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RESEARCH ARTICLE

Performance analysis of spandex incorporated single jersey fabrics for sportswear

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Abstract

Objectives: The main objective of this study is to substantiate the effects of spandex on the properties of plain jersey fabric as compared to the commercial knit sports wear. **Method:** Three single jersey plain knitted fabric samples were produced with full feeder spandex (4.45%), half feeder spandex (2.22%), and without spandex. 34/1 Ne cotton yarn and 20D spandex were used. Standard test methods were followed to analyze the fabric properties. ASTM D 3774: 2004, ISO 6330:2012, ISO 12945-2, ISO 12947-1:1998 and ISO 13938-1:1999 methods were used to measure the variation between cotton and cotton/spandex plain jersey fabric, different physical properties in particular GSM, width, abrasion resistance, pilling, bursting strength, and shrinkage of the specimens. **Findings:** The physical, dimensional, and mechanical properties of cotton/spandex plain jersey knitted fabrics were investigated. The results were compared between knitted fabrics made from 100% cotton and spandex with cotton. The effect of spandex percentage was also studied. A significant effect was observed on the physical, dimensional, and mechanical behaviors of single jersey fabric. Results revealed that the GSM, shrinkage, abrasion resistance, and bursting strength increased and the width reduced with the increased amount of spandex percentage. No apparent effect on the pilling resistance was observed. **Applications:** The manufactured spandex incorporated knitted fabrics can be found in a wide range of applications. The main endeavor is to use for active sportswear.

Keywords: Bursting strength; cotton yarn; pilling resistance; spandex; single jersey; sportswear

1 Introduction

Single jersey fabrics are extensively used in innerwear and outerwear. The main advantages of jersey knit fabric are versatility, wrinkle resistance, durability, softness, and elasticity. That's why jersey is an extremely popular cloth for men, women, and child's wear. The power of recovery after stretching in single jersey fabrics is generally inadequate, and therefore spandex (**Lycra**, spandex, and elastane are mostly synonymns)is increasingly used to impart a greater level of stretch and more dimensional recovery than can be achieved with cotton alone. The use of spandex has resulted in fabrics that fit better on the body like a second skin and have good shape retention without any deformation throughout the life of the garment [1–3].

Lycra has a wide variety of applications such as swimwear, active sportswear for floor gymnastics on the fields, because of its comfort and fit. Knitted fabric has a stretch providing total freedom of movement and has two important functions to perform in particular, namely providing total freedom of movement and transmission of sweat to the next textile layer in the clothing system. Knitted fabrics prove to be an ideal basis for functionally appropriate sportswear with new combinations of fabrics and yarns and with advances in fabric construction. Knitted clothing is often worn next to the skin, and therefore requires special attention [4,5].

Spandex is a common term used to describe elastomeric fibers that have an extension-at break of more than 200 percent and demonstrate rapid recovery when tension is released [6]. Spandex stretch elasticity can be as high as 500 percent while the elastic recovery approaches 95 percent. Spandex yarns add major elastic properties to all kinds of fabrics such as circular knits, warp knits, flat knits, wovens, nonwovens, lace, and narrow fabrics [6,7].

Single knit fabrics must have the spandex plated with a ground yarn like cotton, viscose, etc., and special feeders are used to ensure faultless plating. Cotton/spandex knit fabrics may contain spandex in every course or alternating courses, classified as full plating 'and half plating, respectively. In jersey fabrics, the most uniform appearance is obtained with spandex in every course. Knitting on every second feed creates a ridged effect [2].

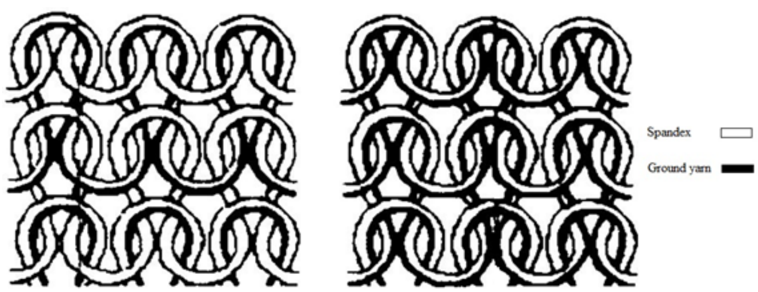

Fig 1. Loop diagram of cotton/single jersey fabrics: (a) in alternating courses (half plating), (b) in every course (full plating)

The physical properties such as stitch density, mass, thickness, bursting strength, air permeability, pilling, spirality, and shrinkage of single jersey knit fabric have changed due to the use of spandex. The weight and thickness of the elastane containing fabrics are higher, fabrics tend to be tighter but spirality, air permeability, and the pilling grade gets lower [7,8]. Elastane yarn percentage is one of the most important parameters of single jersey plated fabric. The percentage of elastane influences fabric characteristics. A lot of researches investigated the effects of the elastane ratio on fabric properties. Although there are many experimental studies on the physical properties of cotton/spandex fabrics, most of these papers have focused on the properties of knitted fabrics containing spandex [3,9–13].

The main goal of this research was to study the effect of spandex on the physical, dimensional, and mechanical properties of single jersey plain fabrics. The other aim was to compare all properties with the same structured fabric made with cotton alone for justifying the characteristics of fabric used in sportswear.

2 Materials and Methods

2.1 Materials and fabrication

34/1 Ne Combed cotton yarn was collected from Unitex Spinning Mill Ltd., Bangladesh, and 20D spandex yarn (filament) was collected from Creora, Korea.

