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Evaluation of Moisture Management Properties of Plated Interlock, Mini Flat Back Rib and Flat Back Rib Structures

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Abstract
Moisture management is a very fundamental criterion for any type of fabric. Hence, in this study three different knits viz plated interlock, mini flat back rib and flat back rib fabric structures with 100% eri silk (top), 100% bamboo (bottom) and 100% tencel (bottom) with the combination of two different yarn counts were used. The yield was tested for moisture management properties. It was identified that the bi-layer eri silk (14.3 tex) combined with bamboo (14.8 tex) and tencel (14.8 tex) plated interlock, mini flat back rib and flat back rib knit structure fabrics were excellent. Due to the high level of comfort and breathable nature, eri silk with bamboo and tencel fabrics are recommended for performance based garments.

Key words: *eri silk, flat back rib, moisture management, mini flat back rib, plated interlock.*

Introduction

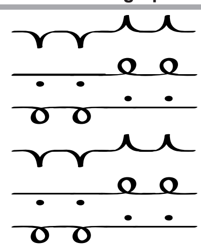
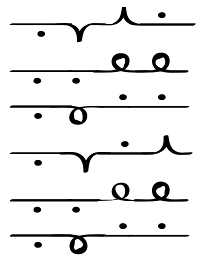
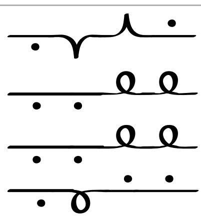
Thermo-physiological comfort determines the breathability and moisture management of fabric, consisting in heat and moisture transport through it. Moisture can be in the form of vapour and liquid. Clothing provides a microclimate between the body and the external environment and acts as a barrier for heat and vapour transfer between the skin and the environment. The moisture management property is a necessary facet of any cloth for attire that deals with vesture comfort. Moisture management is the controlled movement of liquid (perspiration) from the skin surface to the environment through the fabric [1]. The human body perspires in two forms: insensible (in vapour form) and sensible perspiration (in liquid form). To be in a comfortable state, clothing should allow both types of perspiration to transmit from the skin to the outer surface [2]. The air permeability and moisture management properties of commercial single jersey and rib knitted fabrics were studied. The results indicated that commercial knitted fabric's air permeability increased at a rate disproportionate to the mass of fabric. The air permeability of rib fabrics was higher compared to jersey fabrics. Also, when the mass of these fabrics increased, the moisture management properties of 30/1 single jersey and rib fabrics decreased [3]. A study was taken up on the moisture and thermal management properties of woven and knitted tri layer fabrics. It was found that fabrics manufactured from bamboo charcoal/micro polyester/lyocell possessed high air permeability, water vapour permeability, thermal conductivity and wicking tendency, as well as a faster drying rate. Tri layer fabrics made of a bamboo/micro polyester/lyocell combination had high water absorption [4]. In the moisture management characteristics of knitted casein fabrics, the water vapour permeability values were observed to be same in cotton and casein, but based on the maximum wetting radius and one way transport values, cotton fabric was found to be better and more standard than casein fabric [5]. The comfort and moisture management properties of polyester/milkweed blended plated knitted fabrics for active wear applications were analysed. The results showed that plated fabric made from 40% milkweed/polyester is an efficient moisture management fabric when used in both of the ways tested when compared to other fabrics [6]. The moisture management properties of bamboo/viscose/tencel single jersey knitted fabrics were studied. It was found that an increase in the tencel content brought a decrease in the wetting time, absorption rate, spreading speed, and overall moisture management. But is was also found that there was an increase in the maximum wetted radius [7]. The effect of blend proportion on the moisture management characteristics of bamboo/cotton knitted fabrics was taken up for research. The results described that upon an increase in the bamboo content, there was a decrease in the wetting time, wetted radius, spreading speed and OMMC but an increase in the absorption rate [8]. An investigation on the effect of filament fineness on the comfort characteristics of the moisture management of finished polyester knitted fabrics was conducted. The tests indicated that the fabrics containing 108 filaments in yarn gives better wetting, higher wicking and optimum moisture vapour transmission [9].

Any physical activity will produce different levels of the need to release excessive heat and maintain a stable body temperature. Warp knitted raschel material is effective in summer sportswear owing to its good air porosity, low thermal and tide vapour resistance, and smart moisture management properties [10]. Textured polyester yarn knitted materials measure higher air permeability properties than polyester knitted materials of same yarn count and knit structure [11]. The construction, thickness, and material affect heat transfer between the human body and the environment [12]. The thermal comfort property of a clothing system during dynamic conditions should be assessed based on moisture vapour pressure alteration within the clothing, the surface temperature of the clothing, and on the heat loss from the body [13]. The garment should have the ability to release the moisture vapour held in the microclimate to the atmosphere so as to reduce the dampness at the skin [14]. Water vapour permeability plays a very important role when there is only little sweating, or insensible perspiration, or else very little sweating [15]. During heavy activity, when liquid perspiration production becomes high, to feel comfortable the clothing should possess a good liquid transmission property [16]. Wicking is an important property to uphold a feeling of comfort during sweating conditions. It applies the capillary theory to rapidly remove sweat and moisture from the skin's surface, transport it to the fabric surface, and then evaporate it [17]. As regards the moisture management properties of double-face fabrics, it was suggested that polypropylene (back) and cotton (face) fabric had better moisture management properties [18]. The blending of wool fibre with polyester and regenerated bamboo fibre produced fabrics with better moisture management properties than those without blending [19]. The highest overall moisture management capacity values for polyester fabrics were compared to those of cellulose-based fabrics, and it was suggested that cotton fabrics caused wetness to be felt more than for other fabrics [20]. Fabric tightness had different effects on various knitting types in terms of moisture management properties, and the fabrics with a high thickness and mass per unit area were found to be low in moisture management indices [21]. In another study regarding the relationships between cover factors and moisture management properties for bamboo-knitted fabrics, it was noted that the wetting time increased; however, a decrease in the maximum wetted radius, rate of absorption, spreading speed, and overall moisture management capacity was observed as the cover factor of the fabric increased [22].

