Hindawi
Journal of Engineering
Volume 2017, Article ID 4310782, 7 pages
https://doi.org/10.1155/2017/4310782

Research Article

Tensile Properties of Single Jersey and 1×1 Rib Knitted Fabrics Made from 100% Cotton and Cotton/Lycra Yarns

Dereje Berihun Sitotaw and Biruk Fentahun Adamu

Textile Engineering Department, Bahir Dar University, Ethiopian Institute of Textile and Fashion Technology (EiTEX), Bahir Dar, Ethiopia

Correspondence should be addressed to Dereje Berihun Sitotaw; dere96@yahoo.com

Received 30 June 2017; Revised 13 September 2017; Accepted 19 September 2017; Published 25 October 2017

Academic Editor: Yuanxin Zhou

The tensile properties such as tensile strength which is measured as breaking force in Newton (N) and elongation percent (%) at break of single jersey and 1×1 rib (knitted with full needles) knitted fabrics made from 100% cotton and cotton/Lycra yarns (5% Lycra yarn content in 95% combed cotton yarn) are investigated in this research. The sample fabrics are conditioned for 24 hours at $20 \pm 1^{\circ}$C temperature and $65 \pm 2\%$ relative humidity before testing. Ten specimens (five for lengthwise and five for widthwise) have been taken from each of the two knitted structures, those made from 100% cotton and cotton/Lycra (at 95/5 percent ratio blend) yarns. According to the discussion and as found from the investigations, the tensile properties of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra yarns are significantly different from each other and both of the knitted fabrics have high elongation percent at break with cotton/Lycra blend yarns as compared to 100% cotton yarn. Knitted fabrics made from cotton/Lycra blended yarn have low breaking force and high elongation percent at break relative to knitted fabrics made from 100% cotton yarns.

1. Introduction

Knitted fabrics are produced by intermeshing the yarns 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 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 governs the fabric performance in use by causing a change of dimensions of strained knitted fabrics [1–3]. A change of dimensions of strained knitted fabric can be defined by increasing dimension in one direction as dimension in other directions is decreasing [4, 5]. In many cases, it is important to know how much the knit will deform in one or another direction. On the other hand 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 [6, 7]. Processes of deformation of knitted fabrics are described in concept of extensibility of knitted fabric and the deformation can be determined and influenced by different factors.

References [5, 8, 9] investigated the effect of knit structures and raw materials on plated knitted fabrics tensile properties and the results showed that the tensile strength and elongation at break of plated single jersey, plated rib 4 : 2, and plated purl knitted fabrics are different due to the variations in physical and chemical properties of cotton, silk, polyester, polyamide, viscose, bamboo, and their blends at different ratio and count. References [10, 11] reported that the mechanical property of knitted fabrics is the matter of yarn, fabric structure, and the knitting process and found that tensile property of jacquard weft knitted fabrics is different in birds eye, striped jacquard, and twill jacquard knit structures.

References [12, 13] experimentally investigated the parameters of colored double jacquard fabrics as the coefficient of stitch density, the stitch length, the surface density, and the extensibility of fabric. It has been established that extensibility

Table 1: Fiber properties.

Type of fiber	Origin	Staple length	Short fiber index	Nep	Trash	Micronaire
		Properties				
Cotton (100%)	Upper Awash	28 mm	12.8	300	4.06	4.2

Table 2: Yarn specifications.

Machine type	Twist (1/m)	Ne	U%	CVM	Thin−50%	Thick+50%	Neps+200%	TIP	Lycra count
Ring frame	750	28	9.21	11.70	0	33.6	29.8	63.4	40 denier

Table 3: Fabric specifications.

Machine type	Machine number	Speed (rpm)	Adjusted loop length (mm)	Machine diameter (inch)	Number of needles	Gauge	Number of feeders	Number of cam tracks	Remark
MAYER & CIE	60	30	3.21	34	2976	28	108	4	Circular for single jersey
	99	20	3.25	30	1404	18	62	1	Circular for 1×1 rib

Table 4: Equipment and materials used.

