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Research article

Fabrication and characterization of stretchable denim fabric using core spun yarn

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GRAPHICAL ABSTRACT

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ABSTRACT

This study aimed to investigate the effect of extensibility on cotton blended polyester-spandex core-spun yarn in the weft direction of 3/1 right-handed Z-twill denim. For the preparation of samples, 100% ring spun cotton yarn of 42 tex (14^s/1 Ne) was used as warp, and 70:30, 30:70, 60:40, and 40:60 cotton-polyester core-spun yarn of 30 tex (20^s/1) was used in the weft direction. Four categories of denim fabric were fabricated by using the air-jet weaving machine. Spandex yarn was used as a core material of weft with a percentage of 2%, 2.5%, 1.9%, and 1.8% respectively. Different physio-mechanical characteristics namely tensile and tearing strength, GSM, growth and recovery percentage, initial modulus, bending length, drape co-efficiency, abrasion resistance, flexural rigidity were evaluated to justify the quality of fabricated pieces of denim. Water wicking and breathability were taken into consideration when determining comfort. Higher cotton containing specimens exhibited lower tensile and tearing strength. Additionally, the produced denim fabrics showed balanced drapability and good breathability.

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1. Introduction

Among all traditional fibrous products, denim fabric is one of the most common goods in our fashion era which is widely accepted by all classes of people [1]. The popularity of denim is due to its special properties like durability, easy wearability, longer washability, etc. [2,3]. As the demand for denim fabric had increased day by day, so the comfort properties of denim fabric should be enhanced. Basically, in the clothing industries, comfort properties are one of the vital concerns for the quality of fabric which largely depends on the fabric construction. So, proper and developed fabric constructions have been designed to achieve better comfort features [4,5].

Various fibrous items can be made from denim fabric. Different weighted denim fabrics are produced based on their end-uses. Yarn count, fabric density, EPI, and PPI decide the weight of denim. The weight of denim fabric usually ranges from 5 to 15 oz/yd^2. For medium denim, weight lies between 5 to 10 oz/yd^2 where the weight range of heavy denim fabric is 10–15 oz/yd^2. Medium denim is suitable for dresses or tops that require draping, softness and versatility, while heavy denim is suitable for pants and skirts with blue jeans. Cotton fibre is mostly used for making denim fabric but very few from cotton blended one. Usually, open-end yarns are employed in denim, but a significant introduction of ring-spun or compact yarns is also found. The same denim fabric can also be hybridized with ring-spun and rotor spun yarns [1,6].

Denim fabric consists primarily of twill fabric. According to the direction of yarn, denim fabric can be categorized into three groups as right-hand twill, left-hand twill, and broken twill [7,8]. Left-hand twill denim is usually smoother than that of right-hand twill. It is also easier to differentiate as the weft threads appear to shift left upward as opposed to right upward. Broken twill has There are no directional consequences of broken twill [1].

Human skin is very flexible and can stretch with body movements. So, they expect that their clothing will expose the same attitude [9]. But for many clothing materials, like denim fabric does not pose such types of attitude due to the absence of stretchable fibre in its composition as well as the heaviness of the fabric. However, by adding a cotton yarn and spandex yarn blend or using a cotton-polyester blended spun yarn, the stretch capacity and the prevention of wrinkles can be improved [10]. Though the introduction of spandex with cotton yarn provides the relatively good stretchability, there is an issue of unevenness on denim's surface. On the other hand, the improvement of stretchability and fabric lightweight are not prominent for the cotton/polyester blended spun yarn. In order to offer the stretch capability of the denim fabric, a core-spun yarn is used as the weft yarn [9]. The core-spun yarn is wrapped with cotton yarn and has spandex as its core yarn. By introducing core-spun yarn, the drawbacks of the paper denim fabric, such as heaviness, roughness, and wrinkles caused by low stretch capacity, can be greatly improved. The combined impact of fabric weight and elastane percentage on the physico-mechanical properties of denim garments must therefore be understood so that manufacturers can design their products according to customer requirements [11–13]. Many researchers have researched various properties of denim fabrics made from 100% cotton, double-core, and core-spun weft yarns with different weft densities so far [14, 15, 16, 17, 18, 19, 20, 21, 22, 23].

Denim is widely used for manufacturing shirts, pants, jackets, trousers, jeans, wall coverings, curtains, cushions, upholstery, ornaments, mattresses, lampshades, seat covers, separators, kilims, rugs, mats, doorstops, etc. [24]. The non-apparel application of denim is not only used as home textile but also used in automotive, marine and transportation textiles, technical textiles, denim wastes for industrial purposes. Recently, denim has been used as artwork, such as outdoor and indoor exhibits, exterior and interior design, etc. Existing apparel and non-apparel denim items and probable applications were recognized by a severe investigation of present and upcoming possibilities [24, 25, 26].