The geometric properties of bi-layer knitted materials primarily have an effect on their moisture management properties, with fibres having a secondary influence [23]. Double knit structures with completely different inlay tuck points greatly influence the physical, moisture management and thermal transmission properties, as distinct from inlay materials [24]. Tencel is used as an outer layer to make the sportsman or woman feel comfortable through quick evaporation and drying. Under these circumstances, in addition to low thermal resistance and excessive air permeability, fabrics have to provide a better water vapour transfer, wicking ability and rapid drying rate [25]. Since double layer knitted fabrics made of various combinations have an effect on fabric production, hence suitable attention needs to be paid while selecting combinations for functional active and sportswear fabric production [26]. The wicking characteristics of bi-layer cloth with a one tuck purpose shows an associated increasing trend once the sew density and thickness decrease. It was determined that the wet permeability of a bi-layer knitted structure will increase with a rise in the sew density and tightness. The drying ability of bi-layer cloth with a one tuck purpose is primarily influenced by the thickness and weight. It is the power to transfer perspiration from the inner layer of the material to the outer layer, and it simply gets evaporated and dried [27]. The lower thickness and mass per unit are exhibit higher thermophysical properties, air porosity, vapour porosity, wicking, wetness permeability, drying rate and moisture management properties. The lower range of tuck sewing shows higher thermal comfort properties [28]. The moisture management property of materials considerably affected the moisture diffusion and temperature distributions within cold protecting vesture systems, and influenced the thermal and moisture sensations [29]. With the Coolmax fibre, the moisture management properties of spacer materials will be improved, allowing them to be used in snug-fitting shirts worn under protecting vests with improved comfort [30]. Increasing the fabric tightness factor by decreasing the stitch length results in an improvement in fabric moisture management properties [31].

Among the four forms of silk obtainable in India, eri silk, being of discontinuous filaments, possesses some distinctive properties [32]. Increasing awareness concerning eco-friendly property practices and organic textile products affects the choice of fibres. Eri silk is a fibre that is gaining importance and is a favourite of designers and animal activists [33] due to environmental considerations. However, Eri, the main non-mulberry tamed assortment of silk, is not reelable and is utilised for the creation of spun yarn. It is nearly as fine as mulberry silk and considerably milder. It has remarkable warm properties. Moreover, Eri fibre can enhance excellent imported wool to obtain different sorts of woven and knitted items [34]. Viscose rayon × eri silk of 2/40s (VRE1) materials have the highest endurance both in the warp and weft directions. Viscose × eri silk of 2/40s (VRE1) union cloth exhibits the highest resistance to abrasion. Viscose × eri silk of 2/40s (VRE) exhibits the highest worth of the drape coefficient (%). Overall, the performance of viscose × eri silk of 2/40s (VRE1) union cloth gives higher physical results [35]. Eri small stuff material has reasonable physical, structural and luxury properties, confirming the quality of eri silk knit materials for primarily performance- based clothes. Fabrics made from these yarns have a reasonable demand in the international market. As a result of eri spun silk fabric being made by non-violence and being stiffer, it has satisfactory wicking, thermal insulation and heat properties [36]. Eri silk knit has good comfort properties, which confirm its quality for lightweight winter active applications. It's expected that cloth created from these yarns has high demand within the international market as a result of eri silk fabric being created by non-violent ways (without killing the silk worm) as well as having higher dimensional, thermal and wicking properties [37]. Eri/cotton (67:33) blended fabrics show the highest crease recovery. Tussar/cotton, muga/cotton and eri/cotton union fabrics are comparable in physical and comfort properties. Eri silk – cotton union fabrics are produced by an eco-friendly method and are stronger, soft to wear, durable, and good in all seasons. Therefore, eri silk – cotton blended fabrics are as suitable for making apparel products as union fabrics made of conventional silk – cotton [38]. Eri knit

Table 1. Sample codes, fabric structure, cam order, and technical graph.

Sample code	Fabric structure	Cam order and feeder repeat	Technical graph
S1EB, S2ET, S3EB, S4ET, S13EB, S14ET, S15EB, S16ET	Plated interlock (connecting with more tuck points)	(F1 F2 F3 F4 F5 F6..... Repeat) Dial – ⊔∨–⊔∨– ⊔∨–⊔∨– Cylinder – ⊓–∧⊓–∧ ⊓–∧⊓–∧	
S5EB, S6ET, S7EB, S8ET, S14EB, S18ET, S19EB, S20ET	Mini flat back rib (connecting with partial tuck points)	(F1 F2 F3 F4 F5 F6..... Repeat) Dial – –∨–⊔∨– ⊔∨––∨– Cylinder – ⊓–∧⊓–∧ ––––––	
S9EB, S10ET, S11EB, S12ET, S21EB, S22ET, S23EB, S24ET	Flat back rib (no connecting)	(F1 F2 F3 F4..... Repeat) Dial – –∨∨– ⊔∨∨– Cylinder – ⊓––∧ ––––	