S/r number	Name of equipment	Tests
(1)	Uster tester-5	U%, CVM, Thin, Thick, Nep
(2)	Round sample cutter	Sample fabric
(3)	MESDAN TENSO Tensile tester	Breaking force (N) and elongation (%)

decreases by increasing of number of standing needles in a back needle bed (i.e., by increasing of floats).

As reviewed in different research results, the tensile property of knitted fabrics has 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 tensile strength and elongation of single jersey and 1×1 rib knitted fabrics. This research is designed to study the tensile properties of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra blend (95/5 in percentage) by conducting scientific tests and analysis.

2. Materials and Methods

2.1. Materials. Cotton/Lycra blend and 100% cotton yarns are used for this study. The Lycra accounts for about 5% content (40 denier = 133 Ne) while cotton accounts for 95% content (35 Ne) in the resultant 28 Ne combed cotton/Lycra blended yarn (cotton/Lycra = 95/5%) and the Lycra is plied with the cotton yarn. Tensile properties of single jersey and 1×1 rib (knitted with full needles) knitted fabrics produced from these yarns are designed to be studied. These fabrics are produced from the cotton fibers (shown in Table 1) and cotton/Lycra blended yarns shown in shown in Table 2.

Yarn specifications (see Table 2), knitting machine settings, and fabric parameters (see Table 3) are controlled constantly throughout the study.

2.2. Experiments. Single jersey and 1×1 rib knitted fabrics are the raw materials (fabrics) for this study. These fabrics are produced on circular knitting machines with the machine parameters and fabric specifications shown in Table 3. Tests for yarn and knitted fabrics properties are performed using the equipment shown in Table 4.

3. Results and Discussion

3.1. Results. Tensile properties of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra blended yarns are studied by performing proper laboratory tests. The experiments are done as directed in ASTM D5035-95, termed as Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method) using MESDAN TENSO Tensile tester at 300 mm/min clamp speed, 75 mm gauge length (sample length), 5 kN load cell, and 0 N pretension [14, 15]. The results are recorded as per this standard and shown in Table 5 (for single jersey) and Table 6 (for 1×1 rib).

3.2. Discussion. Tensile properties such as tensile strength and elongation percent at break of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra (95/5%) blended yarns test results are recorded in Tables 5 and 6. The tensile strength is measured by the amount of maximum force required to break the fabrics in Newton while the elongation is the fabrics extension percent (%) until the fabric is broken.

The tensile strength of single jersey made from 100% cotton has the maximum breaking force between 211 N and 235 N with an average 220.8 N along the length of the fabric and between 149 N and 166 N with an average of 159 N

Table 5: Tensile properties of single jersey knitted fabrics.

Knitted fabrics made from	Test direction	Tensile properties	Specimens (1)	(2)	(3)	(4)	(5)	Avg
100% cotton	Lengthwise	Max. breaking force in N	217	215	235	211	226	220.8
		Elongation (%) at break	130.8	116	112.4	119.2	117.2	119.12
	Widthwise	Max. breaking force in N	162	160	166	149	158	159
		Elongation (%) at break	139.4	139.2	131.2	132	134.4	135.24
Cotton/Lycra	Lengthwise	Max. breaking force in N	127	130	127	123	132	127.8
		Elongation (%) at break	222	215.2	219.2	228	213	219.48
	Widthwise	Max. breaking force in N	178	181	189	181	190	183.8
		Elongation (%) at break	194	194	202	193	208.4	198.28

Table 6: Tensile properties of 1×1 rib knitted fabrics.

Knitted fabrics made from	Test direction	Tensile properties	Specimens (1)	(2)	(3)	(4)	(5)	Avg
100% cotton	Lengthwise	Max. breaking force in N	345	337	346	317	280	325
		Elongation (%) at break	57.2	50	55	51.2	45.6	51.8
	Widthwise	Max. breaking force in N	90	97	93	101	126	101.4
		Elongation (%) at break	317.6	328.8	264.4	316.4	259.6	297.36
Cotton/Lycra	Lengthwise	Max. breaking force in N	278	277	281	276	269	236.2
		Elongation (%) at break	146	118.8	113.2	124	120.6	124.52
	Widthwise	Max. breaking force in N	88	75	79	71	83	79.2
		Elongation (%) at break	521.2	602	658.8	721.2	588.4	618.32

Table 7: Description for tensile strength of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra (95/5%).

