Indian Journal of Fibre & Textile Research
Vol. 49, March 2024, pp. 91-95
DOI: 10.56042/ijftr.v49i1.9541

Short Communications

Thermal comfort properties of silk knitted denim fabrics

T Sathish Kumar[1], M Ramesh Kumar[2,a], D Raja[2], C Prakash[3] & V Thirumurugan[4]

[1]Department of Textile Processing, SSM Polytechnic College, Namakkal 638 183, India

[2]Department of Fashion Technology, Sona College of Technology, Salem 636 005, India

[3]Department of Handloom and Textile Technology, Indian Institute of Handloom Technology, Fulia Colony, Nadia 741 402, India

[4]Department of Textile Technology, Bannari Amman Institute of Technology, Sathyamangalam 638 401, India

Received 18 March 2023; revised received and accepted 2 June 2023

This study has been aimed to develop three different knitted denim fabrics (3/1 twill) using cotton (30s) and eri silk (2/80 Nm) yarns in different proportions (100% cotton, 50/50 cotton/eri silk, 100% eri silk). Dimensional, physical and thermal comfort properties have been analysed for the developed samples. Thermal properties of the fabric are analysed using a flat plate thermal conductivity tester, and the wicking ability is measured with a vertical wicking tester. Eri silk knitted denim fabric is found with the excellent dimensional, physical and thermal comfort properties better than that of cotton and 50/50 cotton/eri silk blended knitted denim fabrics. The results indicate that the eri silk knitted denim fabric is more suitable for functional wear applications.

Keywords: Cotton, Fabric comfort, Eri silk, Knitted denim, Thermal property, Twill weave

Knitted denim fabric changed the fashion trends of people, as these are smooth, more extension and suitable for fashion market. Single jersey knitting machine is used to create the denim effect of the knit fabrics[1]. Knitted denim fabrics offer additional properties, like woven denim fabrics. The twill effect has been developed by circular knitting machine and then compared with the woven and knitted denim fabric comfort properties. Better results were observed in knitted denim fabrics[2]. Knitted denim fabrics have similar appearance to woven denim fabrics. This kinds of knitted denim fabrics are competitive to woven denim garments, as these are softer, cheaper and more elastic than woven denim fabric. The dimensional stability and the strength of the knitted denim fabric are lesser, as compared to woven denim fabrics[3]. Twill design produced hard and cheap denim fabrics. Denim structure improved comfort and aesthetics properties[4]. When comparing the external characteristics of denim fabrics before and after washing and finishing, denim treated with bio washing was more pliable than non-treated fabric. However, the pliability of the denim did not increase with washing intensity or frequency. The knitted denim fabric appearance was found improved and the fabric quality was excellent[5]**.**

The human body regulates and strives to maintain a temperature of 37 ºC in all varied situations. During heavy activities the body produces lots of heat energy and hence the body temperature increases. Thus, it is necessary to transport heat from the body to the environment so as to maintain the body temperature at 37 ºC. Also, to reduce the very high temperature, sweating starts in the human body. Due to this sweating process, the human body experiences a reduced body temperature, thus leaving the body cool. In this accord, garments are to be designed to enable the human body to adapt itself to the varying climatic conditions[6]. Knitted fabrics were made with polyester micro denier and regular denier yarns and fibres. Microfibre textiles demonstrated outstanding drapeability. It was discovered that the microfibre fabrics have superior wicking properties than the typical denier cloth. Also, the microfibre textiles' water drop absorbency, drying rate, and overall absorbency were superior to those of the regular denier materials.[7]. Cotton or viscose plays a pivotal role in influencing mechanical properties like bursting strength or pilling properties. Polyester yarns exhibit superior mechanical properties as compared to cotton or viscose[8]. The dimensional stability of knitted structures differs from conventional yarns. In general, for both the grey and dyed knitted fabrics, the stitch density decreased and the weight increased as the stitch length is increased. Moreover, for greige and dyed dry-relaxed fabrics from siro yarn, the twist had an influence on fabric properties; the effect being relatively more prominent for slack samples[9]. The air movement in the knitted fabric is directly influenced

[a] Corresponding author.
E-mail: ramesh@sonatech.ac.in

by yarn, fabric structure, yarn loop length and tightness factor of knitted fabric[10]. There is a decrease in the density of the plated interlock when three knit yarns are utilized. A decrease in porosity and the length of loop is found when there is an increase in the thickness of the knitted fabrics[11]. The nature of knitted loop totally depends on the yarn's physical aspects and mechanical procedures[12]. The yarn linear density, stitch length and fabric length were highly responsible for the fabric areal density[13]. The thickness was higher in the honeycomb than in single pique structure[14]. The fabric mass per square meter increases by increasing machine gauge and decreasing stitch length, but there is an increase in thickness and porosity[15].