Fabrics' moisture management properties are relevant to perspiration i.e., removal of sweat in liquid form from the body surface. It's particularly important for performance and operational textiles, as it provides the comfort and protection that customers expect. In order to offer a pleasant 'hand feel,' denim fabric should be lightweight, flexible, smooth, but not too thin. The front waist, crotch, and pelvis generated considerably greater garment pressure to the user during everyday activities such as standing, walking, and sitting than other measured body areas [19,27, 28, 29, 30, 31].

The Vision of this work was to weave the denim fabrics using different yarns in weft direction in different percent and analyze the impact of different weft yarn on the properties of denim. In this analysis, performance properties were compared with each other like tensile strength, tearing strength, stretching, growth, and recovery percentage, initial modulus, bending length, drape co-efficiency, abrasion resistance, flexural rigidity, water wicking and breathability properties of resulting denim. Thereafter, the outcomes of the elastane content on the physical properties of each fabric were comparatively investigated.

1.1. World market for denim and jeans

39 percent of worldwide jeans sales are in North America, followed by 20 percent from Western Europe, 10 percent from Japan and Korea, and 31 percent from the rest of the world. America spent more than 14 billion US dollars on jeans in 2004, and 15 billion US dollars in 2005. In the year ended April 30, 2011, America purchased $13.8 billion worth of men's and women's jeans, according to market research firm NPD Group. With demand growing by 5 percent and supply growing by 8 percent annually, the world-wide denim market expanded in 2007. More than 50 percent of denim, especially in China, India and Bangladesh, is manufactured in Asia. Figure 1 displays the worldwide demand for jeans and Table 1 indicates the number of denim factories in the world [12,26].

1.2. New possibilities of denim

The 'destructive effect' can be created directly on the knitting nowadays and cannot be subjected to the wear and tear techniques used in distressing denim as the rubbing techniques will cause drop stitches that would allow useless fabrics to be unraveled.

Stoll created a software-based knitting program to create new knitting techniques and use unique denim knitting yarns by using an innovative leading German flat knitting machine manufacturer. However, it is now possible to authentically produce "destroyed" impact. In doing so, the flat knitting machine maker claims it has been able to show the unlimited possibilities for knitted clothing in terms of denim. Stoll collaborated closely with project collaborators from Spain and Germany to improve its technique for denim knitting [12].

Not only is its denim knitting technique unique in the industry, but it also gives the producer ecological, social, and economic benefits. The development of the used look by the knitting process is very different in that it is environmentally friendly, using much less water than woven denim during development, and there is a time-saving factor compared to the normal production of denim products by reducing production steps. The knitted product leaves the knitting machine almost 'ready-to-wear' without the need for complicated wear and tear and washing processes that require extra labor. Not only the new knitting programs, but also the implementation of new hardware in the form of a new computer for translating the denim look, the Stoll CMS ADF-3, were prerequisites in order to understand the denim knitting patterns in practice. The Stoll CMS ADF-3 was specifically developed to meet the requirements of denim manufacturing and provides optimum conditions for a genuine per 936 + ect [32]. The CMS ADF-3 proves to be extremely versatile in both vertically and horizontally programmable movements of the yarn carriers and is therefore especially suitable for the development of denim knitwear.

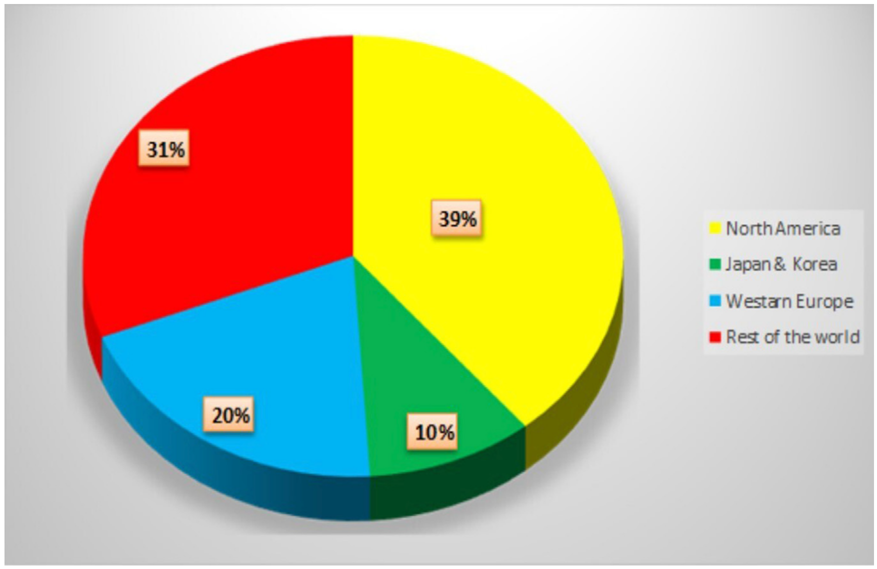

Figure 1. World-wide market of jeans.