Three single jersey fabric samples were fabricated on JIUNN LONG single jersey circular knitting machine (Taiwan). Machine diametre, gauge, number of feeders, and needles of knitting machine were specified as 26", 24E, 78 and 1960 respectively. One

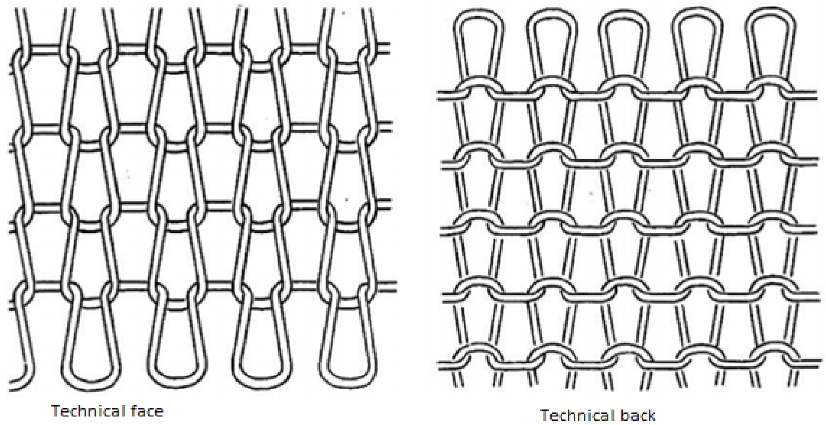

Fig 2. Single jersey knit

Fig 3. Cotton yarn

Fig 4. Spandex (filament yarn)

fabric was produced without spandex yarn, another one with spandex fed at 50% of the feeders and the last one where spandex fed at each of the feeders. Fabrics were produced by maintaining the same stitch length of 3.15mm for cotton and 1.15mm for spandex.

2.2 Pretreatment and dyeing

Heat setting was carried out on Bruckner stenter machine (Germany, 2015). The maximum air pressure and steam pressure of the machine were 10 bar and 7 bar. The parameters were maintained for heat setting as mentioned in Table 1. Samples identifications are stated in Table 6. The wales per inch (WPI), courses per inch (CPI), and stitch density per square inch are tabulated in Table 7.

Scouring, bleaching, and dyeing processes were carried out on a winch-type sample dyeing machine (China). Table 2 indicates the recipe of the scouring and bleaching process. 1g/L Acetic Acid and 0.3 g/L Bio Polish B600N were maintained for enzyme treatment. The dyeing recipe is tabulated in Table 3. The fabrics were dyed with reactive dyes and the dyeing process

Table 1. Parameters for heat setting

Parameters	Value/amount
Temperature	195-200°C
Duel Time	40 s
Overfeed	25%
BWLF (Chemical)	5g/L

was done by exhaust dyeing method. After dyeing, the fabric was dried by using the Dilmenler dryer machine (DMS053, Turkey, 2006). The temperature was used 130°C for drying and fabric speed was maintained as 25m/min.

Table 2. Recipe of scouring and bleaching process

Chemicals/parameters	Amount
Wetting agent	1 g/L
Sequestering agent	1 g/L
Detergent	1 g/L
Anti-creasing Agent	1 g/L
Caustic soda	2 g/L
Hydrogen per oxide	2 g/L
Stabilizer	2 g/L
PH	10.5-11.5
Temperature	100°C
Time	1 hr
Materials : liquor	1:20

Table 3. Recipe of dyeing process

Chemicals/parameters	Amount
Wetting agent	1 g/L
Sequestering agent	1 g/L
Gluber salt	50 g/L
Soda ash	20 g/L
Levelling agent	1 g/L
Reactobond deep yellow LW	1 g/L
Reactobond deep red LW	1 g/L
Temperature	60°C
Time	1 hr 30 min
Materials : liquor	1:20

2.3 Sample Testing

The specimens were held in standard conditions (RH = 65% ±2%, T = 20 °C ±2 °C) according to the requirements of ISO 139:2005 before the investigation carried out [14]. Stitch length was determined by HATRA Course Length Tester (SDL International Ltd., England). After the relaxation & conditioning of knit fabric samples, GSM of samples was measured by using GSM cutter (James Heal, England) and weighing balance [15]. The cutter was placed on to a flattened distortion-free fabric, and then, the samples were cut from different places. The cut samples were of 100 cm^2 size which were weighed by using an electronic balance, and the weight of the 100 cm^2 samples was converted to the weight of 1 m^2 samples in gram by multiplying the results with 100. Wales per inch (WPI) and courses per inch (CPI) of the samples were taken according to the ASTM D8007-15e1 test method by using counting glass [16]. The counting glass contains a rectangular scale beneath its magnifying glass, and that scale has an inch length at its every vertical. The test was done by placing the counting glass on a flattened fabric sample and then counting the number of loops in wales and course direction to find the WPI and CPI, respectively. Then, the stitch density was calculated by using WPI and CPI values. Stitch density can be defined as the total number of loops or stitches in a unit area. For this experiment, stitch density was calculated by using the equation (1) given below. Fabric width was measured by using ASTM D 3774: 2004 method[17]. Measuring tape was used to measure the width of the samples. After conditioning, the samples were laid with minimum tension at the edges just for removing any wrinkle or distortion in the fabric, and then the width was measured by using measuring tape from one edge to the other. The readings were taken in inch. ISO 6330:2012 test method was used to measure the shrinkage[18]. The distance of points (which was marked in 35×35 cm^2 before wash) was measured in both lengthwise and widthwise direction. Shrinkage was calculated using the formula (2) and (3) given below. Pilling test was done by Martindale Pilling Tester (SDL International, England). The method used for the experiment was ISO 12945-2[18]. The samples were subjected to multi-directional rubbing for 250, 500, and 2000 cycles. After each completed cycle the samples were brought under sufficient light and compared to standard photographs and grading was done. The grading system for the visual pilling assessment authorized by ISO is given in Table 6 . The abrasion property was tested with the help of the Martindale abrasion tester. ISO 12947-1:1998 test method was used[19]. Here, revaluation of 250, 500, 750, 1000, and 1250 cycles are operated & finally the samples are assumed. Intervals for the measurement of weight loss are stated in Table 6. ISO 13938-1:1999 Test method was used to measure the bursting strength of the specimens[19]. The bursting strength was done by using a Hydraulic Bursting Strength Tester (Manufacturer: Laboratory Supply Company Ltd, Germany). Bursting strength test is an alternative method of measuring the tensile strength of the fabric. It is measured for those types of fabrics which do not have distinct directions of maximum or minimum strength. It is done for both knitted and non-woven fabric[20]. The machine contains a rubber diaphragm which is expanded by using compressed air. The sample is mounted on the diaphragm so that the sample can undergo the same amount of expansion during the test, and this added pressure causes the bursting of the fabric. That pressure is the indicator of the bursting strength of the fabric. Required pressure and required time to burst the fabric were calculated from the machine for all samples. The values were taken five times for each sample and average values were presented in the results.

