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Physio-mechanical properties of Eri silk and its union fabrics

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Abstract
Union fabric is the fabrics where the warp yarns are different from weft yarns. Eri silk and wool is the way to incorporate better appearance in the woolen fabric and to increase the utility of silk fabric. Eri with wool union fabrics was found to be better quality in respect of physio-mechanical properties. The plain weave union fabrics of GSM (130) and 186 GSM as well as eri silk fabric with (85) GSM were prepared in fly shuttle loom. Union fabrics showed 38.80 mm and 0.88 mm fabric thickness, bending length of EWU was 2.16cm (warp) and 2.47 cm in weft but EWU1 union fabric showed 3.90 cm in warp and 2.98 cm in weft way. Decreasing trend was observed in crease recovery and bending length compared eri silk. Both union fabrics have good ultra-violet protection factor (UPF) but brightness index was found to be more in eri silk.

Keywords: Union fabric, Eri silk, wool, physical properties, UPF

Introduction
Survival of textiles industries depends primarily on diversification of current end products to meet national as well as international demands. Textile material containing more than one textile fibers are term as blend, union or mixture. The reason for developing such union fabrics may be to economize on raw material cost, to modify and confer aesthetic properties or to develop a material with specific physical characteristic (Adnan M. 2013) [2]. Union fabric is the fabrics where the warp yarns are different from weft yarns. Union fabric can be obtained with different novelty effect that can cater to the today's fashion world (Arora and Sharma, 2010) [3]. Eri silk is one of the varieties of silk available in India. In India four varieties of silk are available ie. mulberry, muga, tassar and eri silk. Eri fibre fineness (14-16 microns) is very close to wool fibre which can be easily blended with wool. By blending of eri with wool, fabric properties like smoothness, luster, durability, dimensional stability, pilling properties and crease resistance improved as eri has better above properties than wool. There has been a great demand for silk mixed/blended fabrics in the recent times due to the increased prices of raw silk. If the silk is blended with cheaper fibres, the cost can be reduced so that the resultant fabric can have all the desirable properties (Jacob and Padma Latha 1994) [12]. The staple length of the fibre is about 57 mm. It has excellent thermal properties, which can be a substitute for wool. Eri silk is highly crystalline than any other non-mulberry silks (Sreenivasa *et al.*, 2005) [20]. It has tremendous blending possibilities with other fibres like wool. Blends or union fabrics can be created with variegated novelty effect that caters to the fashion world today (Kulkarni A. *et al*. 2011) [14]. The courser and uneven eri silk yarn is most suitable for handloom sector and appropriately used as shot weft. It is new enterprise in this sector, since *Ahimsa silk* is compatible to interweave with wool. These union made-ups exhibited greater tensile strength with better elongation, resistance to abrasion, excellent hand- feel properties (Sannapapamma, *et al*. (2015) [17]. Wool is an unique animal protein fibre enjoys a special position among textile fibres because of its unmatched properties of warmth, excellent drape, high absorbency, outstanding strechability, excellent resilience, water repellence, flame retardance, crispness and superior compressional recovery (Verma N 2011) [22]. Blending of silk and wool is the way to incorporate better appearance in the woolen fabric and to increase the utility of silk fabric. The yarn can be used for the production of warmer varieties of fabrics. The combined effect of warmth and comfort of wool with high strength, luster and good hand property of silk can be successfully achieved through blending. Silk and wool both being animal (protein) fibres, have almost similar chemical properties. Silk is a finer, lustrous, strong fibre compared to wool.

The yarns produced by blending silk and wool will be bulkier and cheaper compared to pure spun silk yarn. Silk competes with wool because of its high elasticity, colour brilliance, resistance to pilling, strength and colour fastness properties (Gill and Singh 2002) [10]. Blending of silk and wool is a way to incorporate better appearance and strength in the woolen fabric and increase the utility of silk fabric. The yarn can be used for production of warmer varieties of fabrics. The combined effect of warmth and comfort of wool with high strength, luster and good hand property of silk can be successfully achieved through blending to increase its market value (Papnai and Goel 2005) [17]. Eri silk has a vast potential in both domestic and international markets and emerging as "The fabrics of next millennium. The Eri silk cocoons cannot be reeled in raw filament yarn but are spun either by hand spun or milled spun. The hand spun yarn does not equally distribute the slubs and snars. By manipulating at various stages viz., yarn, fabric, design, fashion style etc can bring a diversification in the Eri end products (Taga G and Bhaishya K. B. , 2012) [21]. Therefore, an attempt was made to construct union fabric from eri silk and wool with different yarn count. The fabric produce from union of eri and wool yarns were analysed for its physio-mechanical properties for further use in textile industry.