Table 1. Number of denim factories in world region.

Sl. no.	Region	No. of denim factories
1.	China	297
2.	Bangladesh	44
3.	Asia (other countries)	104
4.	North America	9
5.	Latin America	46
6.	Europe	41
7.	Africa	15
8.	Australia	1
Total denim factories (world-wide)		557

2. Materials and methods

2.1. Materials

100% ring-spun carded cotton yarn of 42 tex (14^s/1 Ne) and four types of cotton-polyester blended yarns of 30 tex (20^s/1 Ne) were collected from Square Yarns Limited, Kashimpur, Gazipur, Bangladesh. In this study, the ring spnning frame was equipped with attachment for production of core spun yarn. To produce core spun yarn, cotton and polyester blends were used as sheath fibre for covering the core filament (spandex). The parameters of cotton and polyester are given in Table 2 and Table 3. Spandex yarn (filament) of 70 D was imported from Texhong Textile Group Limited, Xuzhou, Jiangsu, China. The spandex draft was 3.8. The production parameters of four samples were same. The spandex was fed in the centre.

Table 2. Uster HVI1000 test report of cotton fibre properties.

Fibre properties	Mean value
Spinning Consistency Index (SCI)	145
Staple length	29.85 mm
Uniformity index (UI)	83.6%
Fibre strength	32.7 g/tex
Elongation	5.50%
Micronaire value	4.5 μg/inch
Fineness	0.177 tex
Short Fibre Index (SFI)	8.5
Color Grade (CG)	Middling
Moisture %	7.3%
Reflectance %	75.3%
Yellowness (degree)	9.4

2.2. Methods

2.2.1. Determination of yarn quality

Samples were taken after one shift of production for quality tests of CVm%, Um%, hairiness, thick and thin places, neps and tenacity, etc. Uster Tester UT3 was used for the study of CVm%, Um%, hairiness, thick and thin places, and neps. For the measurement of resistance per kilometer (RKM) and elongation, Uster Tensojet was used, and ASTM D1907 standard test method was followed for the measurement of yarn count (fineness). In addition, a mechanical Shirley Twist Tester was used for measuring the inserted twist in the yarn. Different quality parameters of the yarn were furnished in Table 4 and Table 5. Figure 2 indicates the typical core-spun yarn.

2.2.2. Denim fabric preparation

Four categories of twill structure denim fabrics were fabricated using the air-jet weaving machine (Piconol, Omni Plus Summum, Belgium). Different loom parameters such as cam shedding, cam beat-up, positive let-off, and positive take-up mechanisms were fixed for the manufacturing of all samples. The design for the experiment and the loom status for the preparation of the samples are illustrated in Table 6. For making samples, the fabrics were woven with sizing using 100% cotton ring-spun yarn as warp and cotton blended polyester-spandex core-spun yarn as weft. The warp yarn was dyed with indigo dye to the blue shade while the weft yarn was remaining undyed. The fabric design, drafting plan, and lifting plan are shown in Figure 3. In 3/1 right-handed twill, the repeat size is 4. Here, the weft thread goes under three warp threads in a repeat. Right-handed twill means the direction of the twill is from bottom left to top right. It is also known as “Z-twill”.

Table 3. Polyester fibre properties.

Characteristic	Value
Length, mm	38
Linear density, den	1.20
Tenacity, g/den	6.40
Breaking extension, %	22.0

Table 4. Experimental result of Uster Test of warp and weft yarn.

Types of yarn	Yarn count in tex (Ne)	Yarn composition (%)	Quality parameters							
			Um%	CVm%	Thin/1000m (-50%)	Thick/1000m (+50%)	Neps/1000m (+200%)	IPI/1000m	Hairiness	Sh (-)
Warp	42 (14)	100% Cotton	11.68	14.87	5	133	170	308	3.69	0.66
Weft	30 (20)	70% Cotton +30% Polyester 2.0% Spandex	11.60	14.80	4	128	167	299	3.88	0.65
		60% Cotton +40% Polyester 2.5% Spandex	11.67	14.79	5	135	169	309	3.59	0.88
		40% Cotton +60% Polyester 1.9% Spandex	11.58	14.73	6	133	175	314	3.02	0.91
		30% Cotton +70% Polyester 1.8% Spandex	11.65	14.89	7	135	172	314	4.0	0.90

Table 5. Warp and weft yarn twist and strength.