Dial: ⊔ – *Dial tuck stitch*
∨ – *Knit stitch*
– – *Dial miss stitch*

Cylinder: ⊓ – *Cylinder tuck stitch*
∧ – *Cylinder knit stitch*
– – *Cylinder miss stitch*

F-Feeder *(F1-Feeder 1, F2- Feeder 2, F3- Feeder 3, F4- Feeder 4, F5- Feeder 5, F6- Feeder 6)*

Table 2*. Sample codes, fabric structure, fibre, yarn linear density, fabric areal density and thickness.* ***Note:*** *In the fabric sample plan, short codes were used to describe the samples: E-100% Eri silk yarn, B-100% Bamboo yarn, T-100% Tencel yarn.*

S. No	Sample code	Fabric structure	Fibre		Yarn linear density, tex		Fabric areal density, G/m^2	Thickness, mm
			Top	Bottom	Top	Bottom		
1	S1EB	Plated interlock	Eri Silk	Bamboo	16.7	19.7	334	1.19
2	S2ET	Plated interlock	Eri Silk	Tencel	16.7	19.7	332	1.26
3	S3EB	Plated interlock	Eri Silk	Bamboo	16.7	19.7	310	1.28
4	S4ET	Plated interlock	Eri Silk	Tencel	16.7	19.7	293	1.22
5	S5EB	Mini flat back rib	Eri Silk	Bamboo	16.7	19.7	231	1.07
6	S6ET	Mini flat back rib	Eri Silk	Tencel	16.7	19.7	228	1.11
7	S7EB	Mini flat back rib	Eri Silk	Bamboo	16.7	19.7	250	1.05
8	S8ET	Mini flat back rib	Eri Silk	Tencel	16.7	19.7	237	1.01
9	S9EB	Flat back rib	Eri Silk	Bamboo	16.7	19.7	239	1.18
10	S10ET	Flat back rib	Eri Silk	Tencel	16.7	19.7	233	1.22
11	S11EB	Flat back rib	Eri Silk	Bamboo	16.7	19.7	245	1.19
12	S12ET	Flat back rib	Eri Silk	Tencel	16.7	19.7	238	1.21
13	S13EB	Plated interlock	Eri Silk	Bamboo	14.3	14.8	254	0.98
14	S14ET	Plated interlock	Eri Silk	Tencel	14.3	14.8	237	1.05
15	S15EB	Plated interlock	Eri Silk	Bamboo	14.3	14.8	215	0.98
16	S16ET	Plated interlock	Eri Silk	Tencel	14.3	14.8	229	1.07
17	S17EB	Mini flat back rib	Eri Silk	Bamboo	14.3	14.8	190	1.08
18	S18ET	Mini flat back rib	Eri Silk	Tencel	14.3	14.8	163	0.98
19	S19EB	Mini flat back rib	Eri Silk	Bamboo	14.3	14.8	179	1.01
20	S20ET	Mini flat back rib	Eri Silk	Tencel	14.3	14.8	205	1.07
21	S21EB	Flat back rib	Eri Silk	Bamboo	14.3	14.8	180	1.04
22	S22ET	Flat back rib	Eri Silk	Tencel	14.3	14.8	158	0.96
23	S23EB	Flat back rib	Eri Silk	Bamboo	14.3	14.8	190	1.05
24	S24ET	Flat back rib	Eri Silk	Tencel	14.3	14.8	162	0.98

normally has smart moisture management properties, ensuring their quality for mostly performance based clothes. It can be discerned that variables like the yarn count, material tightness and knitting structure have a big influence on the wicking and moisture management properties. OMMC indexes of an eri silk knit area unit was found to vary from ‘very good’ to “excellent’, which indicates the quality of eri silk yarn for matching the skin, as well as for active wear applications [39]. Silk is indeed the most ideal fabric to use at home and in the furnishings industry. From ancient to modern times, silk has always been regarded as the most luxurious product, representing the ultimate comfort one can possess in daily life [40]. Eri silk knit wear is the newest trend due to its higher softness and luxury nature compared to other fibres. Various studies depict the moisture management properties of knitted materials. Therefore, this study aimed to seek out the moisture management properties of eri silk with bamboo and eri silk with tencel bi-layer knitted materials.

Materials and fabric development

Twenty four bi-layer fabrics were prepared using 16.7 tex and 14.3 tex 100% eri silk as well as 19.7 tex and 14.8 tex 100% bamboo and tencel. ***Table 1*** shows the sample codes, fabric structure, needle order, cam order, and technical graph of eri silk bi-layer knitted fabrics.

In this experimental work, bi-layer fabrics were developed in which the inner layer (next to the skin) was made of eri silk yarn, while the outer layer was made up of bamboo and tencel yarns. In other words, eri silk fibre on the top, and bamboo and tencel on the bottom. All samples were produced on a circular multi-track weft knitting machine (Keumyong knitting machine) of 34 inch diameter, 82 feeders, 18 gauge and 3840 needles. Plated interlock, mini flat rib and flat back rib knitted fabrics were produced using two different yarn counts and two different loop lengths (0.3 cm and 0.4 cm).