Material and Methods

In this experiment, the union fabric was prepared by using eri silk yarn in warp and wool yarns were used as weft with GSM (130) and 186 GSM. Apart from that eri silk fabric with (85) GSM was also woven in fly shuttle loom.

Conditioning of samples

Prior to testing, all the samples were conditioned to attain moisture equilibrium and tested in standard atmospheric condition of 65±2% relative humidity and temperature 27±2 °C as per IS standard Method IS-6359-1971.

Analysis of physical properties

The EPI, PPI, GSM of the eri silk and union fabrics were determined by using standards methods. Thicknesses of the samples were analyzed according to BS test method 2544:1954. The bending lengths of samples were tested using a stiffness tester at 45˚ angle by following ASTM- D-1388 method. Crease recoveries (degree) of samples were tested according to I.S method: 4681-1968 by using the Shirley's crease tester (Booth, 1968) [7]. The tensile strength, elongation of eri silk and union fabric was analyzed according to ASTM D-5035 test method Instron tensile tester 5965, UK.

Analysis of Air permeability ($m^3/m^2/min$)

By using the prolific air permeability tester at pressure differential of 10 mm, the samples were analyzed. The air permeability, the volume of air was measured in cubic a centimeter which was passed per second through 1 cm^2 of the fabric at a pressure of 1 cm of water. All the samples were tested according to IS test method 11056: 1984.The air flow rate is then recorded by using rotameter from the instrument.

Analysis of Whiteness, Yellowness and Brightness Index

The whiteness, brightness and yellowness of union fabric was measured using Premiere Spectra Scan 5100+ computer matching system at 10 ^{0} Observer.

Analysis of Ultraviolet Protection Factor (UPF): The UPF values of the untreated and treated fabrics were measured using a Shimadzu UV–2600 spectrophotometer in the range of 280 to 400nm. The UPF value of each fabric was determined from the total spectral transmittance based on AS/NZS 4399:1996 methods.

Result and Discussion

Construction details: A plain weave eri silk fabric of 40 inches width was prepared in fly shuttle loom by using pure eri silk yarn 2/140 in warp and 1/140 in weft direction with S twist. (Table 1). Similarly two variety of union fabric with plain weave of 40 inches width were woven in fly shuttle loom from pure eri silk yarn (2/140) in warp direction and pure wool yarn (1/56) in weft direction with S twist (EWU) and 2/30 warp wool and 2/30 eri silk in weft way for another union fabric (EWU1) (Table 1). The eri silk and union fabrics were evaluated for it physio- mechanical properties -fabric thickness, bending length, crease recovery, air permeability and analytical properties like whiteness index, brightness index yellowness index and ultra-violet protection factor.

Table 1: Constructional details of Eri silk and Eri/Wool Union Fabrics

Fabric	Weave type	Yarn	Twist direction	Yarn count	Yarn type	Direction	Fabric width	Loom used
Eri silk (EEP)	Plain	Eri 100%	S twist	2/140	2 ply	Warp	40 inches	Fly shuttle
		Eri 100%	S Twist	1/140	1 ply	Weft		
Eri/wool union (EWU)	Plain	Eri 100%	S twist	2/140	2 ply	Warp	40 inches	Fly shuttle
		Wool 100%	S twist	1/56	1ply	Weft		
Eri/wool union (EWU1)	Plain	Wool 100%	S twist	2/30	2 ply	Warp	40 inches	Fly shuttle
		Eri 100%	S twist	2/30	2 ply	Weft		

Physio- mechanical Properties eri silk and union fabric
Fabric thickness and fabric count

The thickness property of eri silk fabric was observed to be 33.00 mm. But union fabric (EWU) showed 38.80 mm of fabric thickness and 0.88 mm thickness was showed by (EWU1) union fabric. This may be due irregular yarn surface and coarser yarns counts twist per inch etc. The difference in thickness may be due to the fibre types, yarn twist, blend proportion and fabric structure (Boruah S. and Kalita Baishya B, 2018) [8]. The data reflects that the eri silk fabric have (74) EPI and (69) PPI but union fabric (EWU) showed 78 (EPI) and 79 (PPI) and EWU1 showed 24 EPI and 26 PPI. The values of warp direction are lower than the weft direction in all union fabric samples except in eri silk fabric. The fabric construction (EPI, PPI, count, weave type) proves to be playing a major role in the performance of the fabric (Bharani, M., *et al.* 2012) [5]. Fabric properties like thickness, count, properties are associated with fabric aesthetic stability and surface properties are associated with fabrics aesthetics.