	N	Mean	Std. deviation	Std. error	Minimum	Maximum
Single jersey lengthwise tensile strength (N)						
95.00	5	127.8000	3.42053	1.52971	123.00	132.00
100.00	5	220.8000	9.65401	4.31741	211.00	235.00
Total	*10*	*174.3000*	*49.48861*	*15.64967*	*123.00*	*235.00*
Single jersey widthwise tensile strength (N)						
95.00	5	183.8000	5.35724	2.39583	178.00	190.00
100.00	5	159.0000	6.32456	2.82843	149.00	166.00
Total	*10*	*171.4000*	*14.19076*	*4.48751*	*149.00*	*190.00*
1×1 rib lengthwise tensile strength (N)						
95.00	5	276.2000	4.43847	1.98494	269.00	281.00
100.00	5	335.2000	11.88276	5.31413	317.00	346.00
Total	*10*	*305.7000*	*32.22508*	*10.19046*	*269.00*	*346.00*
1×1 rib widthwise tensile strength (N)						
95.00	5	79.2000	6.64831	2.97321	71.00	88.00
100.00	5	98.2000	7.79102	3.48425	90.00	110.00
Total	*10*	*88.7000*	*12.12023*	*3.83275*	*71.00*	*110.00*

across the width of the fabric. The single jersey made from cotton/Lycra blended yarn has the maximum breaking force between 123 N and 132 N with an average of 127.8 N along the length and between 178 N and 190 N with an average of 183.8 N across the width of knitted fabric (see Tables 5 and 7). The tensile strength of 1×1 rib knitted fabric made from 100% cotton has maximum breaking force between 317 N and 346 N with an average of 335.2 N along the length of the fabric and between 90 N and 110 N with an average of 98.2 N across the width of the fabric. The 1×1 rib knitted fabric made from cotton/Lycra blend has the maximum breaking force between 269 N and 281 N with an average of 276.2 N along the length and between 71 N and 88 N with an average of 79.2 N across the width of the fabric (see Tables 6 and 7).

Table 8: Description for elongation (%) of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra (95/5%).

	N	Mean	Std. deviation	Std. error	Minimum	Maximum
Single jersey lengthwise elongation (%)						
95.00	5	219.4800	5.90186	2.63939	213.00	228.00
100.00	5	119.1200	6.98226	3.12256	112.40	130.80
Total	*10*	*169.3000*	*53.24436*	*16.83735*	*112.40*	*228.00*
Single jersey widthwise elongation (%)						
95.00	5	198.2800	6.72250	3.00639	193.00	208.40
100.00	5	135.2400	3.88947	1.73943	131.20	139.40
Total	*10*	*166.7600*	*33.62602*	*10.63348*	*131.20*	*208.40*
1×1 rib lengthwise elongation (%)						
95.00	5	121.0000	5.69210	2.54558	113.20	128.40
100.00	5	51.8000	4.51221	2.01792	45.60	57.20
Total	*10*	*86.4000*	*36.79167*	*11.63455*	*45.60*	*128.40*
1×1 rib widthwise elongation (%)						
95.00	5	617.8000	29.34553	13.12372	588.40	658.80
100.00	5	314.3600	10.24734	4.58275	303.40	328.80
Total	*10*	*466.0800*	*161.26385*	*50.99611*	*303.40*	*658.80*

