

INVESTIGATE THE FABRIC PERFORMANCE OF TENCEL-COTTON BLENDED DENIM IN TERMS OF THE PERCENTAGE CHANGE OF TENCEL

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Abstract: *In terms of sustainability & wearing comfort, denim manufacturers are entering a new era of product variety. Tencel's regenerative nature and unique mechanical qualities usher in a new era for the denim industry. In this work, denim fabrics were manufactured using Tencel Cotton blended yarn using very fine yarn (20 Tex or 30 Ne), and fabric performance was examined following factors like tensile strength and other relevant metrics. For better evaluation, All the structures were 2/1 RHT (right-hand twill) that contained 115 EPI & 70 PPI and also indigo blue dyed. According to the result of the investigation, 100% Tencel Fabric (both the warp and the weft yarn were 100% Tencel) demonstrated the highest quality of fabric performance in terms of tensile strength, tearing strength, stiffness, air permeability, and water vapor permeability than any other cotton or cotton Tencel blended fabric. However, a downward trend of abrasion resistance was observed in Tencel or cotton Tencel blended fabric concerning the percentage change of Tencel. Additionally, the performance of the fabric was significantly improved by the percentage addition of Tencel fiber in the warp and weft directions. In addition, a denim fabric made entirely of cotton performed the least well when compared to fabrics made entirely of Tencel or a blend of Tencel and cotton.*

Keywords: Tencel, Cotton-Tencel Blended Yarn, Denim Fabric, Fabric Performance.

ISTRAŽIVANJE PERFORMANSI TKANINE TENCEL-PAMUČNOG MEŠOVINOG TEKSASA U POGLEDU PROCENTALNE PROMENE TENCELA

Apstrakt: *U pogledu održivosti i udobnosti nošenja, proizvođači teksasa ulaze u novu eru raznovrsnosti proizvoda. Tencelova regenerativna priroda i jedinstveni mehanički kvaliteti uvode novu eru za industriju teksasa. U ovom radu, teksas tkanine su proizvedene korišćenjem Tencel Cotton mešanog prediva koristeći veoma fino predivo (20 Tek ili 30 Ne), a performanse tkanine su ispitane prateći faktore kao što su zatezna čvrstoća i druge relevantne metrike. Za bolju procenu, sve strukture su bile 2/1 RHT (desni keper) koje su sadržale 115 EPI & 70 PPI i takođe obojene indigo plavom bojom. Prema rezultatu istraživanja, 100% Tencel tkanina (i predivo osnove i potke su 100% Tencel) pokazala je najviši kvalitet performansi tkanine u pogledu zatezne čvrstoće, čvrstoće na kidanje, krutosti, propusnosti vazduha i propustljivosti vodene pare od bilo koje druge pamučne ili pamučne Tencel tkanine. Međutim, pri-*

mećen je opadajući trend otpornosti na habanje kod Tencel ili pamučne Tencel tkanine u vezi sa procentualno promenom Tencel-a. Pored toga, performanse tkanine su značajno poboljšane procentualnim dodavanjem Tencel vlakana u pravcima osnove i potke. Pored toga, teksas tkanina napravljena u potpunosti od pamuka pokazala se najmanje dobro u poređenju sa tkaninama napravljenim u potpunosti od Tencel-a ili mešavine Tencela i pamuka.

Ključne reči: Tencel, pamučno-tencel mešano predivo, teksas tkanina, performanse tkanine.

1. INTRODUCTION

To generate the warp-confronted fabric known as denim, the weft is positioned under two or more warp strings. In contrast to cotton duck, this twill weaving creates corner-to-corner ribbing. Indigo denim, which has a colorful twist thread but a white weft thread, is the most well-known type of denim. The white weft yarns predominate on one side of the cloth while the blue twist strings predominate on the other because of the twist-confronted twill weaving. The indigo coloring technique, in which the center of the twist threads remains white, improves denim's ability to remove stains [1].