Types of yarn	Yarn count in tex (Ne)	Yarn composition (%)	Twist/meter (TPM)	Yarn breaking strength (lb)	Elongation%	RKm (Resistance/km)
Warp	42 (14)	100% cotton	646	128	4.81	12.46
Weft	30 (20)	70% Cotton +30% Polyester 2.0% Spandex	845	135	5.01	18.75
		60% Cotton +40% Polyester 2.5% Spandex	792	130	4.99	18.07
		40% Cotton +60% Polyester 1.9% Spandex	788	150	5.17	21.79
		30% Cotton +70% Polyester 1.8% Spandex	790	158	5.30	21.88

2.2.3. Pretreatment and finishing process

The sizing process was carried out due to an increase in the strength of the warp yarn. The applied sizing materials (modified starch) chemically bond the fibers with each other and also make a protecting coating that lessens warp yarn abrasion at the time of weaving. It also decreases yarn hairiness preventing them from entangling with one another at the loom. The purpose of singeing was to remove the protruding fibers from the fabric surface, and it was done by using a gas singeing machine (Osthoff-senge, Germany) at two double-jet burners were used on both sides of the fabric in one pass where fabric passing speed and flame intensity were 60 m/min and 18 mbar respectively. For removing the sizing ingredients, the recipe is used in the desizing mentioned in Table 7. The photograph of developed 3/1 right-handed Z-twill denim is shown in Figure 4.

2.3. Characterization

All the specimens were conditioned at the standard atmosphere of 65 ± 5% relative humidity and 20 ± 2 °C temperature for 24 h as per requirements of ISO 139:2005 before performing the test carried out [33,34].

2.3.1. Determination of EPI and PPI

Ends per inch (EPI) and picks per inch (PPI) of the samples were taken as per ASTM D3775 - 17e1 test method using counting glass [35].

2.3.2. Measurement of GSM

The GSM of samples was measured using a GSM cutter (James Heal, England) and electrical weight balance after fabric sample conditioning [36].

2.3.3. Tensile strength measurement

The CRE mode is the most widely used method. The BS 2576 (strip method) method is used to determine the breaking strength and elongation of the denim fabrics. Both warp and weft five samples are stretched in a parallel to the direction of warp and weft and two samples do not hold the same longitudinal threads [37]. The size and accuracy of the load cell (0.5–25 kN), the distance of cross-head travel (0.1–2 m), and the rate of cross-head travel (0.1–500 mm/min) must be taken into account during the time of the test [38].

2.3.4. Tearing strength measurement

The tearing strength of the fabric samples was measured by the falling-pendulum (Elmendorf-type) apparatus followed by ASTM D1424:09 [39].

2.3.5. Stretch, growth and recovery% measurement

The stretch, growth, and recovery of the samples were measured according to ASTM D3107-07 [40].

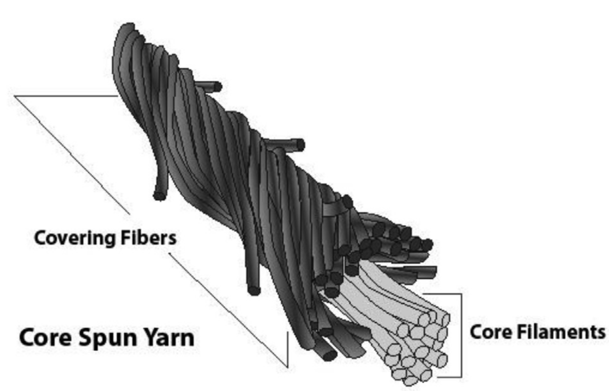

Figure 2. Typical core-spun yarn.

Table 6. Design for the experiment and loom features for preparation denim.

Parameters	Sample code			
	DFT1	DFT2	DFT3	DFT4
Nature of weave	3/1 twill	3/1 twill	3/1 twill	3/1 twill
Warp yarn	100% cotton ring-spun yarn	100% cotton ring-spun yarn	100% cotton ring-spun yarn	100% cotton ring-spun yarn
Weft yarn	(cotton + polyester + spandex) in % Core-spun yarn (sheath: cotton-polyester blended yarn and core: spandex)			
	70 + 30+2.0	60 + 40+2.5	40 + 60+1.9	30 + 70+1.8
Fineness of warp yarn	42 tex (14^s/1 Ne)	42 tex (14^s/1 Ne)	42 tex (14^s/1 Ne)	42 tex (14^s/1 Ne)
Fineness of weft yarn	30 tex (20^s/1 Ne)	30 tex (20^s/1 Ne)	30 tex (20^s/1 Ne)	30 tex (20^s/1 Ne)
Reed density	48	48	48	48
Loom speed	850	850	850	850
(EPI x PPI)	75 × 58	75 × 58	75 × 58	75 × 58
Type of loom	Air-jet	Air-jet	Air-jet	Air-jet