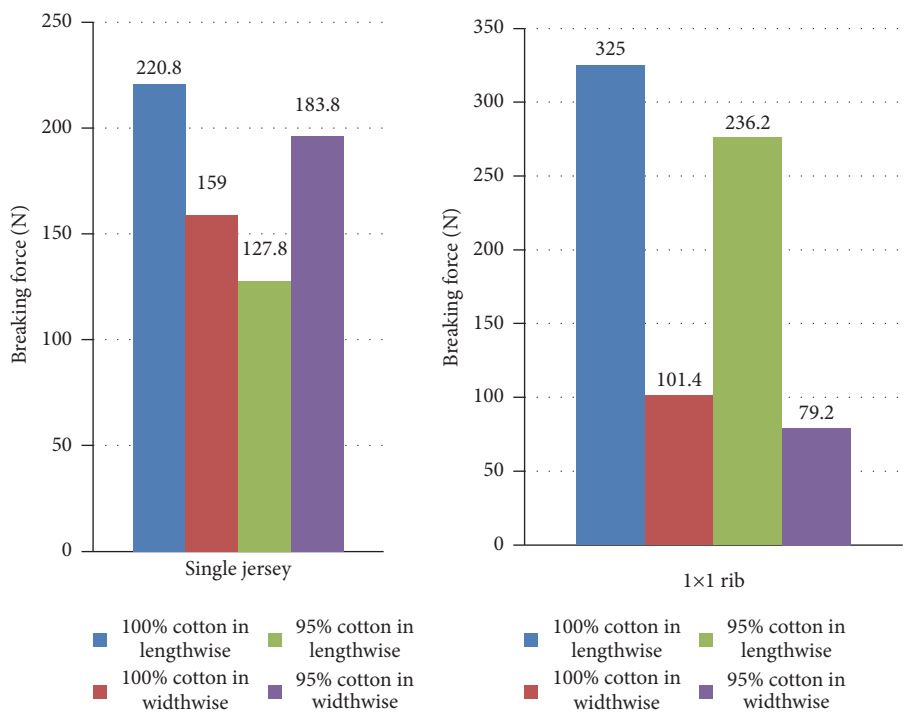

Figure 1: Tensile strength of single jersey and 1×1 rib knitted fabrics.

The elongation percentage at break for the single jersey knitted fabric made from 100% cotton is found between 112.4% and 130.8% with an average 119.12% along the length of the fabric and between 131.2% and 139.4% with an average of 135.24% across the width of the fabric. The single jersey made from cotton/Lycra blended has the elongation percent at break between 213% and 228% with an average of 219.48% along the length and between 193% and 208.4% with an average of 198.28% across the width of fabric (see Tables 5 and 8). The elongation at break of 1×1 rib knitted fabric made from 100% cotton has between 45.6% and 57.2% with an average 51.8% along the length of the fabric and between 303.4% and 328.8% with an average of 314.36% across the width of the fabric. The 1×1 rib knitted fabric made from cotton/Lycra blended has the elongation at break (%) between 113.2% and 128.4% with an average of 121% along the length and between 588.4% and 658.8% with an average of 617.8% across the width of the fabric (see Tables 6 and 8).

As shown in Table 7 and Figure 1, the maximum force in Newton required to break the fabrics is different. Single