Heat and vapour transport, sweat absorption and drying ability are the major properties, on which the thermal comfort of clothing depends[16]. The main purpose of clothing is to maintain normal body temperature and to protect the body from varying external conditions. Thermal insulation is defined as the effectiveness of a fabric in maintaining the normal temperature of a human body under equilibrium conditions. Thermal insulation of fabrics depends largely on the thickness of the fabric and it is independent of the fibre material[17]. The proper yarn linear density selection is crucial for double-layered fabrics. Because of this, there is more moisture dispersed in the inner layer than the outer layer due to inner diffusion[18]. Active sportswear with one tuck point and an outer microfibre polyester bi-layer knitted fabric with good air permeability, low thermal resistance, good water vapour permeability, wicking ability, and drying rate is preferable. This fabric keeps the wearer dry while allowing for extra heat during vigorous exercise. These characteristics contribute to the comfort of this bi-layer fabric[19]. Raw materials, structural parameters and knitting pattern of the fabric are the factors on which thermal conductivity and thermal resistance depend. The fabrics made of yarns from cotton, polyester and viscose are highly suitable for sportswear[20]. These materials also exhibit high comfort[21]. The wicking characteristics of bi-layer fabric with one tuck point improvise the trend when there is a decrease in stitch density and thickness. It was also observed that the moisture absorbency of the bi-layer knitted structure increases with an increase in stitch density and tightness fabric[22]. Water vapour permeability, and air permeability depend on the knitted materials' thickness and surface porosity[23]. The experimental design took into account the fibre type, machine gauge, number of yarn feeds, and presence of elastomeric yarn. It has been discovered that these elements have a major impact on fabric wicking[24]. Wetting and wicking behavior affect the moisture and thermal comfort of clothing systems. The capillary pore distribution and bath ways as well as surface tension are utilized in identifying the wicking behaviour[25]. The water vapor permeability, air permeability, thermal conductivity and thermal resistance of micro denier polyester inner and outer bi-layer knitted fabrics are higher as compared to cotton/cotton, cotton/polyester, and cotton/ polypropylene combinations fabrics. Micro denier polyester possesses excellent thermal properties[26]. Yarn count, fabric density, and knit construction have a significant impact on wicking and moisture management properties[27]. Knitwear made with eri silk is currently fashionable due to its superior softness and comfort when compared to other materials. Various researches illustrate how comfortable knit textiles are. Thus, the goal of this study is to determine the dimensional, physical, wicking, and thermal qualities of knit denim fabrics made of cotton, cotton/eri silk, and eri silk.

Experimental

The knitted denim fabrics were prepared using 25.0 tex (2/80s Nm) spun eri silk yarn, and 19.7 tex (30s) cotton yarn. All fabrics were produced in four track knitting pailung knitting machine. The machine specifications are: denim knit- pailung Taiwan machine, machine diameter 26 inch, machine gauge 22, number of feeders 60, total number of needles 1776, machine model KSFP, needle and cam arrangement 4 track needle and cam arrangement, fabric type 3/1 twill knitted denim (Fig. 1). Fabric type, fabric structure, fabric wales/inch, courses/inch, loop length and fabric areal densities are presented in Table 1.

Fabric physical properties, such as fabric weight per unit area (GSM) and thickness, were measured according to the ASTM D3776 and ASTM D1777-96 standards respectively. The fabric bursting strength of the samples was measured according to the ASTM D 3786. The fabric pilling of the samples was measured according to the ISO 12945-1. The fabric elongation length and width growth % of the samples were measured according to the ASTM D 2594 standard. All sample tests were performed under the standard

1	2	3	4	5	6	7	8	9	10	11	12
-	^	^	^	^	-	^	-	^	^	^	-
^	^	-	-	^	^	^	^	-	^	-	^
^	-	^	^	^	-	-	^	^	^	^	-
^	^	-	^	-	^	^	^	-	-	^	^
A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**

(^)-Knit, (-) Miss, and ABC- Needle order

Fig. 1 — Knitted denim fabric cam order

Table 1 — Fabric constructional details

[Fabric structure 3/1 twill, wales/inch 28, course/inch 32, loop length 2.9mm (face side) and 3.2mm (back side-float)]

Fabric	Knitting feeders	Knitted denim fabric	Fabric areal density g/m^2
Type 1	60	100% Cotton	236
Type 2	30	50/50Cotton/eri	285
Type 3	60	100% Eri	312

Table 2 — Dimensional stability test results

Fabric	Dimensional stability, %	
	Length	Width
100% Cotton	-5.8	-7.7
50/50 Cotton/eri silk	-7.8	-8.6
100% Eri silk	-8.3	-9.5

atmospheric conditions of 65% RH and 27 ± 2 °C. Five readings were taken for each of the samples and average was calculated. The vertical wicking capabilities of the samples were determined by following the DIN 53924 standard in both the course and wale directions. The dimensions of the fabric specimen were 200 mm × 25 mm. The test was conducted in both the wale- wise and course-wise directions. The specimen was suspended vertically, with its bottom end dipped in a reservoir of distilled water at a depth of 30 mm. The wicking height was measured after 1, 3, 5 and 10 min for direct evaluation of the fabric's wicking ability.