Physical characterisation of test samples

All the samples were tested in American Society for Testing and Materials D1776 standard atmospheric conditions of 21 ± 1°C and 65 ± 2% RH. Five readings were taken for each of the bi-layer fabrics, and then the averages were calculated. The bi-layer knitted fabrics were measured for their loop length, thickness, and areal density. The loop length was derived by unraveling 10 courses, and their total length was measured. The average loop length was determined using the formula: total length × no. of wales/10. The thickness of the fabric was measured on a digital thickness tester. All the fabric samples were wet relaxed prior to testing by washing with detergent at 30 °C, followed by flat drying. ***Table 2***, shows the sample codes, fabric structure, fibre on the top and bottom layers, yarn linear density, loop length, fabric areal density and thickness.

Comfort characteristics

Testing of moisture management properties

According to the American Association of Textile Chemists and Colorists test method 195, the multi-directional moisture transport capabilities of the fabrics were measured using a Moisture Management Test (MMT) device. The fabric specimen is placed between two horizontal electrical sensors, each with concen-

Table 3. *Moisture management results grading of eri silk bi-layer knitted fabrics.* ***Note:*** *In the fabric sample plan, short codes are used to describe the samples: E-100% Eri silk yarn, B-100% Bamboo yarn, T-100% Tencel yarn. Note: WT: wetting time, AR: absorption rate, MWR: maximum wetted radius, SS: spreading speed, AOTI: accumulative one-way transport index, OMMC: overall moisture management capacity.*

S. No	Sample code	WT^b, S		AR, %/S		MWR, mm		SS, mm/s		AOTI, %	OMMC
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom		
1	S1EB	3	2	4	5	1	2	1	1	1	2
2	S2ET	3	2	4	5	1	2	1	2	1	2
3	S3EB	3	2	4	5	2	2	1	1	1	3
4	S4ET	3	2	4	5	2	2	1	2	1	3
5	S5EB	3	2	4	5	1	2	1	3	3	3
6	S6ET	3	2	4	5	1	2	1	2	2	3
7	S7EB	3	2	4	5	1	2	1	3	4	3
8	S8ET	3	2	4	5	1	2	1	3	4	3
9	S9EB	3	4	2	3	1	2	3	4	5	4
10	S10ET	3	4	2	3	1	2	3	4	5	4
11	S11EB	3	5	2	3	1	2	3	4	2	3
12	S12ET	3	4	2	3	1	2	3	3	2	3
13	S13EB	3	3	2	3	2	2	1	4	5	4
14	S14ET	2	4	2	3	1	2	1	5	5	5
15	S15EB	3	3	2	3	2	2	2	4	5	4
16	S16ET	3	4	2	3	2	2	1	5	5	5
17	S17EB	3	5	2	3	2	2	1	4	5	5
18	S18ET	3	5	1	3	2	5	2	5	5	5
19	S19EB	3	5	2	4	2	5	2	5	5	5
20	S20ET	3	5	1	4	2	5	2	5	5	5
21	S21EB	3	5	2	3	3	4	2	5	5	5
22	S22ET	3	4	2	3	3	4	2	4	5	5
23	S23EB	3	5	2	4	3	4	2	5	5	5
24	S24ET	3	5	2	3	4	5	2	5	5	5

Table 4. *ANOVA test.*

S. No.	Variables	Sources of variation	Sum of squares	D.F	Mean score	'F' value	*p* value	Significance
1	Top wetting time	Between groups	2.348	1	2.348	.045	.834	Not Significant
		Within groups	1147.652	22	52.166			
		Total	1150.000	23				
2	Bottom wetting time	Between groups	878.292	3	292.764	21.550	.000	Significant
		Within groups	271.708	20	13.585			
		Total	1150.000	23				
3	Top absorption rate	Between groups	782.286	2	391.143	22.338	.000	Significant
		Within groups	367.714	21	17.510			
		Total	1150.000	23				
4	Bottom absorption rate	Between groups	832.103	2	416.051	27.484	.000	Significant
		Within groups	317.897	21	15.138			
		Total	1150.000	23				
5	Top maximum wetting radius	Between groups	670.929	3	223.643	9.337	.000	Significant
		Within groups	479.071	20	23.954			
		Total	1150.000	23				
6	Bottom maximum wetting radius	Between groups	719.250	2	359.625	17.533	.000	Significant
		Within groups	430.750	21	20.512			
		Total	1150.000	23				
7	Top spreading speed	Between groups	739.500	2	369.750	18.915	.000	Significant
		Within groups	410.500	21	19.548			
		Total	1150.000	23				
8	Bottom spreading speed	Between groups	909.268	4	227.317	17.941	.000	Significant
		Within groups	240.732	19	12.670			
		Total	1150.000	23				
9	Accumulative one way transport capacity index %	Between groups	841.476	4	210.369	12.955	.000	Significant
		Within groups	308.524	19	16.238			
		Total	1150.000	23				
10	Overall moisture management	Between groups	962.350	3	320.783	34.190	.000	Significant
		Within groups	187.650	20	9.382			
		Total	1150.000	23				