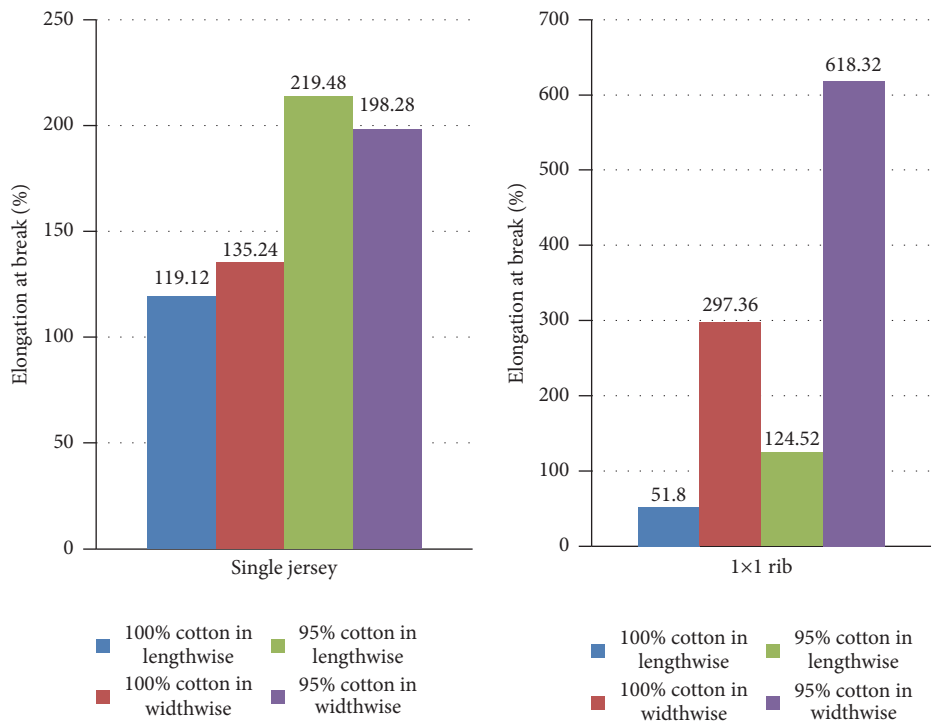

Figure 2: Elongation percent of single jersey and 1×1 rib knitted fabrics.

jersey and 1×1 rib knitted fabrics made from 100% cotton have high breaking force as compared to fabrics made from cotton/Lycra blended yarns. After adding the Lycra yarn, the maximum breaking 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 its widthwise direction. Fabrics with high extension property needs low force to extend and its strength become decreased. Lengthwise breaking strength of 1×1 rib knitted fabrics is higher than single jersey's both lengthwise and widthwise breaking strength. But, the widthwise strength of 1×1 rib is lower than the single jersey's lengthwise and widthwise strengths (see Table 7 and Figure 1).

When the breaking force (strength) of the single jersey and 1×1 rib knitted fabrics increases the elongation percent at break decreased. In this research it is found that tensile strength and elongation percent at break are inversely proportional (see Tables 7 and 8, Figures 1 and 2). The elongation at break of single jersey and 1×1 rib knitted fabrics made from 100% cotton is lower than the elongation of these fabrics made from cotton/Lycra (at 95/5% ratio) blended yarns.

The elongation percent of single jersey and 1×1 rib knitted fabrics increased both in the lengthwise and widthwise with the presence of 5% Lycra yarns in the fabric. But the elongation percent at break of 1×1 rib knitted fabric made from cotton/Lycra blended yarn is higher than single jersey in both the lengthwise and widthwise directions (see Table 8 and Figure 2). The widthwise elongation percent at break of 1×1 rib knitted fabric is higher than its lengthwise elongation percent due to the higher widthwise extension characteristic of 1×1 rib knitted fabrics. It is known that rib knitted fabrics have high widthwise extension due to the high widthwise shrinkage property (see Table 11) of rib knitted fabrics.

The tensile strength of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra blended yarns is significantly different one from the other. The lengthwise and widthwise tensile strength of single jersey knitted fabric are significantly influenced by the Lycra yarns at $F = 412.250$, Sig. = 0.000 and $F = 44.730$, Sig. 0.000, respectively (see Table 9). The F-value in the lengthwise direction is much higher than the widthwise direction because of the high tensile strength (breaking force in Newton) reduction in the presence of 5% Lycra in 95% combed cotton yarn along the length of single jersey knitted fabrics (see Table 7).

The lengthwise and widthwise tensile strength of 1×1 rib knitted fabric is significantly influenced by the Lycra yarns at $F = 108.173$, Sig. = 0.000 and $F = 17.207$, Sig. 0.000, respectively (see Table 9).

The breaking elongation percent (%) of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra blended yarns is significantly different one from the other. The lengthwise and widthwise breaking elongation of single jersey knitted fabric is significantly influenced by the Lycra yarns at $F = 602.515$, Sig. = 0.000 and $F = 329.412$, Sig. 0.000, respectively (see Table 10). The F-value in the lengthwise direction is much higher than in the widthwise direction because of the high elongation percent difference between 100% cotton and cotton/Lycra (95% cotton) along the length of knitted fabrics.

Table 9: Analysis of variance for tensile strength of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra (95/5%).