$$Stitch\ density\ per\ square\ inch = WPI \times CPI \tag{1}$$

$$Length\ Wise\ Shrinkage = \frac{Before\ wash\ Length - After\ wash\ Length}{Before\ wash\ Length} \times 100 \tag{2}$$

$$Width\ Wise\ Shrinkage = \frac{Before\ wash\ Width - After\ wash\ Width}{Before\ wash\ Width} \times 100 \tag{3}$$

Table 4. Assessment of pilling

Grade	Description
5	No change.
4	Slight surface fuzzing and/or partially form pills.
3	Moderate surface fuzzing and/or moderate pilling. Pills of varying size and density partially covering the specimen surface.
2	Distinct surface fuzzing and/or distinct pilling. Pills of varying size and density covering a large proportion of the specimen surface.
1	Dense surface fuzzing and/or severe pilling. Pills of varying size and density covering the whole of the specimen surface.

Table 5. Intervals for the measurement of weight loss

Series of experiment	Abrasion cycles at the breakage of the sample	Abrasion cycles for determination of weight loss
a	$\leq$ 1000	100, 250, 500, 750, 1000 (1250)
b	> 1000 $\leq$ 5000	500, 750, 1000, 2500, 5000 (7500)
c	> 5000 $\leq$ 10000	1000, 2500, 5000, 7500, 10000 (15000)
d	> 10000$\leq$ 25000	5000, 7500, 10000, 15000, 25000, (40000)
e	> 25000 $\leq$ 50000	10000, 15000, 25000, 40000, 50000, (75000)
f	> 50000 $\leq$ 100000	10000, 15000, 25000, 40000, 50000, 75000, 100000, (125000)
g	> 100000	25000, 40000, 50000, 75000, 100000, (125000)

Table 6. Fabric structural parameters

Fabric type	Fabric code	Spandex ratio %	Needle diagram	Fabric structure
Cotton with full feeder spandex	SJFS	4.45	2) 1)	Single jersey plain knitted structure
Cotton with half feeder spandex	SJHS	2.22	2) Refer images below. 1)	
Cotton with no spandex	SJNS	-	2) 1)	

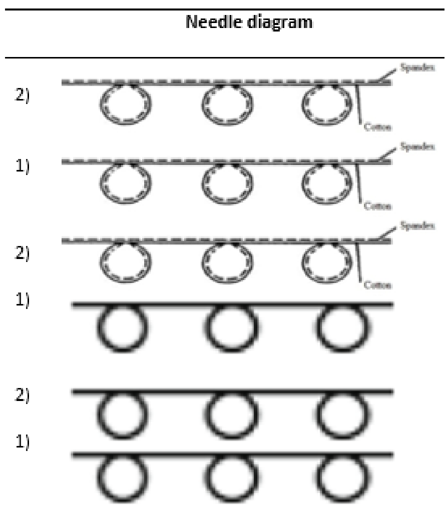

Table 7. WPI, CPI and stitch density of fabrics before and after heat setting

Fabric code	Wale per inch (WPI), Course per inch (CPI) and stitch density					
	Before heat setting			After heat setting		
	WPI	CPI	Stitch density per square inch	WPI	CPI	Stitch density per square inch
SJFS	39.6±0.51	70.2±0.67	2780.6±53.46	39.4±0.51	56.0±0.32	2206.2±27.44
SJHS	39.0±0.45	54.6±0.51	2129.4±31.71	41.2±0.37	45.8±0.37	1887.0±24.03
SJNS	40.0±0.32	40.0±0.55	1600.0±25.14	No heat setting needed		

3 Result and discussion

3.1 Fabric areal density and width

The areal density and width of the plain single jersey knitted fabric both with spandex and without spandex were tested in different processing steps such as scouring and bleaching, enzyme treatment, and dyeing processes. The results of areal density and width are presented in Figure 5 and Figure 6 respectively.