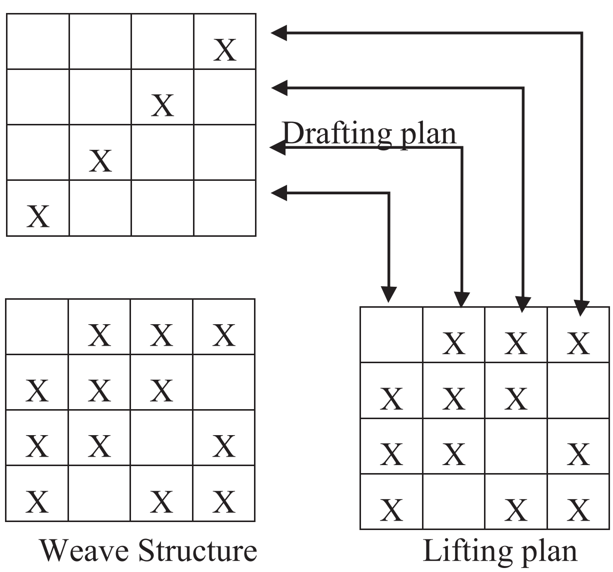

Figure 3. Weave structure, drafting and lifting plan of 3/1 denim fabric.

2.3.6. Bending length, bending modulus and flexural rigidity of fabric

The bending length and flexural rigidity of a fabric were measured by using a stiffness tester at 45° following ASTM D1388-14 [41]. The flexural rigidity can be calculated by using formula 1.

$$G = WC^3 \text{ x } 10^3 \text{ mg/cm} \tag{1}$$

where G is the bending rigidity, W is the fabric weight in g/cm^2, and C is the average bending length of the fabric. Similarly, the bending modulus can be calculated by using formula 2.

$$q = 12 \text{ g x } 10^{-6} /g^3 \tag{2}$$

where q is the bending modulus and g is the fabric thickness in centimeter. The drapability of a fabric with a circular specimen was determined by using a drape metre following the method recommended by Booth [33].

2.3.7. Abrasion resistance of fabric

The abrasion resistance of the denim fabric was examined based on weight loss using a Martindale abrasion tester as recommended in ASTM D 4966-12 [42].

2.3.8. Effect of water on fabric properties

For evaluation of wicking property, a length of the test specimen, preconditioned in 25 ± 2 °C at 65% ± 2% relative humidity, was suspended in warp direction with its lower end immersed in water. The height reached (at a constant time of 2 min) by the water in the fabric

Figure 4. Photograph of developed 3/1 right-handed Z-twill denim.

Table 7. Recipe for desizing.

SL no.	Ingredients	Amount(s) on the weight of material		
1.	Enzyme (Bactosol HP2E, α-amylase)	10 g/L		
2.	Wetting agents	7 g/L		
3.	Fabric passing speed	55 m/min		
4.	Temperature in chemical box	50 °C		
5.	Temperature in different wash boxes	Box 1 & 2	Box 3 & 4	Again box 1 & 2
		75 °C	70 °C	60 °C
6.	Final wash	Normal temperature		

above the water level in the reservoir of water was measured and recorded by using AATCC 198 [43].

2.3.9. Breathability measurement

Breathability e.g., moisture vapor transmission rate (MVTR) is measured over a 24 h period by the rate at which water vapour passes through the fabric. This result is recorded in grams of water vapor per square meter (g/m^2).

3. Results and discussion

3.1. Fabric weight

The weight was measured for all samples to analyze the impact of introducing blended weft yarn in the fabric structure. The results are presented in Figure 5.

The increment of fabric weight shows the following order: DFT2>DFT3>DFT1>DFT4. The increase of polyester and spandex components along with the decrease of cotton in weft yarn has provided heavier fabrics (DFT2 and DFT3). But the result declined when the ratio of cotton components decreased drastically (DFT4). As the density of polyester is lower than cotton, the sample which has a higher amount of polyester has a minimum weight per unit area and vice versa. At the same time, the spandex percentage also influences the weight of the fabrics. DFT2 exhibited the highest weight as it contains the highest amount of spandex (2.5%) in blended weft yarn. So, the reduction of cotton in the weft direction by introducing polyester and spandex should be considered for an optimum level as like the composition of the DFT2 sample.

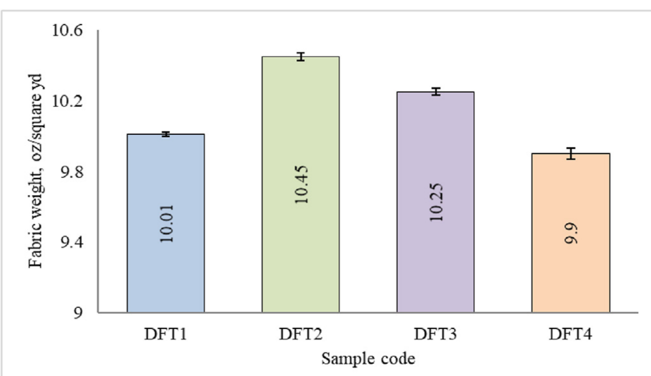

Figure 5. Weight of different denim samples.