Denim has been around for more than 400 years. The traditional cloth known as denim was produced in Europe and is still used and produced today. By studying denim's past, humans can observe how it went from being associated with 194 Denim peasants and the working class to being accepted in all socio-economic classes. The phrases "twill," "innovation," and "rivets" might be used to summarize the development of denim [2].

The primary raw material for denim production is cotton, which has excellent properties and distinctive properties but also creates sustainability concerns. Cotton is the king of textile fibers and one of the most abundant natural fibers, yet its growth involves the application of numerous insecticides, herbicides, and chemicals [3].

Due to ongoing sustainability issues & meet the demand of their valuable customers, Maximum buyers pushed the suppliers to diversify their products with sustainable as well as cost-effective materials [4] less is understood about the implications for suppliers trying to meet sustainable procurement requirements and the organisational challenges of aligning marketing with sustainable supply chain management. An exploratory case study of a UK University catering department has been undertaken, to explore the strategies, processes and relationships associated with synthesising sustainable supply chain and green marketing needs. The empirical findings illustrate the divergence between organisational perspectives on sustainability and procuring sustainable products

with marketing demands. Thus, the findings extend the theoretical discussion on sustainable supply chains by providing empirical data based on real-life implementation and from this an emergent aligned supply chain model is proposed, which confirms two drivers for alignment, 'lean and resource efficient' and 'local and seasonal' - contingent on market demand. The findings emphasise the benefits of a reverse information flow, the importance of intermediaries, and relationships in its fulfilment, while indicating the resurgence of a supply 'push' of sustainable products into core markets. Future research directions are also posited. Nowadays, fabric producers are changing their eye direction of raw materials selection & focus on other materials such as Tencel, hemp, linen & recycled polyester [5].

The class of high comfort fibers includes cellulose fibers. The "TENCEL Fibre Process," a registered trademark of Courtaulds Fibres Ltd. Company that uses N-methyl-morphine-N-oxide (NMMO) to dissolve cellulose, is one of the key advancements in modern regenerated cellulosic fiber technology. Lyocell is the generic name for Tencel [6].

A solvent spinning method is used to create lyocell from wood pulp. Since more than 99% of the solvent is recycled during the process, producing fiber is incredibly eco-friendly. Although a variety of linear densities and staple lengths can be created, the usual fiber produced is 1.4 dtex, 38 mm. The fiber has a circular cross-section and a smooth surface, which gives it a high shine in its unprocessed state [7].

TENCEL® features an extremely smooth surface, a distinct nano-fibril structure, and a very high absorption capacity. As a result, Tencel exhibits all physiological qualities much more strongly than other cellulosic fibers, including high absorbency, warm and dry (as an insulation layer), high heat capacity, cool and dry to the touch, actively reduce temperature, neutral electric properties, and gentleness toward the skin. The amount of water absorbed and how it is distributed within the swollen fiber structure determine the underlying physiological features [8].

Lyocell fibers are notable for having a high degree of strength in both the dry and wet states. Standard Lyocell fibers have a higher breaking strength wet or

dry compared to other cellulose fibers (viscose). Lyocell is the only synthetic cellulosic fiber that is stronger than cotton while wet, retaining 85% of its dry strength. Additionally, Lyocell and cotton differ significantly from one another in terms of vapor permeability and thermal transmission [9].

Lyocell fiber provides superior qualities in comparison to other RCFs. As a result, it is frequently utilized in a variety of industries, including clothes, non-woven, conveyor belts, industrial filter material, and even pharmaceuticals. For textiles, Lyocell fiber can also be mixed with cotton, hemp, silk, synthetic fibers, and viscose fiber [10].

This fiber’s versatility results in exceptional fabrics for women’s lingerie, men’s casual and fitted clothing, and both. Additionally, Lyocell fiber has the benefit of being utilized in a less polluting spinning process than the one for conventional viscose, which is the cause for its current market breakthrough [11]. Tencel® fiber, which is derived from eucalyptus wood, is employed to make fabrics that are bacteriostatic, bacteriostatic, and very hygroscopic [12].