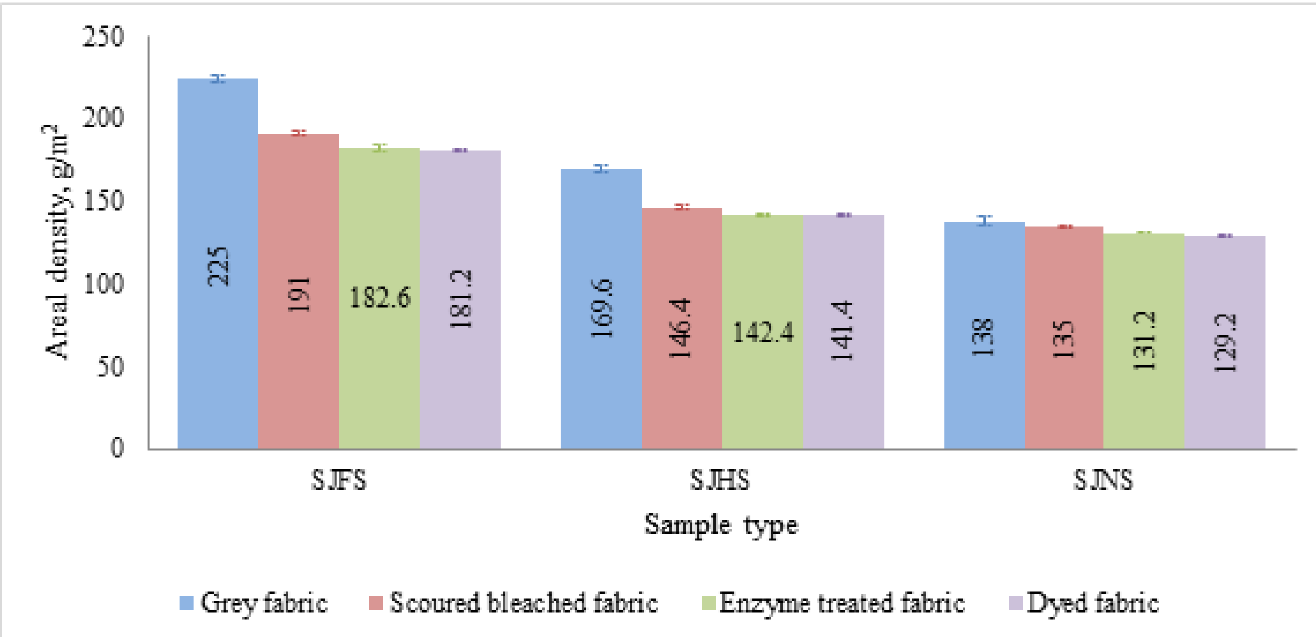

Fig 5. Spandex-areal density dependence of singlejersey fabrics on different processes

A significant effect of spandex was found on fabric areal density in the grey state. The areal density of fabric increased with the increase of spandex percentage. It was found that the areal density increased 22.89% and 63.04% for SJHF and SJFS respectively compared to SJNS in grey state. The additional spandex is mainly responsible for increasing the weight of the fabric and at the same time, the courses and wales come closer thus increase stitch density which is also liable for increasing of GSM. On the other hand, the areal density decreased after pretreatment and dyeing process.

For the SJFS specimen, the areal density decreased 15.11% at the scouring and bleaching process, 4.39% decreased during enzyme treatment and 0.77% decreased at the dyeing process. For SJHS fabric, the areal density decreased 13.68% at the scouring and bleaching process, 2.73% decreased during enzyme treatment and 0.70% decreased at the dyeing process. For the SJNS sample, the areal density decreased 2.17% at the scouring and bleaching process, 2.81% decreased during enzyme treatment and 1.52% decreased at the dyeing process. At the scouring and bleaching process, the highest weight loss was observed for the SJFS specimen and, at the dyeing process, the highest weight loss was observed for the SJNS specimen.

In the grey state, the areal density increased for the samples SJFS and SJHS due to the addition of spandex in the fabric structure compared to SJNS. For chemical applications in different processes i.e. pretreatment and dyeing process, the areal density was decreased for all samples. During scouring and bleaching, GSM decreased because of removing impurities like oil, wax, fat, coloring matters from the fabric surface. The highest amount of GSM change occurred for all samples in this processing step. In enzyme treatment, the GSM decreased due to the removal of hairy fibres from the fabric surface. So, it is clearly evident from Figure 5 that the areal density is greatly influenced by spandex used in the fabric.

Here, the results show that the spandex used in the fabric structure has some impacts on fabric width. The width increased slightly for SJHS and SJFS and decreased for SJNS in all processing steps (see in Figure 6).

3.2 Bursting strength

Bursting strength test is an alternative method of measuring the tensile strength of the fabric. It is measured for those types of fabrics which do not have distinct directions of maximum or minimum strength. It is done for both knitted and non-woven

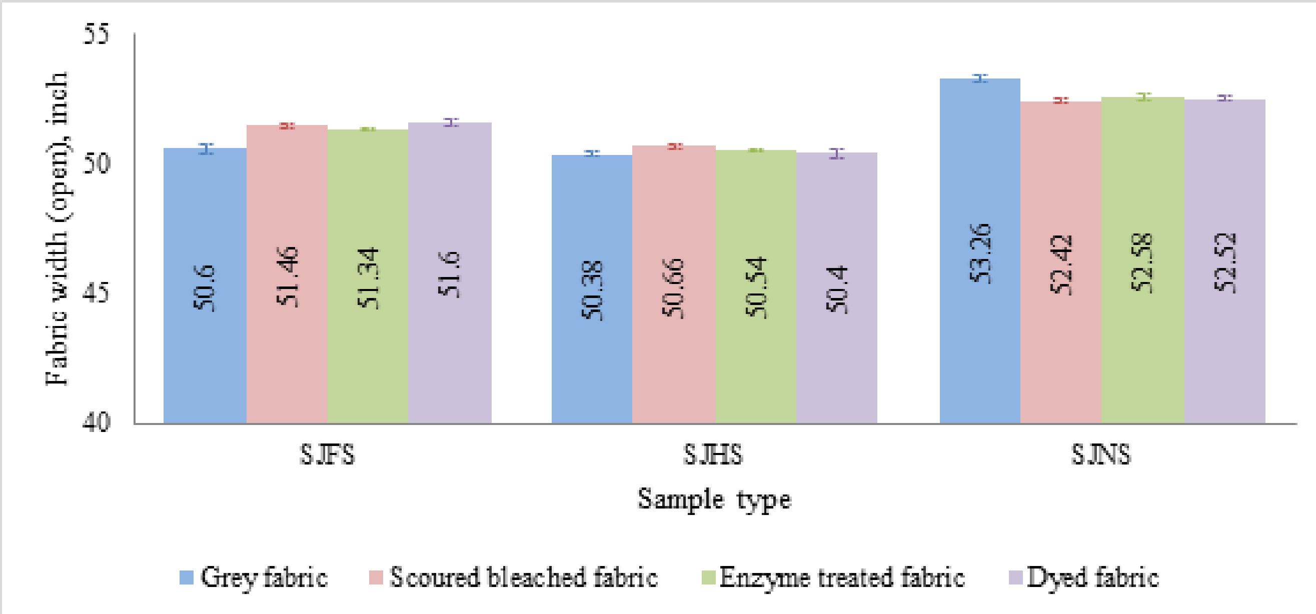

Fig 6. Spandex-width (open) dependence of single jersey fabrics on different processes

fabric[21]. Figure 7 shows the bursting strength of the samples of SJFS, SJHS, and SJNS.