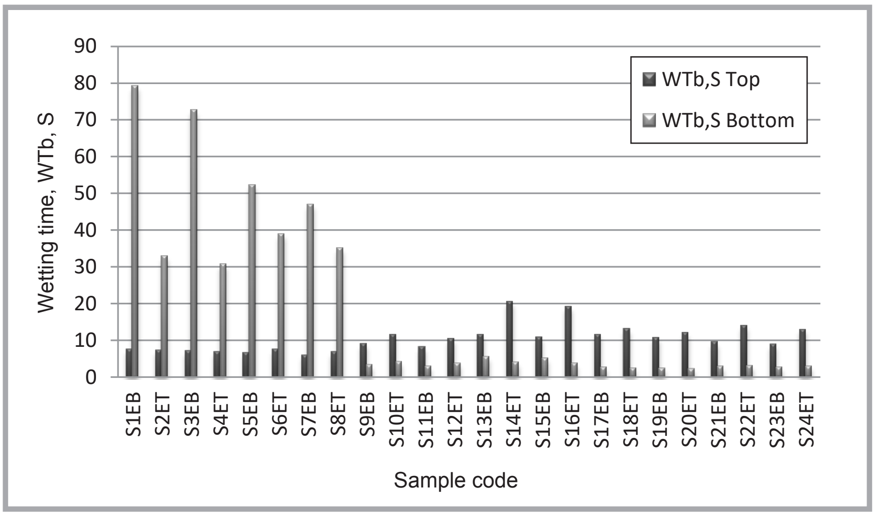


Figure 1. *Wetting time of eri silk bi-layer knitted fabrics (top and bottom).*

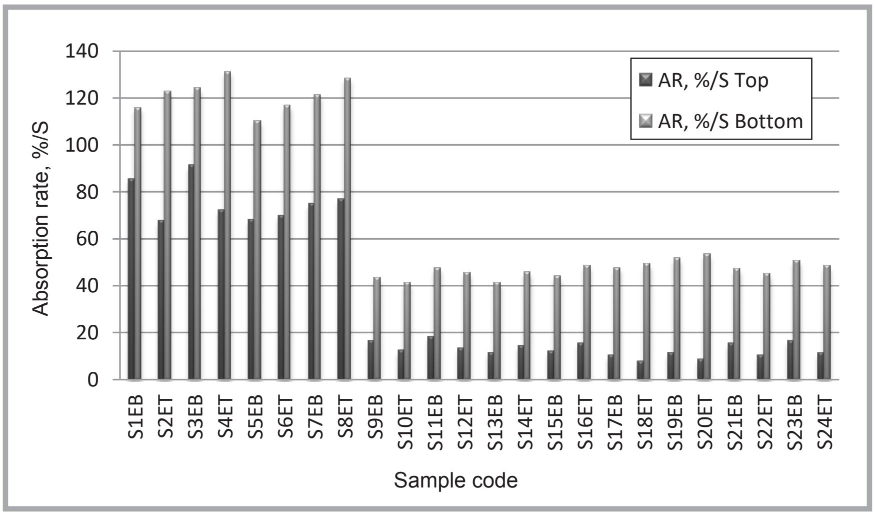


Figure 2. *Absorption rate (%) of eri silk bi-layer knitted fabrics (top and bottom).*

tric pins. A predetermined amount of test solution is dropped onto the top centre of the fabric specimen surface. The test solution freely moves in multi-directions, spreads on the fabric top surface, moves through the specimen from the top to bottom surface, and radially spreads on the bottom surface of the specimen. The electrical resistance values were used to calculate fabric liquid moisture movement, which quantifies the dynamic liquid moisture transport behaviors of the fabric. In this experiment, specimens of 8.0 × 8.0 cm^2 size were washed and conditioned for a day in standard atmospheric conditions before testing. The indices were converted from values to grades based on five grade scale (1-5) according to the American Association of Textile Chemists and Colorists 195 test method. The five grades of the indices represent the following: (1) poor, (2) fair, (3) good, (4) v. good, and (5) excellent. The results of moisture management properties of eri silk bi-layer knitted fabrics are summarised in ***Table 3***.

Statistics

One-way analysis was utilised to check the significant difference between the moisture management properties of eri silk with bamboo and Tencel combinations of raw materials at a 5 percent significance level using SPSS 16.0 version. ***Table 4*** reveals one-way ANOVA test results showing the significant difference between the moisture management properties of eri silk with bamboo and eri silk with tencel combinations of raw materials for two different yarn counts: 30s & 40s, and three different fabric structures: platted interlock, mini flat back rib, and flat back rib, with two different loop lengths of fabrics. *p*-values (sig.) of the above variables are less than 0.05 at a 5% significance level. Thus, there is a significant difference between the moisture management properties, except for the top wetting time, in the study.

Results and discussion

Wetting time

Figure 1 shows the wetting time results of eri silk bi-layer knitted fabrics. The wetting time is the time taken to wet the top and bottom surfaces of the material after the initiation of the test. As the wetting time is one of the utmost parameters of moisture management, ***Table 3*** indicates that the the wetting time of eri silk with bamboo as the top layer – and tencel as the bottom layer is medium and slow, respectively. This holds true for samples S1EB to S9ET. Regarding S9EB and S10ET, the wetting time becomes medium and fast for bamboo as the eri silk top layer tencel as the bottom layer, respectively. When an comparison is made for samples S11EB to S24ET, the wetting time is observed to be medium for all eri silk top layers, whereas it is very fast for flat back rib in the bottom bamboo layer. It is clearly seen that sample S13B possesses a medium wetting rate, while S14ET has a fast one. Very fast wetting rates are also observed for mini flat back rib and flat back rib samples with bottom layers of bamboo and tencel.