	Sum of squares	df	Mean square	F	Sig.
Single jersey lengthwise tensile strength					
Between groups	21622.500	1	21622.500	412.250	.000
Within groups	419.600	8	52.450		
Total	*22042.100*	*9*			
Single jersey widthwise tensile strength					
Between groups	1537.600	1	1537.600	44.763	.000
Within groups	274.800	8	34.350		
Total	*1812.400*	*9*			
1×1 rib lengthwise tensile strength					
Between groups	8702.500	1	8702.500	108.173	.000
Within groups	643.600	8	80.450		
Total	*9346.100*	*9*			
1×1 rib widthwise tensile strength					
Between groups	902.500	1	902.500	17.207	.003
Within groups	419.600	8	52.450		
Total	*1322.100*	*9*			

Table 10: Analysis of variance for elongation (%) of single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra (95/5%).

	Sum of squares	df	Mean square	F	Sig.
Single jersey lengthwise elongation (%)					
Between groups	25180.324	1	25180.324	602.515	.000
Within groups	334.336	8	41.792		
Total	*25514.660*	*9*			
Single jersey widthwise elongation (%)					
Between groups	9935.104	1	9935.104	329.413	.000
Within groups	241.280	8	30.160		
Total	*10176.384*	*9*			
1×1 rib lengthwise elongation (%)					
Between groups	11971.600	1	11971.600	453.813	.000
Within groups	211.040	8	26.380		
Total	*12182.640*	*9*			
1×1 rib widthwise elongation (%)					
Between groups	230189.584	1	230189.584	476.500	.000
Within groups	3864.672	8	483.084		
Total	*234054.256*	*9*			

Table 11: Widthwise shrinkage of single jersey and 1×1 rib knitted fabrics.

Type of fabric	Shrinkage in %
Single jersey from 100% cotton	20.9
Single jersey cotton/Lycra	33.19
1×1 rib from 100% cotton	28.88
1×1 rib from cotton/Lycra	48.72

The lengthwise and widthwise elongation percent of 1×1 rib knitted fabric are significantly influenced by the Lycra yarns at $F = 453.813$, Sig. = 0.000 and $F = 476.500$, Sig. 0.000, respectively (see Table 10). The F-value for the 1×1 rib across the widthwise is higher because of the higher difference between the elongation percent of 1×1 rib knitted fabric made from 100% cotton and cotton/Lycra (95% cotton) blended yarn. The widthwise elongation of 1×1 rib knitted fabrics increased as compared to its lengthwise elongation due to the presence of 5% Lycra in the 95% cotton yarn.

4. Conclusion

The tensile properties of single jersey and 1×1 rib knitted fabrics have been investigated in this research. The tensile strength which is measured as breaking force in Newton and elongation percent at break are the two tensile properties investigated in the lengthwise and widthwise direction of the single jersey and 1×1 rib knitted fabrics made from 100% cotton and cotton/Lycra blended yarns. The ratio of cotton to

Lycra was 95% to 5%, respectively, and the presence of Lycra yarn in the combed cotton yarn significantly influences both the lengthwise and widthwise tensile strength and elongation percent of the two knitted fabrics. The single jersey's tensile strength reduced with the cotton/Lycra yarn along the length while its tensile strength is slightly increased across the width as compared to 100% cotton yarn. The elongation percent of single jersey increased more in the lengthwise than in the widthwise with the presence of 5% Lycra in 95% cotton yarn as compared to 100% cotton yarn. The 1×1 rib knitted fabric's tensile strength and elongation percent at break in the lengthwise and widthwise directions of the fabric increased with the cotton/Lycra blended yarn as compared to 100% cotton yarn. It is found that Lycra yarn may not improve the tensile properties of all types of knitted structures. Though the type of yarns used in these two fabrics significantly influences the strength and elongation, the type of structure has its own influence in order to withstand the applied force in the lengthwise and widthwise directions of the fabrics. The 1×1 rib knitted caused the big difference between lengthwise and widthwise in maximum breaking force or elongation at break due to the greater extension characteristic across the width of the rib knitted fabrics. Single jersey knitted fabrics are single sided fabrics and produced on one set of needles [16]. This leads single jersey to have low shrinkage and high curling tendency. The shrinkage is more with rib knitted fabrics across its widthwise directions than its lengthwise and single jersey.