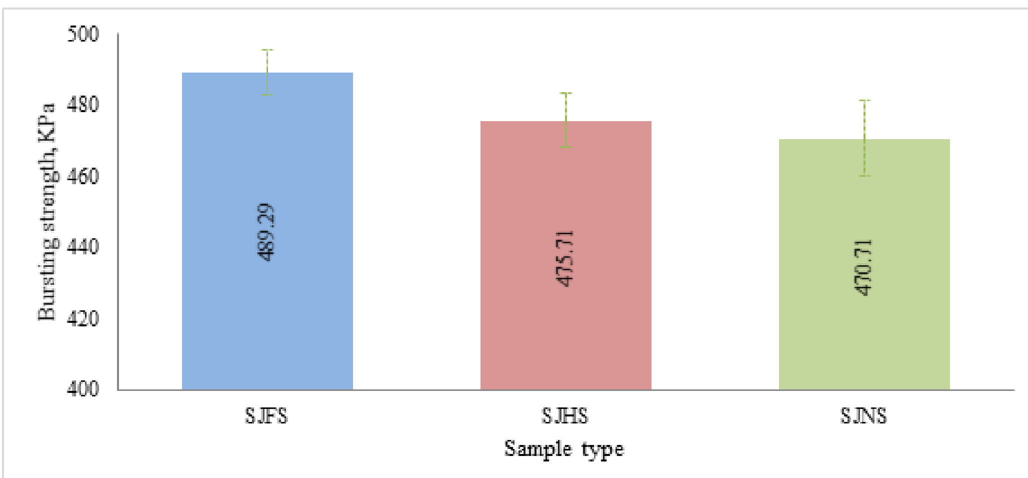

Fig 7. Spandex-bursting strength dependence of single jersey fabrics

It is seen from Figure 7 that the spandex percentage has a significant effect on the bursting strength of plain single jersey fabric. The bursting strength was increased with the increase of spandex percentage used in the fabric. The bursting strength was increased as1.06% and 3.95% for SJHF and SJFS respectively compared to SJNS. The sample with full feeder spandex showed the highest strength whereas the sample with no spandex showed the lowest result. The spandex used in the course contributes to increase the strength. Simultaneously, bursting time does not have a significant effect on strength at all. The required time to burst for SJNS was 24.20 s, for SJHS was 26.80 s and, for SJFS was 29.90 s.

3.3 Abrasion resistance

The abrasion resistance was tested for all fabricated specimens. The outcomes showed the impact of spandex percentage used in the fabric. The abrasion resistance was measured as weight loss at the different numbers of cycles. The results are presented in Figure 8.

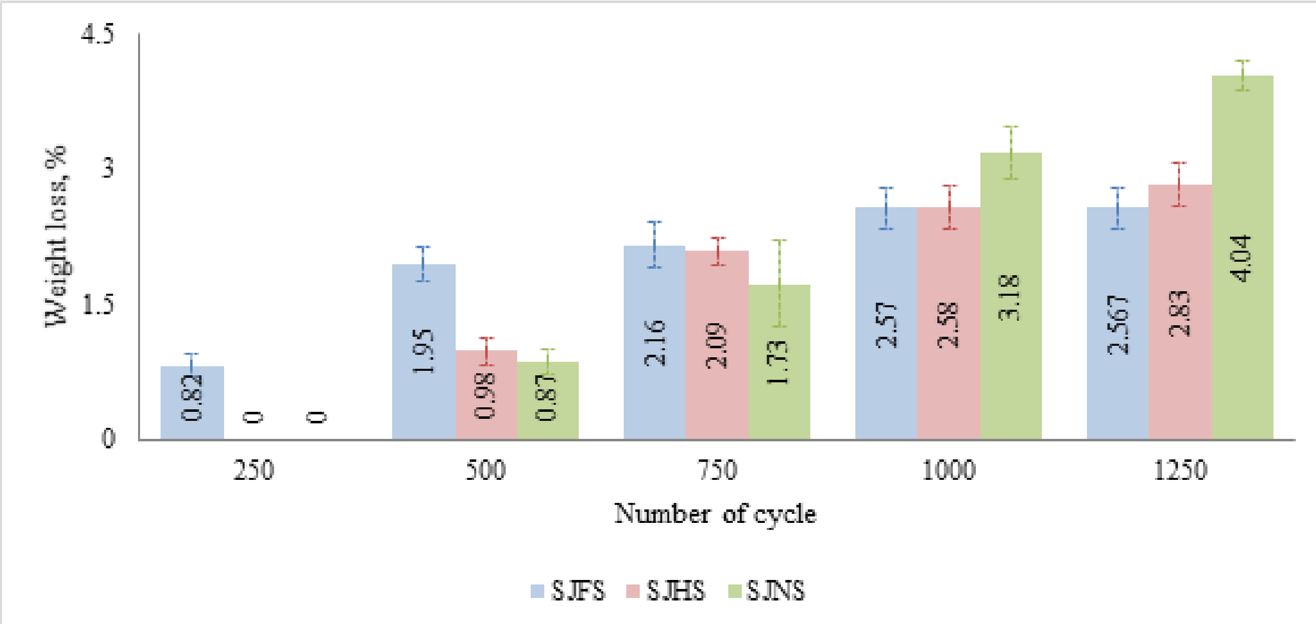

Fig 8. Spandex-abrasion resistance characteristics of single jersey fabric

Figure 8 indicates the importance of spandex used in the knitted structure. It was observed that the normal jersey made with no spandex showed higher weight loss percentage and the next two samples containing half and full feeder spandex respectively showed lower weight loss percentage. The weight loss percentage increased with an increase of the number of cycles. No weight loss showed for SJHS and SJNS at 250 cycles. The abrasion was carried on the face surface only and the spandex yarn present in the back part of the fabric which was unaffected. At 1000 cycles, the weight loss was 18.87% and 19.18% lower for SJHF and SJFS respectively than SJNS. The same scenario observed at 1250 cycles and it indicates that the weight losses 29.95% and 36.38 % lower for SJHF and SJFS than SJNS.