Absorption rate

Figure 2, shows the absorption rate results of eri silk bi-layer knitted fabrics. During the initial change in water content during the test, the speed of liquid moisture absorption on both surfaces of the material is termed as the absorption rate. It may be further noted that the absorption rate was fast for eri silk's top surface, and the bottom was very fast for fabric made up of bamboo and tencel. Further investigation showed the absorption rate to be slow for the top made of eri silk and in the medium range for the bottom side manufactured from bamboo and tencel. Sample S18ET indicated a very slow absorption rate on the top and medium rates on the bottom. Samples S19EB and S20ET clearly displayed a very low absorption rate on the top layers and a fast one on the bottom layer. Finally, samples S21EB, S22ET and S24ET clearly showed slow absorption rates on the top side and medium on the bottom, whereas sample S23EB had a slow absorption rate on the top and a fast one on the bottom. It should be noted that all the top layers were eri silk and the bottom was a combination of bamboo and tencel.

Maximum wet radius

Figure 3 shows the maximum wetted radius results of eri silk bi-layer knitted fabrics. The top and bottom surfaces of the material measuring the largest radius is called the maximum wet radius. Being another important aspect of moisture management, the maximum wet radius was recorded. Samples S1EB, S2ET, S5EB, S6ET, S7EB, S8ET, S9EB, S10ET, S11EB, S12ET and S14ET exhibited no wetting on the top layer of the fabric and a small radius on the bottom. The maximum wet radius was small on both the top and bottom layers of S3EB and S4ET. As far as samples S13EB, S15EB, S16ET and S17EB are considered, the top and bottom layers of the fabrics also displayed a small wet radius. The maximum wet radius was observed as medium on the top layer and large on the bottom layers for samples S21EB, S22ET and S23EB, and sample S24ET had a large radius on the top and a very large one on the bottom layer. As already mentioned, all the top sides were manufactured using eri silk and tencel, with bamboo utilised for the bottom.

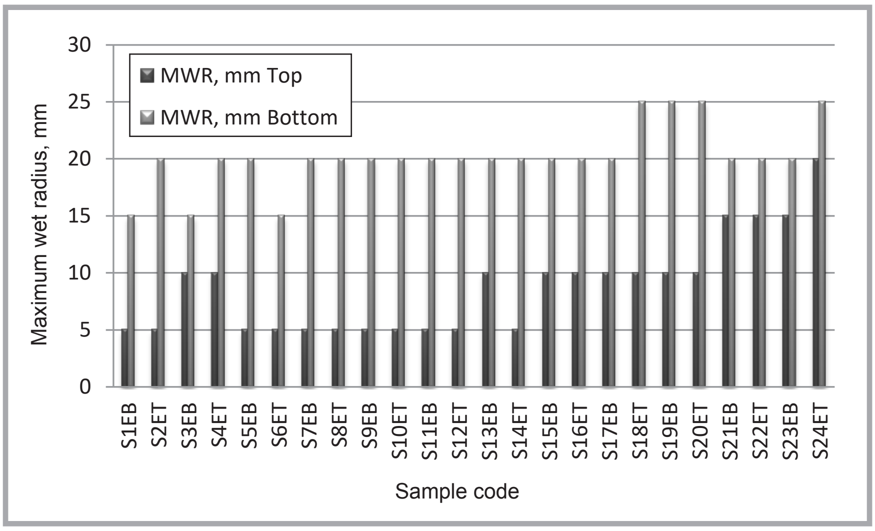


Figure 3. *Maximum wet radius (mm) of eri silk bi-layer knitted fabrics (top and bottom).*

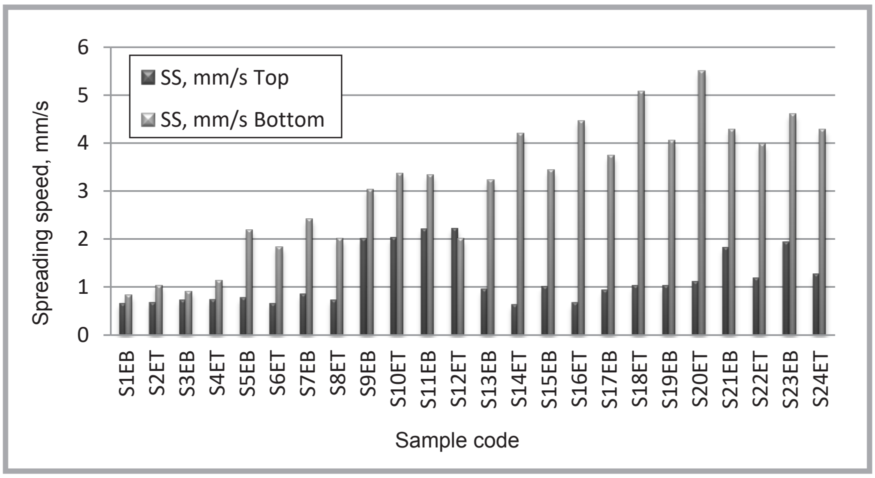


Figure 4. *Spreading speed (mm/s) of eri silk bi-layer knitted fabrics (top and bottom).*