Results and Discussion

Dimensional Stability Properties

The fabric dimensional stability was measured according to the ISO 6330 method. The fabric sample of size 50cm × 50cm (marking gauge 35cm × 35cm) was taken parallel to the width of the fabric. The samples were washed in normal water at 30°C for 30 min, and subjected to hydro-extraction for 3 min. Finally, fabrics were dried in a flat surface until completely dry. The dried specimens were measured in both length and width directions. The change in length/width dimensions from the original state is expressed as a percentage of the dimensional stability of fabrics in length/width wise directions.

The dimensional stability (length-wise) results of 100% cotton, 50/50 cotton/eri silk and 100% eri silk knitted denim fabrics is given in Table 2. The results clearly show that the eri silk knitted denim fabric has higher length-wise shrinkage %. This may be due to effect of yarn linear density, loop length, fabric structure and fabric areal density.

The dimensional stability (width-wise) results of 100% cotton, 50/50 cotton/eri silk and 100% eri silk knitted denim fabrics is given in table 2. The results clearly show that the eri silk knitted denim fabric has higher width-wise shrinkage. This may be due to the effect of yarn linear density, loop length, fabric structure and fabric areal density. Based on the dimensional stability in the knitted denim fabric in length-wise and width-wise directions, eri silk knitted denim fabric structure can be classified as poor dimensional stable fabric.

The fabric areal density results of 100% cotton, 50/50 cotton/eri silk and 100% eri silk knitted denim fabrics are given in Table 3. The results clearly show that the eri silk knitted denim fabric has higher fabric areal density. This may be due to the effect of yarn linear density and fabric thickness.

Physical Properties

The fabric thickness, bursting strength, pilling and elongation results of 100% cotton, 50/50 cotton/eri silk and 100% eri silk knitted denim fabrics are given

Table 3 — Physical properties test results

Fabric	Areal density GSM	Thickness mm	Bursting strength, kg	Pilling grade	Length-wise growth after 60 s, %	Length- wise growth after 1 h, %	Width- wise growth after 60 s, %	Width- wise growth after 1 h, %
100% Cotton	236	0.78	5.22	4.5	6.4	4.8	13.6	10.4
50/50 Cotton/eri silk	285	0.84	6.76	4.5	4.8	4	12	9.6
100% Eri silk	312	0.95	8.1	4.5	4.5	4	11.7	9.3

Table 4 — Vertical wicking properties test results

Fabric	Wicking length- wise after 1 min cm	Wicking length- wise after 3 min cm	Wicking length- wise after 5 min cm	Wicking length -wise after 10 min cm	Wicking width-wise after 1 min cm	Wicking width- wise after 3 min cm	Wicking width- wise after 5 min cm	Wicking width- wise after 10 min cm
100% Cotton	2	3.6	5	7.8	2.2	4.1	5.6	7.9
50/50 Cotton/eri silk	1.5	2.8	3.6	6	1.7	2.5	3.9	5.6
100% Eri silk	1.3	2.4	2.9	5.5	1.4	2.1	3.2	4.8

Table 5 — Thermal properties results

Fabric	Air permeability $cc/s/cm^2$	Warmth retention rate, %	Thermal transmittance $\times 10^{-3}$ $W/(m^2.K)$	Thermal resistance $\times 10^{-3}$ $m^2.K/W$
100% Cotton	17.36	30.3804	23.789	0.0379
50/50 Cotton/eri silk	15.97	31.9794	25.042	0.0399
100% Eri silk	13.88	35.1773	27.546	0.04389

in Table 3. The results clearly show that the eri silk knitted denim fabric has higher thickness due to the yarn linear density.

Eri silk knitted denim fabric also shows higher bursting strength due to yarn count strength product and yarn twist/inch. However, there is no changes in pilling for all samples; but slight surface fuzzing is observed.

The results also show that the cotton knitted denim fabric has higher length-wise and width-wise growth %, for both after 60 s and 1 h. This may be due to the cotton yarn elongation properties, cotton knitted denim fabric thickness and fabric areal density.