While some excellent studies have been conducted to examine and assess the characteristics of Tencel fiber blended yarns, the majority of attention has been paid to the performance characteristics of knitted fabrics or plain woven & coarser twill fabrics. The objective of this study was to create denim fabric using finer yarn cotton (30 Ne or 20 Tex) blended with Tencel (30 Ne or 20 Tex) and to examine some of the textiles’ mechanical and comfort properties

2. MATERIALS & METHOD

2.1. Material

For this study, five samples of denim fabric were produced where different percentages of Tencel were used in warp & weft for the production of fabric. All Details are given below;

- ✓ 100% cotton (warp) × 100% cotton (weft)
- ✓ 100% Tencel(warp) ×100% Cotton(weft)

- ✓ (65% cotton, 35% Tencel) ×100% Tencel(weft)
- ✓ (65%Tencel,35% Cotton) × 100% Cotton(weft)

Yarn properties that were used in this study were analyzed by Uster Tester 5-S800 and details were given below;

2.2. Methodology

It was a scientific study based on some actual data from an experiment that was analyzed by pertinent theories from a literature review. To conduct this research, a theoretical framework was developed to produce Tencel-cotton blended fabric where different Tencel was employed and determine its effects on Fabric performance in terms of tensile strength, tearing strength, abrasion resistance, air permeability & water vapor permeability. This experiment’s method is described below;

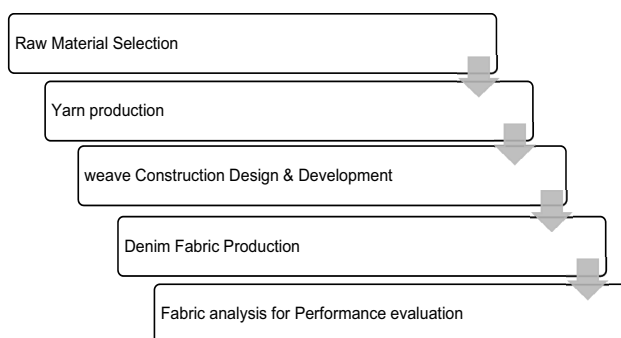


Figure 1. Methodology & Experimental design

Cotton & Tencel fibers were selected for the production of yarn.100% Cotton, 100% Tencel, 65% cotton& 35% Tencel, 65% Tencel & 35% cotton yarns were produced for the production of Denim Fabric. On top that, all yarns were identical in the count which was 30 Ne or 20 Tex. All yarns were blue indigo dyed. To evaluate the performance of Denim Effectively, 2/1 Right-handed twill was selected where All weave structures were the same. Details of Denim samples produced in this study are given below.

Table 1: Yarn characteristics of this experiment

Yarn	percentage of cotton & Tencel	Strength [cN/ Tex]	Elongation [%]	Unevenness [U%]	Hairiness [H]
30 Ne or 20 Tex	100% Cotton	19.50	5.10	8.09	4.16
	100% Tencel	33.47	9.83	8.84	4.38
	65% cotton,35% Tencel)	27.25	8.20	8.37	4.30
	(65% Tencel,35% cotton)	29.97	8.72	8.04	4.38

Table 2: Details of Denim Fabric samples

Sample	warp yarn	weft yarn	Fabric type	weave	Fabric construction (Fineness-Tex, width-M)	Reed width (M)
1	100% Cotton	100% Cotton	Twill	2/1 RHT	$((115*70)/(20*20))*1.42$	1.9
2	100% Tencel	100% Tencel	Twill	2/1 RHT	$((115*70)/(20*20))*1.42$	1.9
3	65% cotton, 35% Tencel	100% Tencel	Twill	2/1 RHT	$((115*70)/(20*20))*1.42$	1.9
4	65% Ten, 35% Cotton	100% Cotton	Twill	2/1 RHT	$((115*70)/(20*20))*1.42$	1.9

2.3. Fabric Testing

In this Experiment, Fabric weight, tear strength, tensile strength, and shrinkage were evaluated according to ASTM D3776, ASTM D1424, ASTM D 5034, and BS EN ISO 6330. Yarn Count & Construction (EPI*PPI) were measured according to ASTM D3775. on top of that, Fabric comfort properties such as air permeability and water vapor permeability, Abrasion resistance & stiffness were measured according to T391 EN ISO 9237:1999, ASTM-E 96, ISO 12947-3:1999 & ASTM D1338.