Surface spreading speed

Figure 4 shows the spreading speed results of eri silk bi-layer knitted fabrics. The test solution dropped at the maximum wetted radius accumulated at the centre of the material, resulting in surface wetting. The spreading speed of the samples indicated that S1EB and S3EB had a very slow spreading speed on both the top and bottom layers. It was observed that S2ET, S4ET and S6ET showed a very slow spreading speed on the top and a very slow one on the bottom sides of the fabrics. Samples S5EB, S7EB and S8ET showed a very slow spreading speed on the top and a medium one on the bottom of the manufactured fabrics. A combination of a medium spreading speed on the top and a fast one on the bottom was interpreted for samples S9EB, S10ET and S11EB. The upper and lower sides of sample S12ET had a medium spreading speed. Likewise, sample S13EB exhibited a very slow and fast spreading speed on the top and bottom layers, respectively. Very slow and very fast spreading speeds were recorded on the top and bottom layers of S14ET and S16ET, respectively. Samples S15EB and S22ET indicated a slow and fast spreading speed on either layer. Samples S18ET, S19EB, S20ET, S21EB, S23EB and S24ET possessed a slow spreading speed on the top layer and a very fast one on the bottom layer.

Accumulative one way transport index

Figure 5 shows the accumulative one way transport index results of eri silk bi-layer knitted fabrics. The difference in accumulative moisture between the top and bottom surfaces of the fabric in the given time period is the accumulative one way transport index. The AOTI was recorded as excellent for samples S9EB, S10E, S13EB, S14ET, S15EB, S16ET, S17EB, S18ET, S19EB, S20ET, S21EB, S22ET, S23EB and S24ET. It was very good for samples S7EB, and S8ET. The AOTI was observed to be good for S5EB and fair for S6ET, S11ET and S12ET. Samples S1EB, S2ET, S3EB and S4ET had a poor AOTI.

Overall moisture management capacity

Figure 6 shows the overall moisture management capacity results of eri silk bi-layer knitted fabrics. The overall moisture management capacity is the capacity of a fabric to manage the transport of liquid moisture, which includes three aspects of performance, the moisture absorption rate of the bottom side being one of them. One way liquid transport capacity is termed as OMMC. Samples S14ET, S16ET, S17EB, S18ET, S19EB, S20ET, S21EB, S22ET, S23EB and S24ET were recorded to have an excellent OMMC, and samples S10ET, S13EB and S15EB possessed a very good one. The results of samples S3EB, S4ET, S5EB, S6ET, S7EB, S8ET, S11EB and S12ET displayed a good OMMC, while fair one

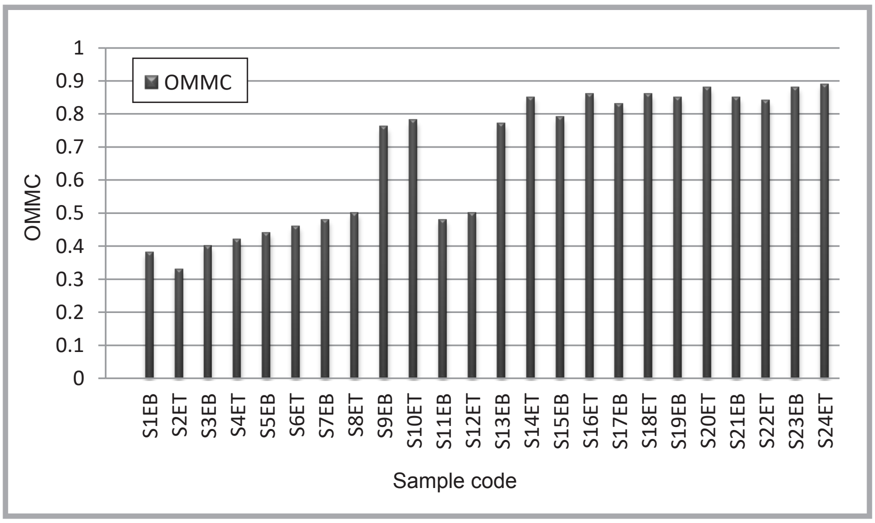


Figure 6. OMMC of eri silk bi-layer knitted fabrics.

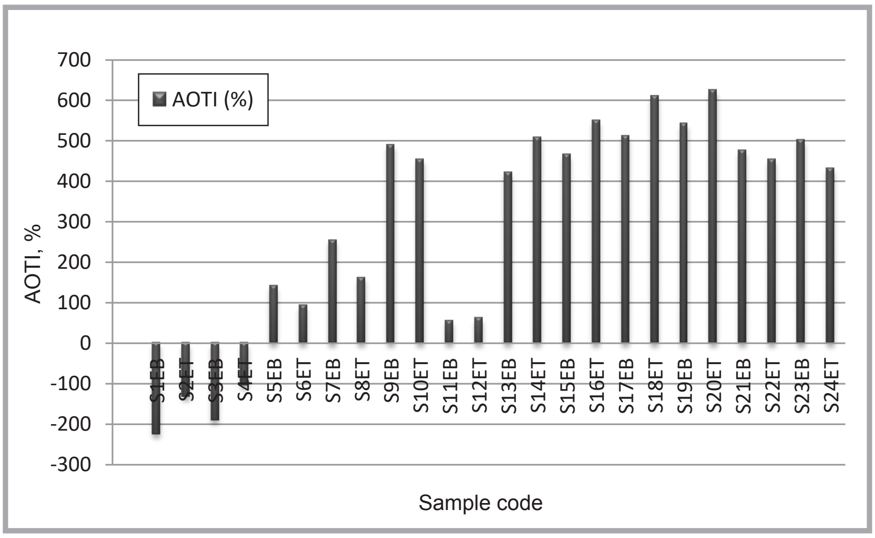


Figure 5. AOTI (%) of eri silk bi-layer knitted fabrics.

was tabulated for samples S1EB, and S2ET.