3.2. Tensile strength of the fabric

The tensile strength of denim is an important parameter and basically, testing is carried out on warp and weft wise separately. Here, Figure 6 presents the results of tensile strength in the direction of warp and weft for the denim manufactured with blended weft yarn and different % of spandex.

For tensile strength in the direction of warp was observed that the sample DFT4 showed the highest strength, and DFT1 showed the lowest strength (Figure 6). It was found that the tensile strength was 16.52%, 18.23%, and 19.94% higher for DFT2, DFT3, and DFT4 respectively compared to the sample DFT1. Though the warp yarn is fully composed of 100% cotton, the resultant tensile strength of fabric depends not only on the strength of ends but also depends on the strength of the weft. So, here the change in tensile strength for warp direction occurred due to the employment of polyester and spandex components in weft yarn.

For weft direction, the same scenario was observed for tensile strength. The specimen of DFT4 showed the highest tensile strength and DFT1 showed the lowest tensile strength (Figure 6). It was observed that the tensile strength was 10.08%, 33.49%, and 39.54% higher for DFT2, DFT3, and DFT4 respectively compared to the sample DFT1. This happened due to the gradual increment of polyester percentage in weft yarn. It is well known that polyester fibre has higher tenacity than that of cotton fibre and gives more breaking strength (Table 5). Besides, higher cotton components containing samples exhibit lower tensile strength. So, the reduction of cotton by introducing polyester and spandex shows a better result in terms of the tensile strength of the resultant fabric.

3.3. Fabric tearing strength

Figure 7 illustrates the results of tearing strength in the direction of warp and weft for the denim samples.

In the case of tearing strength in the warp direction, it was observed that the change was not very prominent (Figure 7) but it was noticeable in the weft direction. DFT4 showed the highest tearing strength and DFT1 showed the lowest tearing strength in the weft direction. It was observed that the tearing strength was 26.56%, 56.93%, and 66.97% higher for DFT2, DFT3, and DFT4 respectively compared to the sample DFT1. This occurred due to the same reasons for the increase of tensile strength which is stated earlier. However, the sample which consumes lower cotton in weft direction gives better results for tearing strength.

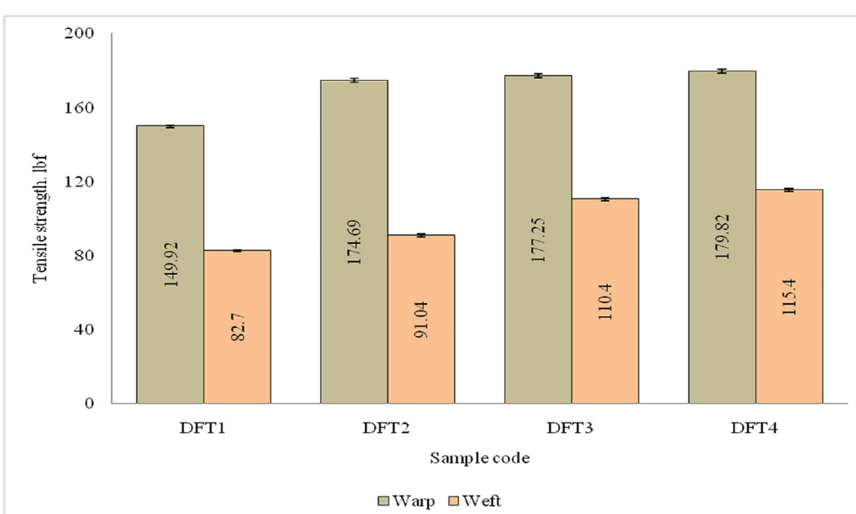

Figure 6. Tensile strength of denim samples in the direction of warp and weft.

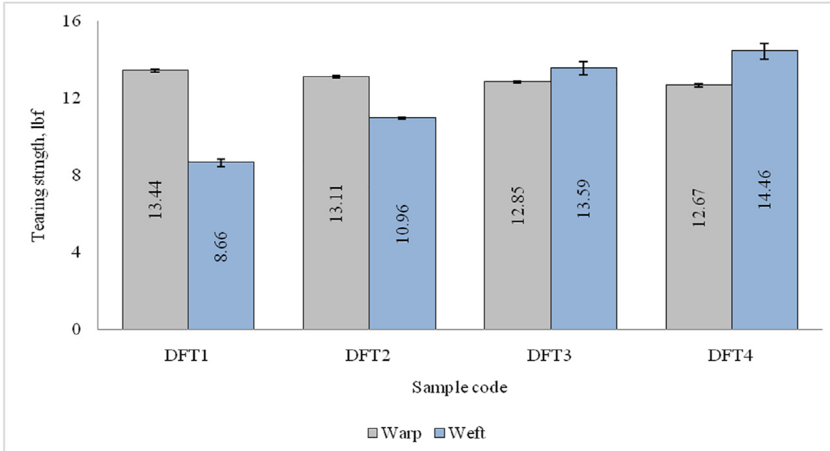

Figure 7. Tearing strength of denim samples in the direction of warp and weft.

