x1 rib because its structure is perfectly balanced. Instead, fabric samples containing Lycra shows less Spirality since Lycra tends to bend the loops towards each other making fabric closer knitted structure which lowers Spirality.

3.10. Tensile property test

Table 15. Lengthwise Tensile properties of single jersey knitted fabrics

Fabric composition	Tensile strength (N)
100% cotton	285.7
Cotton/ Lycra (96%/4%)	193.6

Table 16. Widthwise Tensile properties of single jersey knitted fabrics

Fabric composition	Tensile strength (N)
100% cotton	175.8
Cotton/ Lycra (96%/4%)	211.4

Table 17. Lengthwise Tensile properties of 1×1 rib knitted fabrics

Fabric composition	Tensile strength (N)
100% cotton	375.3
Cotton/ Lycra (96%/4%)	267.5

Table 18. Widthwise Tensile properties of 1×1 rib knitted fabrics

Fabric composition	Tensile strength (N)
100% cotton	147.3
Cotton/ Lycra (96%/4%)	103.1

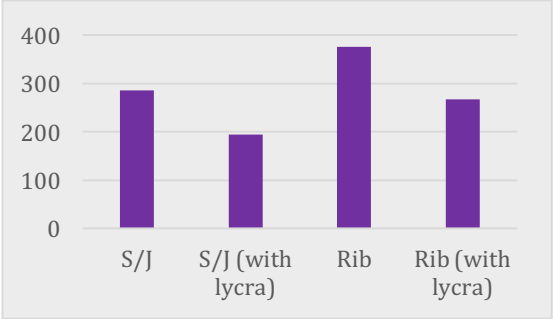

Figure 11. Effect of lengthwise tensile strength in Single jersey & Rib

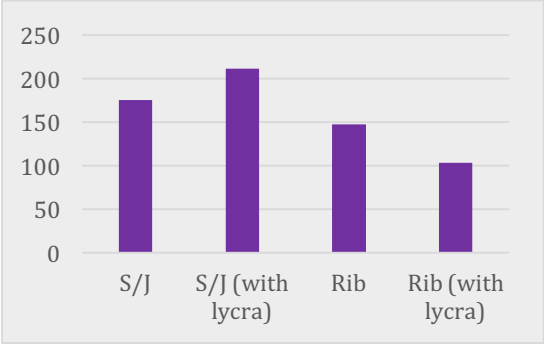

Figure 12. Effect of widthwise tensile strength in Single jersey & Rib

Data obtained from tables (15-18) and as shown in Figure 11 & 12, the maximum force needed to break the fabrics is different. Single jersey and 1×1 rib knitted fabrics made from 100% cotton have high breaking force in lengthwise as compared to fabric made from cotton/Lycra blended yarns. After adding the Lycra yarn, the maximum braking force in the lengthwise of the single jersey decreased as compared to its widthwise breaking force because of the high elongation percent in the lengthwise direction of the fabric. Single jersey knitted fabric has high extension characteristic in the lengthwise than widthwise direction. Fabrics with high extension property need low force to extend, and its strength becomes decreased (Sitotaw and Adamu 2017). Lengthwise breaking strength of 1×1 rib knitted fabrics is higher than single jersey's both lengthwise and widthwise breaking strength due to the balanced structure of rib. But, the widthwise strength of 1×1 rib is lower than the single jersey's lengthwise and widthwise strength because of the high elongation percent in the widthwise direction of the fabric.

4. Conclusion

From this research, the comparative effect of Lycra on Single Jersey and 1×1 Rib Knitted Fabrics made from 100% Cotton and Cotton/Lycra Yarns were observed. The key findings are, the weight and thickness of Cotton / Lycra fabrics are higher, but air permeability and the degree of Spirality are lower than 100% Cotton knitted fabrics respectively. Furthermore, Shrinkage of Cotton / Lycra fabrics is lower than fabrics made of 100% Cotton. Lycra containing fabric shows higher bursting strength. Having lower tensile strength towards the lengthwise direction in Cotton/ Lycra fabrics which on the contrary shows higher tensile strength in widthwise direction for single jersey cotton/ Lycra fabric because of high elongation percentage in the widthwise direction of the fabric. Depending on the quality of the end product, this research results can be beneficial.

5. Data Availability:

The data used to support the findings of this study are available from the corresponding author upon request.

6. Conflict of Interest:

The authors declare that there is no conflict of interest regarding the publication of this paper.

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