RESULT & DISCUSSION

3.1. Tensile strength

Tensile strength is a measurement of how much force a cloth can withstand, support, and elongate

before breaking. In other words, A fabric’s tensile strength is defined as the maximum load it can withstand under one-axial tensile loading without breaking [13]. Tensile strength was measured according to the standard in this experiment. Figure 2, depicts the tensile strength of four different samples in warp & weft directions. From the Analysis, Denim fabric made from 100% Tencel i.e., warp yarn & weft made from 100% Tencel exhibited the highest amount of tensile strength in both warp & weft directions. However, the Percentage increase of Tencel Fiber in the warp & weft direction showed the tensile strength increment tendency in both warp & weft directions. In Sample four of warp direction where tensile strength was approximately 20% higher than sample three because sample four contained higher percentage of Tencel fiber. On the other hand, in sample three especially in weft direction, tensile strength of sample three was

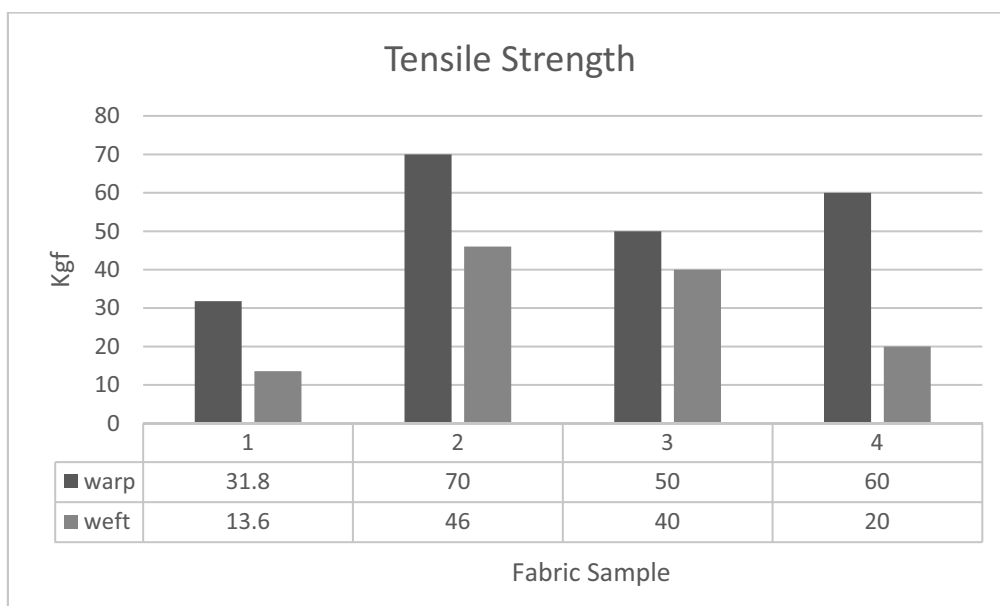


Figure 2: Tensile Strength of Denim sample fabrics

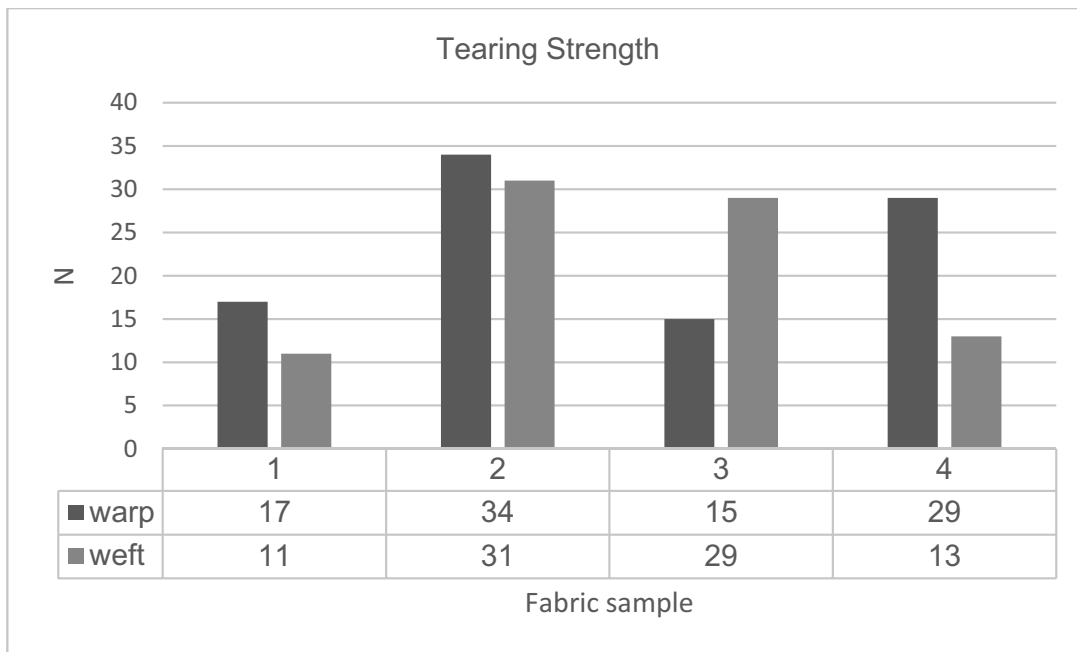


Figure 3: Tearing strength of Fabrics in terms of different Tencel percentages

approximately 100% higher than sample four in weft direction because sample three in weft direction contained a considerable amount of Tencel fiber.

3.2. Tearing Strength

According to ASTM D1682, the force needed to begin or continue tearing cloth in either the weft or warp direction under given circumstances is known as the “tearing strength.” In general, a tear in a fabric or garment develops gradually along a line and can be caused by a moving cloth catching on a sharp object [14]. In other words, the periodic breaking of yarn groups along the fabric is referred to as tearing. One of the crucial mechanical factors that affects the usability of fabrics is tear strength, which can be defined as a mechanical characteristic. Numerous elements, including yarn, fabric structure, fabric treatment type, environmental circumstances, etc., may have