3.4. Stretch percentage of denim fabric

The stretch behavior of fabric is one of the most important features of comfort. The stretch behavior is tested in the weft direction. The stretch percentage was investigated for all specimens and results are illustrated in Figure 8.

The stretchability order was found as DFT2>DFT1>DFT3>DFT4. The stretch value of the samples was 8.89%, 11.11%, and 2.67% higher for DFT1, DFT2, and DFT3 respectively compared to DFT4. The stretchability of fabric fully depends on its structures and the composition of yarn. Spandex is the yarn of high extensibility. Here, the presence of spandex into the sample is mainly responsible for stretchability. Hence, DFT4 showed a lower stretching value because of having a lower amount of spandex whereas the rest of the samples had more content of spandex but DFT2 showed higher stretchability with 2.5% spandex in weft yarn. Moreover, DFT2 gives better results in the presence of less cotton components than DFT1.

3.5. Growth percentage of denim fabric

The growth behavior is another expected performance property for denim fabric. The results of the growth percentage for designed samples are presented in Figure 9.

The growth percent order has been found as DFT4>DFT3>DFT1>DFT2. This is the opposite result of stretchability. It was observed that the growth percentage was 8.69%, 26.09%, and 41.30% higher for DFT1, DFT3, and DFT4 respectively compared to DFT2. The highest growth percentage is responsible for the presence of the lower amount of spandex and the lowest growth percentage is due to the presence of the higher amount of spandex. From the properties of spandex, it is known that spandex shows great elastic recovery. That's why the sample which contains a higher spandex percentage shows a lower growth percentage. Here the sample having better results not only contains a higher spandex percentage but also contains lower cotton percentage.

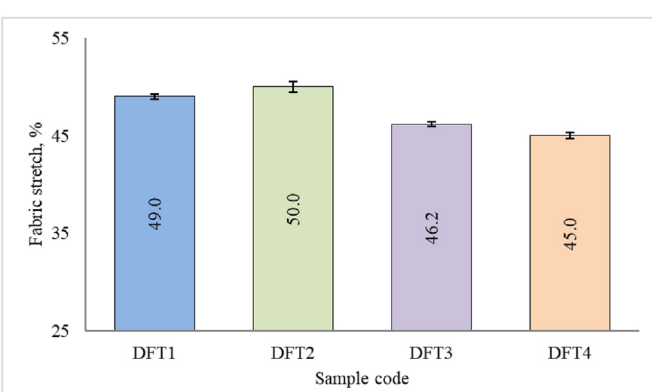

Figure 8. Stretch % of denim samples in the direction of weft.

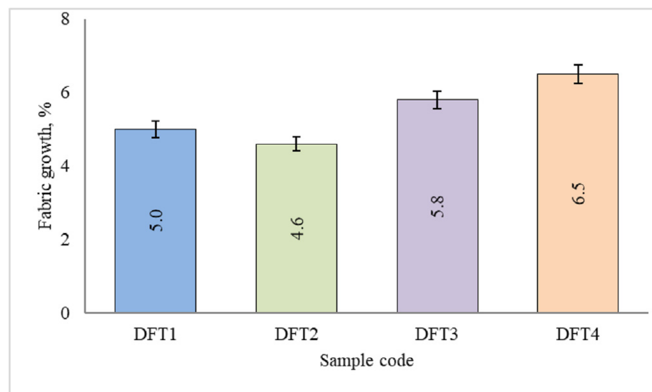

Figure 9. Growth % of denim samples in the direction of weft.

3.6. Recovery percentage of denim fabric

The recovery behavior was investigated for all denim samples. The impact of blended weft yarn and spandex % used in the structure of fabric were analyzed and the results of recovery % are shown in Figure 10.

It was observed that the sample DFT2 showed the highest recovery percentage and sample DFT4 showed the lowest recovery percentage. The presence of spandex in the sample is mainly responsible for the recovery percentage. For a more meaningful explanation, the result of elongation % and resistance/Km for weft yarns may be considered in that case. From Table 5 it is found that the elongation % and resistance/Km of weft yarn for the fabric were in the order of DFT4>DFT3>DFT1>DFT2. So, higher elongation% and resistance properties are responsible for the lower recovery% of resultant denim samples. However, DFT2 shows better results, and it consumes less cotton components than DFT1.

3.7. Aesthetic properties

The aesthetic properties of designed samples are presented in Table 8.