3.4 Pilling resistance

Knitted fabrics with different quantity of elastane, conspicuous by high viscosity and elasticity, having one of the most important performance properties – resistance to pilling is often used in the production of high-quality sportswear. The pilling resistances of the plain single jersey knitted fabric both with spandex and without spandex were tested and rating compared with each other. The pilling resistance was observed after 250, 500, and 2000 cycles. The results are presented in Figure 9.

No significant deviation in pilling resistance was observed due to using spandex in the knitted structure. The pilling resistance was decreased with the increase of the number of cycles. The pilling resistance rating was showed 5 at 250 cycles, 4/5 at 500 cycles, and 4 at 2000 cycles for all samples such as SJNS (no spandex used), SJFH (half feeder spandex used) and SJFS (full feeder spandex used). The pilling grade 5 indicates very slight pilling, 4/5 grade indicates slight pilling to very slight pilling and, grade 4 indicates slight pilling. High resistance was observed for all specimens at 250 cycles. Pilling occurred on the face surface only and spandex was staying behind in the inner part of the fabric which was unaffected.

3.5 Shrinkage behavior

The shrinkage behavior was investigated for all specimens of plain single jersey knitted fabric both with spandex and without spandex used in the knitted structure. The lengthwise shrinkage and width wise shrinkage were inspected and the impact of spandex was analyzed. The results are presented in Figure 10 and Figure 11.