an impact on this attribute [15] Tearing strength was measured according to the standard in this experiment. Figure 3, depicts the tearing strength of four different samples in warp & weft directions. From the Analysis, Denim fabric made from 100% Tencel i.e., warp yarn & weft made from 100% Tencel showed the highest amount of tearing strength in both warp & weft directions. However, the Percentage increase of Tencel Fiber in the warp & weft direction showed the tearing strength improvement tendency in both warp & weft directions. In Sample four of warp direction where tearing strength was approximately 94% higher than sample three because sample four contained higher

percentage of Tencel fiber. On the other hand, in sample three especially in weft direction, tensile strength of sample three was approximately 123% higher than sample four in weft direction because sample three in weft direction contained a considerable amount of Tencel fiber.

3.3. Stiffness

One of the most popular metrics for evaluating the handling and bending rigidity of fabrics is stiffness. For the end consumers, fabric stiffness and handling are crucial deciding factors. The qualities of a fabric, such as the fiber type, yarn content, and fabric structure, influence how stiff a fabric is [16]. Stiffness was measured according to the standard in this experiment. Figure 4, depicts the stiffness of four different samples in warp & weft directions. From the Analysis, Denim fabric made from 100% Tencel i.e., warp yarn & weft made from 100% Tencel showed the lowest stiffness in both warp & weft directions. Moreover, the Percentage decrease of Tencel Fiber in warp & weft directions showed the stiffness increment tendency in both warp & weft directions. On other hand, the percentage of cotton fiber increment in warp & weft directions showed the rising stiffness of fabric in both warp & weft directions. It would be concluded that Tencel or cotton blended fabric contains good drapability & flexibility rather than solely cotton-based denim products. Tencel percentage increment in any cotton-based denim will increase the fabric drapability & flexibility.