The initial modulus of the fabric in the weft direction was found to be nearly 6 times greater than the warp direction. This is mainly due to much higher modulus of cotton blended polyester-spandex core-spun yarn as compared to cotton. The high modulus of weft, which contains

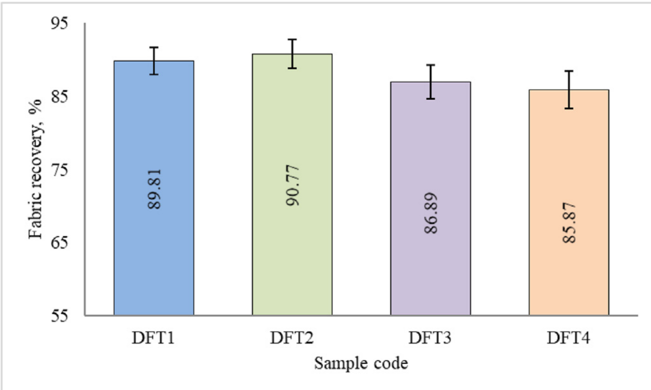

Figure 10. Recovery % of denim samples in the weft direction.

Table 8. Aesthetic properties of developed denim fabrics.

Parameters	Sample code			
	DFT1	DFT2	DFT3	DFT4
Initial modulus, cN/tex (warp)	10.2	12.03	9.4	8.99
Initial modulus, cN/tex (weft)	57.6	60.31	55.2	53.9
Bending length, cm (warp)	3.8	3.7	3.5	3.52
Bending length, cm (weft)	3.4	3.5	2.9	3.0
Drape co-efficiency (%)	47.65	48.20	50.21	51.03
Abrasion resistance, 3800 revs (wt. loss %)	3.30	3.21	3.10	3.11
Flexural rigidity, mg/cm (warp)	640	640	621	540
Flexural rigidity, mg/cm (weft)	4183	4162	4111	4099
Water wicking height, cm (warp)	8.4	8.4	8.4	8.4
Water wicking height, cm (weft)	8.3	8.22	8.1	8.01
Breathability (MVTR), $g/m^2/24$ h	16000	16000	18000	18000

polyester and spandex, indicates the high dimensional stability and shape-retention property of the fabric. The high flexural rigidity of cotton blended polyester-spandex core-spun yarn might have caused bulkier yarn [44]. So, higher flexural rigidity in the weft direction would give better fullness to the denim fabric. The drapability of fabric is a collective effect of several factors such as shear rigidity, flexural rigidity, weight, thickness, and some other insignificant factors. A cotton blended polyester-spandex denim fabric shows balanced drapability as presented in Table 8, which is more desirable for a wearable fabric. Since developed denim fabrics are highly hydrophilic in nature, the wettability of the fabrics was also found to be almost similar in both directions which are apparent from wicking height values as shown in Table 8. The abrasion resistance was found to be notably high even after 3800 cycles as it shows a quite low weight loss (Table 8), indicating its high durability from getting abraded. This may be attributed to the flexibility of movement of yarns with the abrader during the test, due to the loose twill structure of the woven denim. The breathability of a fabric relates to its ability to let sweat in the form of water vapor. The breathability rating of the produced denim fabrics is given away in Table 8 which is extremely good and it is also very important in the context of the aesthetic appeal of the fabric.

4. Conclusion

The performance properties of denim were influenced by the presence of blended weft yarn with various quantities of elastane content included into core yarns where the warp and weft yarn count, fabric ends per inch and picks per inch and finishing process parameters remained the same. The outcomes of the tests explicitly revealed that warp and weft wise tensile strength and weft wise tear strength of the fabric samples were increased along with high polyester content in the blended weft yarn and fabric weight showed the negative trend with the increase of polyester content. In addition, with the spandex percentage in the weft yarn increasing, fabrics were shown a positive trend for stretchability and stretch growth recovery but the fabric growth showed a negative trend. The fabric's initial modulus and flexural rigidity were reported to be greater in the weft direction than in the warp direction. The ideal balance of drapability was discovered. The fabrics' wettability was calculated and the results identical in both directions. Even after 3800 cycles, the abrasion resistance was provided proof that the assessment high, suggesting its high endurance against being abraded. The manufactured denim was reported to have good breathability. In short, the outcomes of this study highlighted the use of different yarns instead of cotton in the weft direction, and also the merits of elastane content fabrics have been focused. Nowadays, customers are displaying a conspicuous and steady trend toward appreciating the comfort properties of the garments. So, fabrics with elastane meet their demand by ensuring these properties.

Declarations

Author contribution statement

Nasrin Akter: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Md. Reazuddin Repon: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Daiva Mikučionienė: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Mohammad Abdul Jalil: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Tarikul Islam, Md. Rezaul Karim: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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