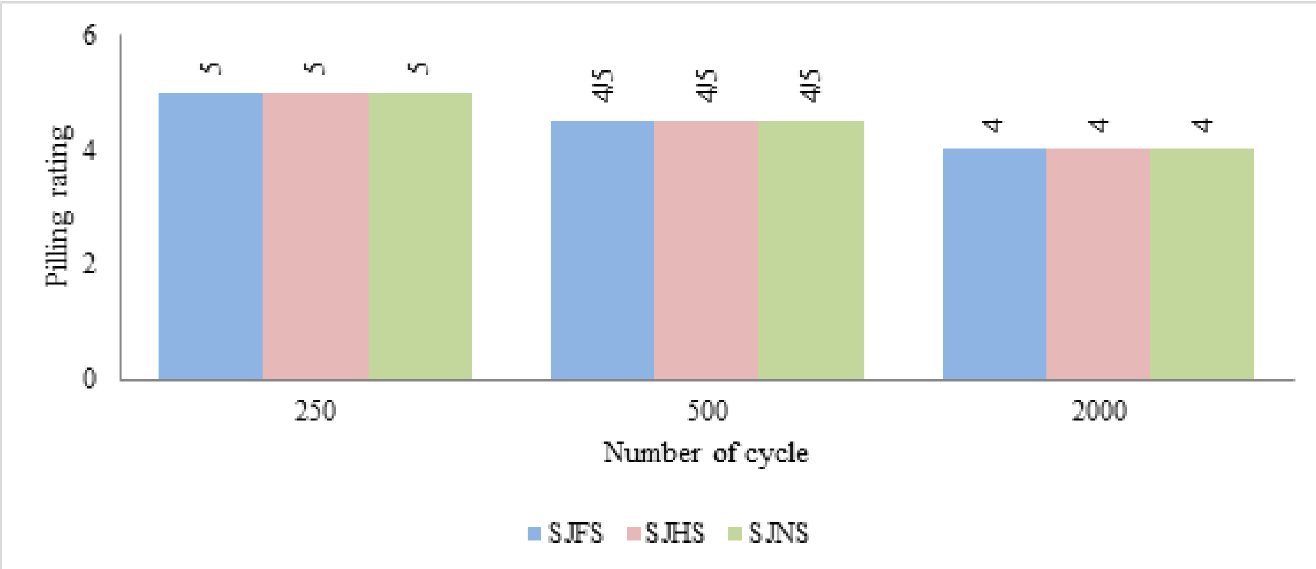

Fig 9. Spandex-pilling resistance dependence of single jersey fabrics

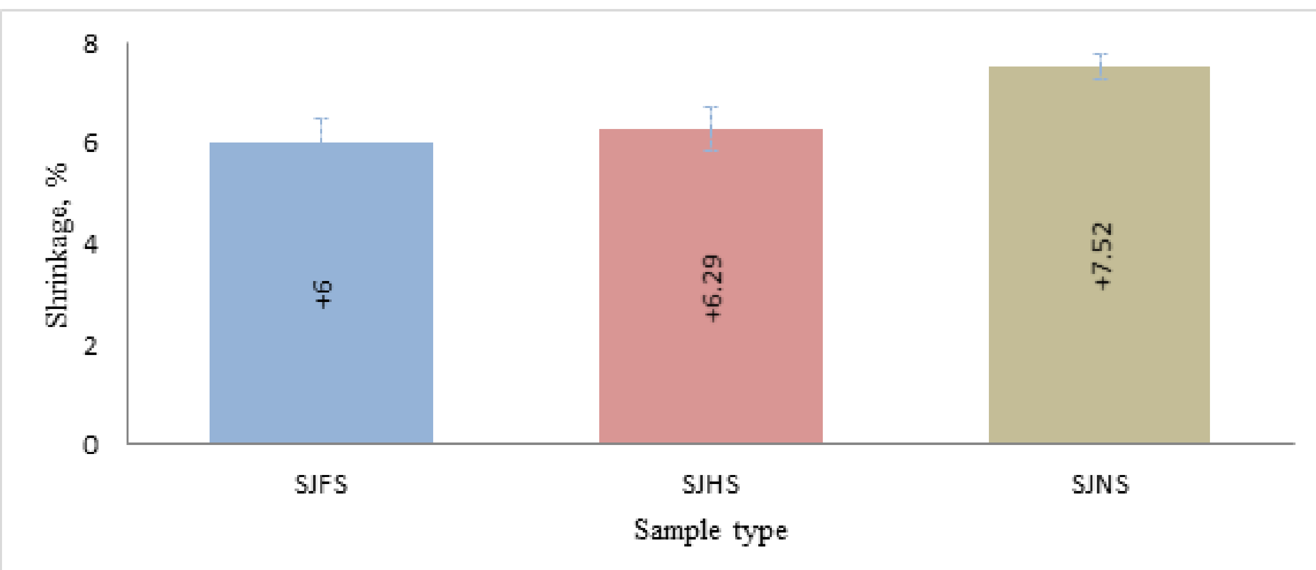

Fig 10. Spandex-length wise shrinkage dependence of single jersey fabrics

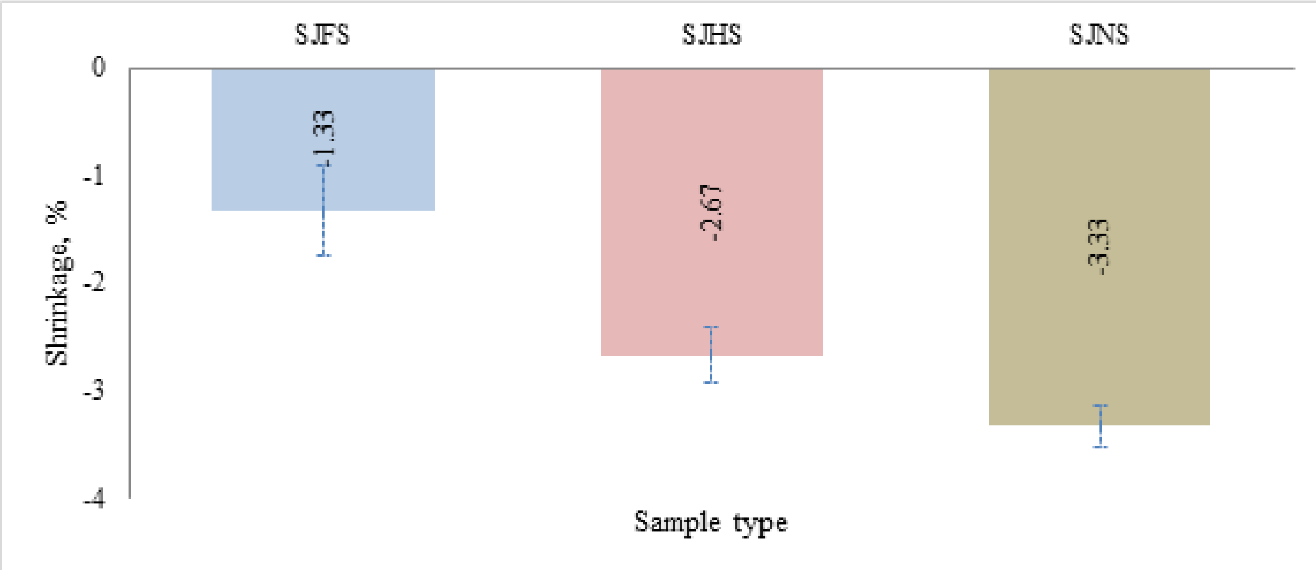

Fig 11. Spandex-width wise shrinkage dependence of single jersey fabrics

A significant impact was observed on shrinkage behavior due to using spandex in the knitted structure. The shrinkage percentage was decreased with the increase of spandex percentage. The same scenario was detected in both lengthwise shrinkage and width wise shrinkage. It was observed that the normal jersey made with no spandex showed higher shrinkage percentage and the next two samples containing half and full feeder spandex respectively showed lower shrinkage percentage in both lengthwise shrinkage and width wise shrinkage. The shrinkage was confirmed 16.36% and 20.21% lower for SJHF (half feeder spandex used) and SJFS (full feeder spandex used) respectively than SJNS (no spandex used) in the length direction and 19.82% and 60.06 % lower accordingly in the width direction. The fabrics got tighter and compact due to using spandex in the fabric structure which tends to retain the dimension of the fabric and does not allow the shape change. This is the reason for less shrinkage. On the other hand, the fabric without spandex is lighter and can't retain its shape.

4 Conclusion

Spandex provides a garment with the requisite elasticity to react to every movement of the body and return to its original size and shape. The dimensional and physical properties of plain jersey fabric made with 100% cotton through similar stitch length and different percentage of spandex were investigated. A major impact on dimensional properties of the fabric such as areal density (GSM) and shrinkage behavior was observed. Other properties such as bursting strength, abrasion resistance, and pilling resistance were also observed to have a significant effect. A major spandex impact was observed in the grey state on fabric areal density. The areal density of fabric increased with the increase of spandex percentage. It was found that the areal density increased 22.89% and 63.04% for SJHF and SJFS respectively compared to SJNS in grey state. Compare to SJNS, the bursting strength increased as1.06% and 3.95% respectively for SJHF and SJFS. The sample with full feeder spandex showed the highest strength while no spandex sample showed the lowest result. The weight loss increased with the number of cycles . No weight loss demonstrated at 250 cycles for SJHS and SJNS. The weight loss for SJHF and SJFS at 1000 cycles was seen 18.87% and 19.18% lower than SJNS and 29.95% and 36.38 % lower at 1250 cycles, respectively. Due to use of spandex in the knitted structure, no significant deviation in pilling resistance was observed. With the increase in the number of cycles, the pilling resistance was decreasing. It was observed that the normal jersey made with no spandex showed higher shrinkage percentage and the next two samples containing half and full feeder spandex respectively showed lower shrinkage percentage in both lengthwise shrinkage and width wise shrinkage.