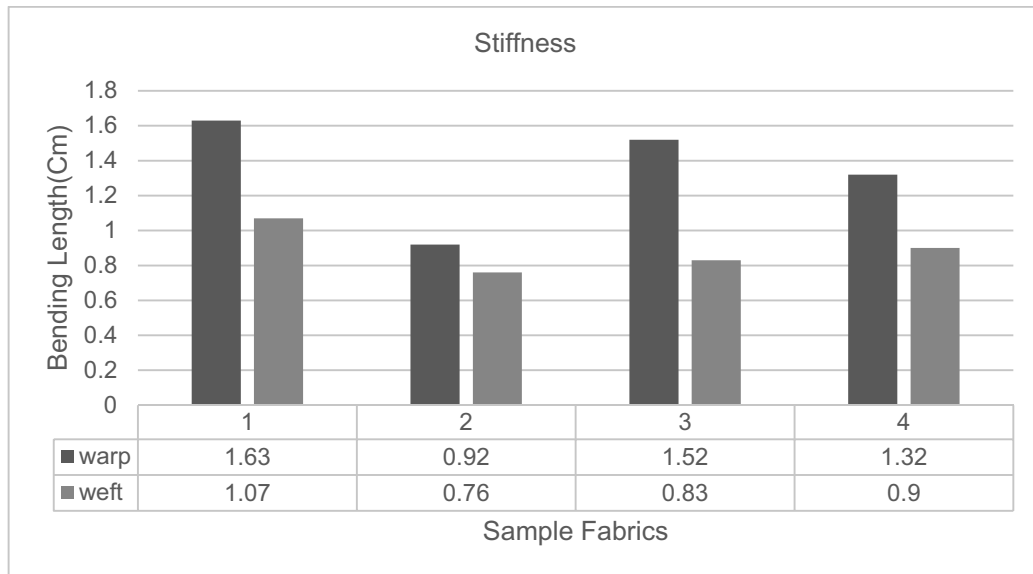


Figure 4: Stiffness of Fabrics in terms of different Tencel percentage

3.4. Abrasion Resistance

Abrasion occurs when a textile fabric surface rubs against another surface, physically destroying the fibers, yarns, and fabrics. When textiles rub against one another while being worn, cleaned, or washed, the fabric may get distorted, yarns or fibers may be ripped out, or the surface may lose the fiber end. The durability of a garment or fabric is significantly influenced by its abrasion resistance qualities, which are the capacity of a textile material to survive surface wear due to flat rubbing contact with another material [17]. Abrasion resistance was measured according to the standard where mass loss% percentage was calculated between 500 cycles & 1000 cycles. Table 3, depicts the abrasion resistance of four different samples in warp & weft directions. From the Analysis, Denim fabric made from 100% Tencel i.e., warp yarn & weft made from 100% Tencel showed the lowest

abrasion resistance owing to the highest percentage of mass loss. Moreover, the Percentage decrease of Tencel Fiber in warp & weft directions showed the abrasion resistance increment tendency in both warp & weft directions. On other hand, the percentage of cotton fiber increment in warp & weft directions showed the rising abrasion resistance of fabric in both warp & weft directions. In words, solely Tencel or Tencel-cotton blended denim was not durable as any other cotton-based denim product. In terms of durability, Tencel increment in warp & weft direction of denim exhibited weaker performance than cotton-based denim products.