Effect of raw material combination

The wetting time of eri silk combined with tencel is very good compared to eri silk combined with bamboo. The absorption rate of eri silk combined with bamboo and that with tencel is the same, with only a slight difference. The maximum wetting radius of eri silk combined with bamboo is found to be better than for eri silk combined with tencel. The spreading speed of eri silk combined with bamboo is found to be higher than for eri silk combined with tencel. The AOTI of eri silk combined with bamboo is marginally higher than for eri silk combined with tencel. An excellent range of OMMC is indicated in eri silk combined with bamboo, which is found to be better than for eri silk combined with tencel.

Effect on yarn count combination

A yarn count comparison between 30 s and 40 s highlights that the wetting time of 40 s is higher than for 30 s. The 30 s count possesses a maximum absorption rate when compared to the 40 s count. The maximum wet radius is reliable for the 40 s count, which comprises small, medium, large and very large, whereas no wetting or small radius is observed for the 30 s count. The spreading speed is either very slow or medium on the top part and very slow, slow, medium or fast on the bottom layer of the 30 s count. But when the 40 s count is studied, it is seen that the spreading speed is very slow or slow on the upper part and very fast or fast on the bottom layer, which, hence, seems to be best of the two. The AOTI is found to be excellent for the 40 s count, whereas it is either poor, fair, good or very good for the 30 s count. The 40 s count reveals a very good or excellent OMMC as compared to the 30 s count.

Effect of fabric structure combination

A comparison between the plated interlock, mini flat back rib, and flat back rib structures indicated that the wetting time of flat back rib was comparatively very good. It was evaluated that the wetting time was slow and very fast in the mini flat back rib, whereas it was a combination of slow, medium and fast in the plated interlock structure. The absorption rate was more likely to be fast and very fast on the top and bottom of the plated interlock structure. Very few were slow or medium. This shows a slightly higher absorption compared to that of the mini flat back rib and flat back rib structures, which are generally slow on the top and fast or medium on the bottom. A descriptive study indicated a small or no wetting radius on the top side of fabric of plated interlock and mini flat back rib structure. While either a medium or fast wetting radius is found on the top side of the flat back rib structure, which is identified to be better than its counterpart. The spreading speed is noted to be greater in the flat back rib structure, being medium or slow on the top side of the fabric, and fast, very fast or medium on the bottom. But to a maximum level, the spreading speed is very slow or slow on the top side, and slow, medium, fast or very fast on the bottom part of plated interlock structure and mini flat back rib. The mini flat back rib shows an excellent AOTI range when compared to the plated interlock and flat back rib structures. The OMMC is relatively higher in the flat back rib structure than in the mini flat back rib and plated interlock structures.

Effect of loop length combination

The wetting time both 0.3 cm and 0.4 cm loop lengths for the top side is identified to be medium, whereas the range for the bottom side shows that the 0.4 cm loop length is better in this regard. The 0.4 cm loop length bears a higher absorption rate compared to the 0.3 cm loop length. On comparing the maximum wetting radius, the 0.4 cm loop length is found to have a good maximum wet radius compared to the 0.3 cm loop length. It can be stated that the spreading speed for the 0.3 cm and 0.4 cm loop lengths is more or less the same. The 0.3 cm loop length shows a better AOTI than the 0.4 cm loop length, while the OMMC of the 0.4 cm loop length is found to be good.

Conclusions

In this research eri silk bi-layer knitted fabrics with different combinations of eri silk with bamboo and tencel in the top and bottom layers were developed. The wetting time of the eri silk combination was found to be excellent. Slight differences are alone exhibited by the absorption rate of eri silk with bamboo and tencel. The maximum wetting rate of eri silk combined with bamboo showed an range excellent. Eri silk combined with bamboo has a relatively higher spreading speed. The AOTI of eri silk combined with bamboo is very good. The OMMC of eri silk combined with bamboo is also very good. A descriptive study of the yarn count shows that the wetting time of 30^s is higher than for the 40^s count. But when the absorption rates are taken into account, the 30^s count possesses a maximum absorption rate, as compared to the counterpart. It is identified that the 40^s count shows a maximum wet radius more. The spreading speed of the 40^s count is observed to be maximum. An excellent AOTI is found for the 40^s count, whereas for the 30^s count it is medium. The 40^s count reveals an excellent OMMC when compared made with 30^s count.

The results reveal that the wetting time of flat back rib is good when compared to the plated interlock and mini flat back rib structures. The absorption rate of the plated interlock structure is slightly higher than for the mini flat back rib and flat back rib structures. A fast wetting radius is observed in the flat back rib structure. The medium range on the top, and fast, very fast or medium on the bottom side of the flat back rib structure indicates its superiority. The AOTI of mini flat back rib is identified as excellent. The flat back rib structure acquires a high position because of its higher OMMC. The 0.4 cm loop length is good, and its absorption rate is also excellent. The maximum wet radius of the 0.4 cm loop length is good as well. The spreading speed is good for both loop lengths, being more or less the same. A better AOTI is found for the 0.3 cm loop length, whereas the OMMC of the 0.4 cm loop length is good. The studies reveal that eri silk bi-layer knitted fabrics generally have good moisture management properties, ensuring their suitability for performance based garments.

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