Table 2: Analysis of physio- mechanical Properties eri silk and union fabric

Sample	Fabric thickness (*mm*)	Fabric Count		Bending length (*cm*)		Crease Recovery (*Degree*)		Air Permeability (*$m^3/m^2/min$*)
		EPI	PPI	Warp	Weft	Warp	Weft	Pressure
Eri silk (EE)	0.33	74	69	2.22	2.25	94	96	220.60
Union (EWU)	0.37	78	79	2.16	2.47	91	89	220.00
Union (EWU1)	0.88	24	26	3.90	2.98	20	33	240.00

(**Note:** EE = 100% eri silk fabric; EWU= Eri /Wool Union fabric; EWU1= Eri /Wool Union fabric)

Bending length
A bending test measures the severity of the flexing action of any textile material. The stiffness of a fabric in bending length is very dependent on its thickness (Jinlian HU, 2008) [13]. The bending length of eri silk fabric was found to be 2.22 cm in warp and 2.25 cm in weft direction but union fabric (EWU) showed 2.16cm (warp) and 2.47 cm in weft direction and 3.90 cm in warp and 2.98 cm in weft was noticed in union fabric (EWU1). In general, there was a decreasing crease trend in bending length except in union fabric (EWU1) compared eri silk fabric. It was observed that higher the stiffness of the fabrics then higher the bending length was noticed (Winks, J.M, (1996) [23], or this may be due to the weave of the fabric, yarn count, yarn twist. The noticeable enhancement in bending length was observed union fabric (EWU1) in both warp and weft direction compared to (EWU) union fabric.

Crease recovery
The crease recoveries of eri silk and union fabrics were assessed and observed that the crease recovery of eri silk was found to be 94˚ in warp and 96˚ in weft directions. Gradual changes in crease recovery angle were observed in eri silk and union fabric. The crease recovery of 91˚ in warp and 89˚ in weft direction in union fabric (EWU) and in (EWU1) union fabric 20˚ in warp and 33˚ in weft were noticed. Interesting to note that decreasing trend was observed in crease recovery union fabric compared to eri silk. It may be due to EPI, PPI and GSM of the fabric. The fabric construction (EPI, PPI, count, weave type) proves to be playing a major role in the performance of the textiles. The cover factor increases with the increase in EPI and PPI, thus resulting in greater fabric strength, the greater is the resistance to fabric and seam breakage *(*Bharani M. *et al*. 2012) [5]. It may be due to weave which have direct effect on bending rigidity of the fabrics. The stiffness is also related to softness and hardness of the fabrics but least bending length attributed to least weight and thickness (Winks, J.M, (1996) [23].

Air permeability
The air permeability of eri silk fabric was shown 220.60 $m^3/m^2/min$ while union fabric (EWU) showed 220 $m^3/m^2/min$ and EWU1 showed 240 $m^3/m^2/min$). Air permeability of EWU union fabrics is less than both EWU1 and eri silk fabrics. There are different factors like weave, cloth count, cover factor have a commendable effect on air permeability by causing a change in length of air flow paths through a fabric (Sermon, P. A., & Leadley, J. G. (2004) [19]. Moreover the yarn twist is also important factor in air permeability test as twist in yarn increases, density and the circularity of yarn increases, reducing the yarn diameter and cover factor thus enhance the air permeability of a fabric (Garde, A. R., 2001) [10]. The least value of air permeability may be due to coarser yarn count, low twist factor, high cloth cover and thickness, hence reducing the amount of air flow through it. Hence, the application of nano silica with polymer and without polymer in different concentrations may be the reason for different air permeability in fabrics.

Whiteness, Yellowness and Brightness Index
The table 3 inferred that whiteness index in eri silk fabric was observed as 33.10 where as in union fabric (EWU) showed 31.01 and 22.7 EWU1 union fabric. Regarding yellowness index decreasing trend was observed in the eri silk and union fabrics (EWU) but the union fabric EWU1 showed 29.35 yellowness index which is more than the other samples. It may be because of different count, and coarse yarn used in weaving EWU1 union fabric. In case of brightness index eri silk fabric is brighter than EWU union fabric followed by EWU1 union fabric. This may be due union of eri silk yarn with wool yarns because the eri silk whites in colour while wool yarn are creame in colour which effect the surface properties of the union fabrics.