3.5. Air Permeability

How well a cloth enables air to move through it is determined by its air permeability. For a variety of fabric applications, including industrial filters, tents,

Table 3: Abrasion Resistance of Fabrics in terms of different Tencel percentage

Sample	Warp	weft	Weight (before) gm	Weight (gm) after 500 cycles	Weight (gm) after 1000 cycles	Mass loss (%)
1	100% Cotton	100% Cotton	3.01	2.99	2.96	1.66
2	100% Tencel	100% Tencel	3.06	3.00	2.84	7.19
3	65% cotton, 35% Tencel	100% Tencel	3.10	3.06	3.02	2.58
4	65%,35% TC	100% Cotton	3.02	3.98	2.89	4.30

sailcloths, parachutes, raincoat materials, shirting, down-proof textiles, and airbags, the ease or difficulty of airflow is crucial [18]. The intra-yarn gaps are affected by fiber cross-section, which also has an impact on the porosity of the fabric. Tencel fiber has a fiber structure with channels that raises the fabric's porosity. Less intra-yarn gaps are present in other cotton fabrics. Tencel fiber has a higher air permeability than cotton fiber as a result [because they have high total surface. Vertically lapped nonwoven technology consists of carding, perpendicular layering of the carded webs, and through-air bonding using synthetic binder fibers. The surface area of the fabric is directly related to the denier and cross-sectional shape of the fibers in the fabric. Smaller deniers yield more fibers per unit weight of the material, higher total fiber surface area, and greater possibilities for a sound wave to interact with the fibers in the fabric structure. The research in the literature uses two methods for measuring acoustical properties of fabric materials: the impedance tube and reverberation room method. Small test samples are in the impedance tube method and sound absorption coefficient is determined at each frequency. Large reverberation rooms and large test samples are used for the reverberation room method. A direct comparative acoustical properties measurement device that was designed and fabricated at Clemson University School of Materials Science & Engineering was used to measure acoustical insulation in this research. This paper provides a description of the measurement devices and acoustical measurement data for vertically lapped nonwoven fabrics made from three different polyester fiber shape and two denier levels. Figure 5, depicts the air permeability

ty of four different samples. From the Analysis, Denim fabric made from 100% Tencel i.e., warp yarn & weft made from 100% Tencel showed the highest air permeability owing to the highest percentage of porosity within the fabric. Moreover, the Percentage increase of Tencel showed the air permeability increment tendency owing to the porosity enhancement within the fabric. On other hand, the percentage of cotton fiber increment showed the decrement of air permeability of the fabric. It would be concluded that Tencel or Tencel-Cotton blended fabric was more comfortable rather than solely cotton-based denim products. Tencel percentage increment in any cotton-based denim will increase the fabric comfortability.

3.6. Water vapor permeability

The ability of a fabric to transmit water vapor from the skin's surface through the fabric and into the environment outside is known as water vapor permeability [20] Figure 6, depicts the air vapor permeability of four different samples. From the Analysis, Denim fabric made from 100% Tencel i.e., warp yarn & weft were made from 100% Tencel showed the highest water vapor permeability. Moreover, the Percentage increase of Tencel showed the water vapor permeability increment tendency. On other hand, the percentage of cotton fiber increment showed the decrement of water vapor permeability of the fabric. Tencel or cotton blend fabrics, as contrasted to denim made entirely of cotton, would be found to be more comfortable. Any cotton-based denim will become more comfortable with the addition of Tencel in warp & weft direction of denim.