Vertical Wicking Properties

Table 4 shows the vertical wicking length-wise and width-wise results of 100% cotton, 50/50 cotton/eri silk and 100% eri silk knitted denim fabrics. The results clearly show that the cotton knitted denim fabric has higher wicking both length-wise and width-wise after 1, 3, 5 and 10 min. This may be due to yarn linear density and knit structure type. Eri silk knitted denim fabric structure shows better wicking property than cotton knitted denim fabric.

Thermal Properties

The air permeability and thermal properties results of 100% cotton, 50/50 cotton/eri silk and 100% eri silk knitted denim fabrics are given in Table 5. The results clearly show that the cotton knitted denim fabric has higher air permeability due to the coarser yarn as compared to cotton yarn linear density**.**

The eri silk knitted denim fabric also has higher warmth retention rate %, thermal transmittance and thermal resistance. The findings are based on the thermal comfort properties of eri silk knitted denim fabrics with coarser yarn and tight structure. Eri silk coarser yarn increases the fabric thickness and areal density.

Eri silk knitted denim fabrics have better physical, thermal comfort properties and vertical wicking characteristics when compared with cotton knitted denim fabrics. Raw material and yarn count have a significant influence on the dimensional properties of eri silk knitted denim fabrics. Eri silk yarn influences the strength, as well as thermal resistance properties. The eri silk knitted denim provides high fashion products with higher potential growth for the industry. The study also revealed that eri silk knitted denim fabric has good comfort properties, which confirms its suitability for light winter active applications. It is expected that knitted denim fabric produced from these eri silk yarns has good demand in the international market because eri silk fabric is produced using non-violent methods (without killing silk worm) and has better dimensional, thermal and wicking properties.

References

1 Didar S A, Patwary S U, Kader S, Akter M M K & Ahmed T, *Res J Eng Sci,* 4 (2015) 9.
2 Jamshaid H, Asfand N, Rajput A W, Basra S A, Zahid B & Ali A, *Ind Textila,* 71 (2020) 3.
3 Değirmenci Z & Çelik N, *Tekst VeKon feksiyon,* 24 (2014) 363.
4 Sheikh S, Hannan M A, Ali A & Rahat A, *DUET J,* 5 (2019) 111.
5 Anita Rachel D & Thirumoorhy M, *EpraInt J Multidiscip Res,* 5 (2019) 6.
6 Oglakcioglu N & Marmarali A, *Fibre Text East Eur,* 64 (2007) 94.
7 Srinivasan J, Ramakrishnan G, Mukhopadhyay S & Manoharan S, *J Text Inst,* 98 (2007) 31.
8 Una lP G & Ureyen M E, *Ind Textila,* 67 (2016) 151-156.
9 Beceren Y, Candan C, Cimilli S & Ulger K, *Fibre Text East Eur,* 18 (2008) 41.
10 Anbumani N, *Indian Text J,* 4 (2008) 17.
11 Wang Q M & Hu H, *J Ind Text,* 37 (2007) 139.
12 Knapton J J F, Ahrens F J, Ingenthton W W & Fong W, *Text Res J,* 38 (1968) 999.
13 Kane C D, Patil U J & Sudhakar P, *Text Res J,* 77 (2007) 572.
14 Uyanik S & Topalbekiroglu M, *J Text Inst,* 108(2017) 1584.
15 Nazir A, Hussain T, Ahmad F & Faheem S, *Autex Res J,* 14 (2014) 39.
16 Haghi A K, *J Therm Anal Calorim,* 76 (2004) 1035.
17 Morris G J, *J Text Inst,* 44 (1953) 449.
18 Babu S B, Senthilkumar P & Senthilkumar M, *Ind Textila,* 66 (2015) 123.
19 Suganthi T & Senthilkumar P, *Indian J Fibre Text Res,* 43(2018)9.
20 Bivainytė A, Mikučionienė D & Kerpauskas P, *Mater Sci,* 18 (2012) 167.
21 Sundaresan S, Sivanganam K J & Selva Kumar A, *Int J Eng Adv Technol,* 8 (2019) 712.
22 Suganthi T, Senthilkumar P & Dipika V, *Fibre Text East Eur,* 25 (2017) 75.
23 Wilbik-Halgas B, Danych R, Wiecek B & Kowalski K, *Fibre Text East Eur,* 14(2006)77.
24 Kumar B & Das A, *Fiber Polym,* 15(2014)625.
25 Bagherzadeh R, Gorji M, Latifi M, Payvandy P & Kong L X, *Fiber Polym,* 13 (2012) 529.
26 Udaya Krithika S M, Prakash C, Sampath M B & Senthil Kumar M, *Fibre Text East Eur,* 28 (2020) 50.
27 Senthil Kumar B, Ramesh Kumar M, Parthiban M & Ramachandran T, *J Nat Fiber,* (2019). doi: 10.1080/ 15440478.2018.1558147.