It was concluded that knitted fabric had good stretch and recovery than woven. Knitted fabrics in combination with spandex form a good recovery. It was found that the knitted fabrics fabricated in this experiment will be suitable for sportswear. The main limitation of this work was to use only one type of yarn linear density for both cotton and spandex. The authors have planned to investigate the effect of spandex on polyester fabric, various yarn counts, and stitch length.

Declaration of conflicting interests

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References

1) Haji MM. Physical and mechanical properties of cotton/spandex fabrics. *Pakistan Textile Journal*. 2013;62(1):52–55.
2) Marmarali AB. Dimensional and Physical Properties of Cotton/Spandex Single Jersey Fabrics. *Textile Research Journal*. 2003;73(1):11–14. Available from: https://dx.doi.org/10.1177/004051750307300102. doi:10.1177/004051750307300102.
3) Sadek R, El-Hossini AM, Eldeeb AS, Yassen AA. Effect of Lycra Extension Percent on Single Jersey Knitted Fabric Properties. *Journal of Engineered Fibers and Fabrics*. 2012;7(2):155892501200700–155892501200700. Available from: https://dx.doi.org/10.1177/155892501200700203. doi:10.1177/155892501200700203.
4) Hu J, Lu J. Recent developments in elastic fibers and yarns for sportswear. In: and others, editor. Textiles for Sportswear. Woodhead Publishing. 2015;p. 53–76. Available from: doi.org/10.1016/B978-1-78242-229-7.00003-5.
5) Gocek İ, Duru SC. Investigating the effects of wicking and antibacterial finishing treatments on some comfort characteristics of Meryl skinlife for seamless activewear/sportswear. *Journal of Engineered Fibers and Fabrics*. 2019;14:155892501985279–155892501985279. Available from: https://dx.doi.org/10.1177/1558925019852790. doi:10.1177/1558925019852790.
6) Senthilkumar M, Anbumani N. Dynamics of Elastic Knitted Fabrics for Sports Wear. *Journal of Industrial Textiles*. 2011;41(1):13–24. Available from: https://dx.doi.org/10.1177/1528083710387175. doi:10.1177/1528083710387175.
7) Uyanik S, Kaynak KH. Strength, fatigue and bagging properties of plated plain knitted fabrics containing different rates of elastane. *International Journal of Clothing Science and Technology*. 2019;31(6):741–754. Available from: https://dx.doi.org/10.1108/ijcst-10-2018-0129. doi:10.1108/ijcst-10-2018-0129.
8) Azim AY, Sowrov K, Ahmed M, Hasan HR, Faruque MAA. Effect of Elastane on Single Jersey Knit Fabric Properties-Physical & Dimensional Properties. *International Journal of Textile Science*. 2014;3(1):12–16.
9) Sitotaw DB. Dimensional Characteristics of Knitted Fabrics Made from 100% Cotton and Cotton/Elastane Yarns. *Journal of Engineering*. 2018;2018(9):1–9. Available from: https://dx.doi.org/10.1155/2018/8784692. doi:10.1155/2018/8784692.
10) Mukhopadhyay A, Sharma IC, Mohanty A. Impact of lycra filament on extension and recovery characteristics of cotton knitted fabric. *Indian Journal of Fibre & Textile Research*. 2003;28(4):423–430.
11) Salopek I, Skenderi Z, Geršak J. Investigation of knitted fabric dimensional characteristics. *Tekstil: časopis za tekstilnu tehnologiju i konfekciju*. 2007;56(7):391–398. Available from: https://hrcak.srce.hr/index.php?id_clanak_jezik=35877&show=clanak.
12) Almetwally AA, Mourad MM. Effects of spandex drawing ratio and weave structure on the physical properties of cotton/spandex woven fabrics. Informa UK Limited. 2014. Available from: https://dx.doi.org/10.1080/00405000.2013.835092. doi:10.1080/00405000.2013.835092.
13) Eltahan E. Effect of Lycra Percentages and Loop Length on the Physical and Mechanical Properties of Single Jersey Knitted Fabrics. *Journal of Composites*. 2016;2016:1–7. Available from: https://dx.doi.org/10.1155/2016/3846936. doi:10.1155/2016/3846936.
14) ISO. Textiles - Standard Atmospheres for Conditioning and Testing. 2005. Available from: https://www.iso.org/standard/35179.html.
15) Standard Test Methods for Mass per Unit Area (Weight) of Fabric. 2013. Available from: https://www.astm.org/Standards/D3776.htm.
16) ASTM. Standard Test Method for Wale and Course Count of Weft Knitted Fabrics (ASTM International, West Conshohocken, 2015). 2015. Available from: https://webstore.ansi.org/standards/astm/astmd800715e1.
17) ASTM. Standard Test Method for Width of Textile Fabric (ASTM International, West Conshohocken, 2004). 2004. Available from: http://database.texnet.com.cn/db-stan/view--442.html.
18) ISO. Textiles - Domestic washing and drying procedures for textile testing. 2012. Available from: https://www.iso.org/obp/ui#iso:std:iso:6330:ed-3:v1:en.
19) ISO. Textiles - Determination of fabric propensity to surface fuzzing and to pilling - Part 2: Modified Martindale method. 2000. Available from: https://www.iso.org/standard/22776.html.
20) ISO. Textiles – Determination of the abrasion resistance of fabrics by the Martindale method – Part 1: Martindale abrasion testing apparatus, Geneva, Switzerland. 1998. Available from: https://www.iso.org/standard/1931.html.
21) Farha FI, Iqbal SMF, Mahmud MA. Compositional and Structural Influence on Some Weft-Knitted Fabrics Comprised of Cotton and Lyocell Yarn. Springer Science and Business Media LLC. 2019. Available from: https://dx.doi.org/10.1007/s40034-019-00135-3. doi:10.1007/s40034-019-00135-3.