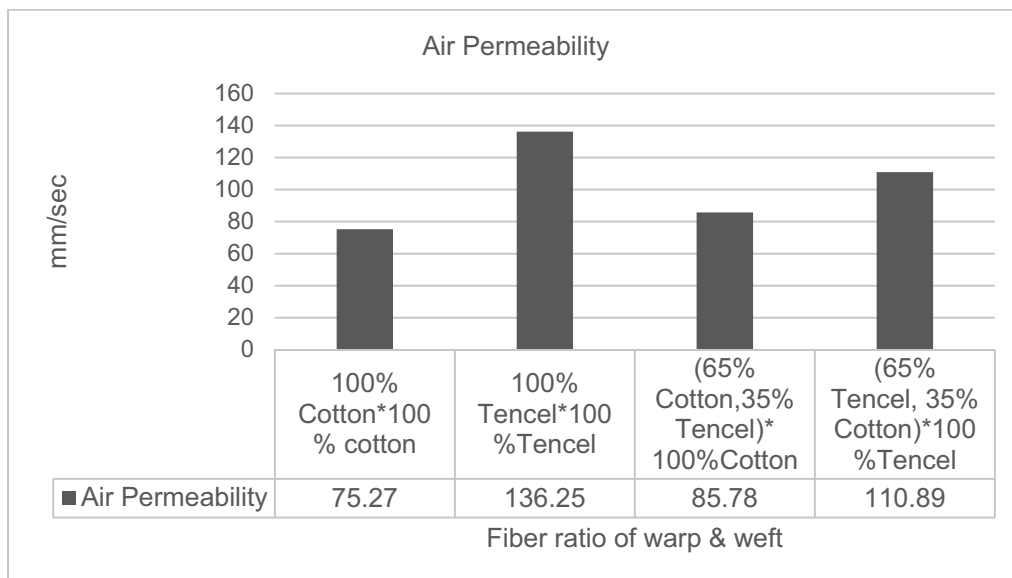


Figure 5: Air permeability of denim fabric samples

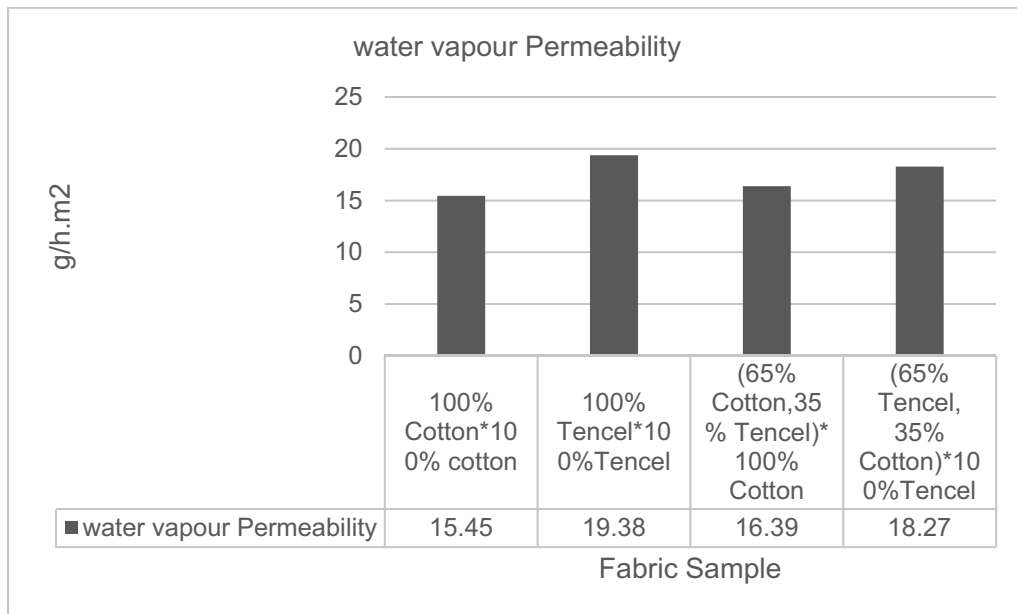


Figure 6: Water vapor permeability of denim fabric sample

4. CONCLUSION

Denim manufacturers should shift their focus away from cotton-based products and toward sustainable & regenerative products that may contain high levels of wearing comfort to meet the demand for diversified products in terms of functional attributes of denim fabric. In this study, the effect of Tencel on the percentage change in denim fabric was highlighted. Analysis revealed that fabrics made of Tencel or yarn made of Tencel and cotton demonstrated high levels of fabric performance. However, the growth of Tencel fiber in warp and weft direct revealed a decline in abrasion resistance. Therefore, the production of denim fabrics will be significantly impacted by fabric produced from cotton and Tencel blends, ensuring the comfort of the fabric. Additionally, this will lessen the reliance on a single source for raw resources like cotton fiber for Denim Business.

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