Table 3: Analysis of Whiteness, Yellowness and Brightness Index of eri silk and union fabrics

Fabrics	Whiteness Index (WI)	Yellowness Index (YI)	Brightness Index (BI)	UVA (315 – 400 nm)	UVB (290 - 315 nm)	UPF (290 -400 nm)	Category
Eri Silk (EE)	33.1	25.1	59.525	17.73	9.82	8.46	-
Union (EWU)	31.0	24.1	55.205	13.21	4.95	15.99	Good
Union (EWU1)	22.65 29.35 41.82	29.35	41.82	12.05	3.05	13.89	Good

(**Note:** EE = 100% eri silk fabric; EWU= Eri /Wool Union fabric; EWU1= Eri /Wool Union fabric)

Ultra-Violet Protection Factor (UPF)
The protection extended by the textile materials, accessories and sun screen lotions are denoted by different terminologies known as UPF (Ultra Violet Protection Factor) and SPF (Rupp J., *et al*. (2001) [17]. The construction parameters and wear conditions of the textile materials, moisture and additives incorporated in processing also affect the UPF of the textile materials (Holme I. (2003) [11]; Bajaj P., Kothari V.K., Ghosh S.B.(2000) [4]; Bohringer B. *et al*.(1997) [6]. The ultra violet protection factor of eri silk and union fabrics were analysed by using Shimadzu UV Spectrophoto meter. The data in table 3 reflects that union fabrics have good ultra-violet protection factor (UPF). It was also confirmed from the results that eri silk fabric has less ultra-violet protection factor (UPF). UPF values of 8.40, was obtained in eri silk fabric, and union fabric (EWU) showed 15.99 UPF and EWU1 showed 13.89. The UPF factor was found to be in good range i.e., 15.99. This may be because of more fabric density and thickness as well as it depends on the porosity (Achwal W.B. (2000) [1]. A UPF with fabric weight and thickness shows better correlation than cloth cover (Saravanan D. (2007) [18]. Therefore, the fabrics give high UPFs with the maximum

number of yarns in warp and weft. Wool helped to enhance the UPF property of the union fabric.

Tensile and elongation properties

The tensile strength, elongation properties of eri silk fabric as well as union fabric was depicted in table 4. It was seen that, in the warp direction the eri silk fabric showed 252 N in weft directions of tensile strength at maximum load was 235 N. Similarly, the elongation at maximum load was found to be 0.34 mm in eri silk fabrics and 0.39 mm in weft directions. Whereas, the union fabric showed 284 N at maximum load in warp direction and tensile strength of 209 N of weft directions by EWU union fabric while EWU1 union fabric showed 125 N in warp and 105 N in weft way. It may be because of yarns used for weaving in eri silk fabric and union fabrics.

Table 4: Tensile strength and elongation of eri silk and union fabrics

Fabrics	Direction	Maximum Load [N]	E @ Max Load [mm/mm]
Eri Silk (EE)	Warp	252	0.34
	Weft	235	0.39
Union (EWU)	Warp	284	0.50
	Weft	209	0.57
Union (EWU1)	Warp	125	0.59
	Weft	105	0.69

(**Note:** EE - 100% eri silk fabric; EWU- Eri /Wool Union fabric and EWU1- Eri /Wool Union fabric).

The elongation at maximum load 0.50 mm obtained 0.57 in both warp and 0.57 mm was in weft direction of union fabric (EWU) and EWU1 union fabric showed 0.59% in warp and 0.69% elongation in weft directions. In case of elongation, an increasing trend was noticed in all samples in weft directions. The elongations in warp direction of eri silk and union fabrics were less than weft directions. Higher elongation (%) may be due to fiber content of eri silk which is considered to be more plastic than elastic. The every crystalline polymer system of eri silk does not resist the polymer movement. When the silk is stretched additionally the polymers, which are already in stretched state and will not elongate further (Jacob M and Latha P, 1994) [12].

Conclusion

The union fabrics with plain weave were prepared from eri silk and wool yarn by using fly shuttle loom. Eri with wool union fabrics was found to be better quality in respect of physio-mechanical properties. The physio-mechanical properties like thickness bending length, crease recovery, tensile strength, elongation percentage of the eri silk fabric and union fabrics were accessed. The union fabric EWU showed higher strength compared to EWU1 union fabric and eri silk. The UPF factor was found to be in good range i.e., 15.99. Both union fabrics have good ultra-violet protection factor (UPF) but brightness index was found to be more in eri silk. The union fabrics prepared from eri silk and wool fibers have great scope in textile markets. Eri Union fabric can be use for various end uses.

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