During the investigation we found that tensile strength which is measured as a maximum braking force in Newton and elongation percent (%) at the break are inversely proportional. Higher breaking force is consumed for low elongation percent at the break and the reverse is also true. Knitted fabrics made from cotton/Lycra blended yarn have low breaking force and high elongation percent at break relative to knitted fabrics made from 100% cotton yarns.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This research is completed with the help of MAA Garment and Textile Factory (located in Mekelle, Ethiopia) and Ethiopian Institute of Textile and Fashion Technology (EiTEX, Bahir Dar University). The staffs of these organizations have been the core investigators for this fruitful work. The authors would like to thank them for their effort and cooperation.

References

[1] E. Eltahan, "Effect of Lycra Percentages and Loop Length on the Physical and Mechanical Properties of Single Jersey Knitted Fabrics," *Journal of Composites*, vol. 2016, pp. 1–7, 2016.

[2] E. Sarıoğlu and O. Babaarslan, "A comparative strength analysis of denim fabrics made from core-spun yarns containing textured microfilaments," *Journal of Engineered Fibers and Fabrics*, vol. 12, no. 1, pp. 22–32, 2017.

[3] K. A. Makhlouf S, "Comparison mechanical properties for fabric (woven and knitted) supported by composite material," *Journal of Textile Science Engineering*, vol. 05, no. 04, Article ID 1000206, pp. 10–4172, 2015.

[4] D. Semnani, "Mechanical properties of weft knitted fabrics in fully stretched statuslong courses direction: geometrical model aspect," *Universal Journal of Mechanical Engineering*, vol. 1, no. 2, pp. 62–67, 2013.

[5] Z. Jinyun, L. Yi, J. Lam, and C. Xuyong, "The Poisson Ratio and Modulus of Elastic Knitted Fabrics," *Textile Research Journal*, vol. 80, no. 18, pp. 1965–1969, 2010.

[6] R. D. Mikučionienė and A. Mickeviciene, "The influence of knitting structure on mechanical properties of weft knitted fabrics," *Materials Science (Mikučionienė)*, vol. 16, no. 3, 2010.

[7] A. N. S. Man, "Dynamic elastic behavior of cotton and cotton/spandex knitted fabrics," *Journal of Engineered Fibers and Fabrics*, vol. 9, no. 1, pp. 93–100, 2014.

[8] D. Vlad and L. Cioca, "Research Regarding the Influence of Raw Material and Knitted Fabric Geometry on the Tensile Strength and Breaking Elongation," *Procedia Technology*, vol. 22, pp. 60–67, 2016.

[9] T. Alpyildiz, B. M. Icten, R. Karakuzu, and A. Kurbak, "The effect of tuck stitches on the mechanical performance of knitted fabric reinforced composites," *Composite Structures*, vol. 89, no. 3, pp. 391–398, 2009.

[10] M. Senthilkumar, N. Anbumani, and J. Hayavadana, "Elastane fabrics - A tool for stretch applications in sports," *Indian Journal of Fibre & Textile Research*, vol. 36, no. 3, pp. 300–307, 2011.

[11] O. Stolyarov, "Structure and mechanical properties of theweft-knitted aramid fabrics for composite reinforcement," in *Internation Textile Conference in Dresden*, p. 9, 2008.

[12] M. Eiduks, O. Kononova, A. Krasnikovs, K. Dzelzitis, G. Kharkova, and A. Vagel, "Modelling and experimental verification of mechanical properties of cotton knitted fabric composites," *Estonian Journal of Engineering*, vol. 17, no. 1, pp. 39–50, 2011.

[13] R. Sadek, A. M. El-Hossini, A. S. Eldeeb, and A. A. Yassen, "Effect of lycra extension percent on single jersey knitted fabric properties," *Journal of Engineered Fibers and Fabrics*, vol. 7, no. 2, pp. 11–16, 2012.

[14] ASTM-D4964–96, Standard Test Method for Tension and Elongation of Elastic Fabrics (Constant-Rate of-Extension Type Tensile Testing Machine), 2016.

[15] ASTM-D5035-11. termed as Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method), 2015.

[16] D. J. Spencer, *Knitting Technology: A comprehensive handbook and practical guide*, vol. 105, Abington Hall, Abington Cambridge CB1 6AH, Woodhead Publishing Limited, England, 2001.