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Physico-mechanical properties of Eri-modal blended yarn

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Abstract
The present study was conducted to analyze the physical and mechanical characteristics of the developed Eri / Modal blended yarn. The diameter, count, fibre density and moisture content were observed maximum in Eri silk followed by modal. However Whiteness Index and the Initial Modulus were found to be highest in modal and lowest in Eri-silk. The results indicated that elongation per cent for Eri silk is higher as compared to modal fibre. In case of yarn, maximum twist, crimps were observed in controlled Eri silk (14.54tpi), (0.38 per cent). The lowest hairiness was observed Eri/Modal 30:70 (4.086/km) which was found least among all the blended as well as controlled yarns. It was also noticed that all the blended yarns exhibited maximum yarn strength than controlled yarns; it may be due to testing yarn with shorter gauge length which in turn enhances the apparent yarn strength. The experimental finding provides information on the properties of Eri silk and its blended yarns that were found to be better quality in respect of physical and mechanical properties than pure Eri/Eri fabric.

Keywords: Eri, modal. blended yarn, physical and mechanical properties

Introduction
Silk is the most cherished of all the textile fibers. The most attractive property of silk fibre is high resistance to deformation (Vatsala R., 2002) [1]. India, has the distinction of being the only country in the world, producing all the four commercially exploited silk varieties *viz*. mulberry silk produced throughout the country, tropical tasar, temperate/oak tasar, produced by tribal inhabiting Central India and Sub-Himalayan Region, Eri silk (spun silk produced mainly in N. E. Region, now practiced in many other states) and muga – golden silk produced only in Brahmaputra valley of Assam province in NE Region. The non-mulberry silks (Tasar, Muga & Eri) are now being popularized as Vanya silk.
The Eri cocoons are open mouthed and Silk produced by this group are simple, elegant and natural with uniqueness in colours. However, there is immense scope for product development and diversification to address consumer preferences in different parts of world. (Gogoi and Kalita, 2009) [2].
Modal is cellulosic fibre, made out of pure wooden chips as the European Schneider Zelkova tree from the beech tree technically. Modal displays high dimensional stability, both for low shrinkage and low unrecoverable extension. (www.holistic-interior-designs.com/modal-fabric.html). Modal is sometimes referred to as "soft as a feather" and the "softest fibre in the world".
Blending of fibrous materials is a technique to achieve and satisfy the requirements of both, the manufacturers and consumers. It is an intimate mixture of fibres of different composition, length, diameter or colour spun together into one yarn in which the constituent fibres are present in the same yarn, in planned proportions (Kadolph and Langford, 1996) [3].
Reasons for producing blended fabrics are to reduce cost or to obtain a different appearance, to obtain a greater number of desirable characteristics that cannot be obtained by using one fibre alone such as absorbency, comfort, lightness, cross dyed effect, wearing and dyeing efficiency. Fibres have been blended to produce fabric and articles of improved functionality (Singh, 2008) [4].
In the field of textiles the present era can truly be called the era of blending. Discovery of different types of man-made fibres and the use of them in staple form have opened immense scope to produce textile having diverse properties and visual appeal to cater the taste of all kinds of people. Diversification in the product can be brought about at various stages *viz*., yarn, fabric, design, fashion and style.

Materials and Methods
Materials
The Eri silk and modal fiber used for the present work was procured from M/S Fabric plus Pvt. Ltd. Guwahati, Assam, India. The chemicals used for the study *viz*., hydrogen peroxide (assay 30% w/v), sodium carbonate (assay −99%), and acetic acid (assay 99%) were purchased from E Merk, India. Marseille soap was used for the degumming processes.

Methods Degumming and bleaching
The degumming and bleaching of the Eri silk cocoons were performed as mentioned elsewhere (Boruah *et al*. 2020). The bleached cocoons were inserted into a pupa rider machine. There is a roller of needles in the unit, which opens the cocoons and forms a continuous web. The web was cut to the required length and processed in a circular dressing system, separating long fibers from short fibers.

Blending of Eri silk with modal
The blending of Eri silk and modal fibers was carried out at different proportions (70:30, 50:50, and 30:70) using a draw frame (gill box – NSC-France). The ribbons were fed into the spreader machine, and the resultant ribbons were joined to make the sliver. In the draw frame, slivers were passed through four passages having seven to eight drafts. The slivers of selected ratios were put in the ring frame with 15–16 drafts running with 4200 rpm. The resultant sliver was drawn again 25–30 times to form a condensed package. The necessary twist was inserted to obtain fine yarn and the individual yarn was wound on a cone. The 100% Eri silk and modal yarns were prepared using the same protocol. Standard temperature (30 ± 2°C) and humidity (80 ± 5%) were kept in the spinning shed.

Assessment of fiber and yarn properties
All the testings were performed after pre-conditioning the samples at 25°C and 65% RH. The length of the Eri silk and modal fibers was measured according to I.S.: 233 Part 2 test method using Baer sorter (Tex Lab Industries, India). The fiber fineness was analyzed using VIBROSCOP-400 (BISFA 2004 & ASTM D − 3822–07). The fiber diameter and density were measured according to I.S. 744–1977 and ASTM D1907/D1907M – 12(2018) methods, respectively. Moisture Content was analysed by IS: 1999, 1973 method. The strength properties *viz*, tensile strength, elongation, initial modulus, and specific work of rupture of Eri silk and modal fiber were assessed with Instron tensile tester (model no. 5567) using standard parameters for fiber (ASTM D: 3822) and yarn (IS: 1670). The Beesley balance was used to evaluate the yarn count. To determine the twist in the yarns, the untwisting method (ASTM D 1422–99) was followed using a twist tester (Microprocessor Twist Tester). Crimp Percentage was analysed using Crimp Tester (Ureka Precision Instrument and company, ASTM 3883 – 90). The Uster Tester-3 (Simadju, Germany) hairiness meter and Uster Tensorapid (Simadju, Germany) was used to perform the yarn strength and elongation (ASTM D-1425). Lea Strength Tester was used to measured the Lea strength (IS: 1671-1977).

Results and discussion
Analysis of Physical and Mechanical Properties of fiber
Physical Properties
Fibre Length
Length is the most important property of a fiber. The length of fiber is directly related to its spinning performance (Gupta *et al*. 2000) [5]. It is evident from the Table (1) that the fibre length of modal fibres ranged from 128mm to 04mm with the mean fibre length of 55.26mm. As Eri- silk fibre was spun from the cut cocoon fibre exhibiting the range from 136mm to 04mm with the mean fiber length of 55.20mm. This fibre length of silk was suitable for blending as it was similar to average length of modal fibre used in the research.

Fibre Count (tex)
The count of the fibre directly affects the properties of resultant yarn and fabric. It is apparent from Table 1 that the count of Eri silk was 0.55tex followed by the count of modal fiber with 0.33tex. From the table it was observed that Eri silk had maximum count than modal fiber.

Fiber Diameter (microns)
Fiber diameter decides a fabric's performance and hand (how it feels). The diameter of Eri silk fiber had the mean value of 17.45micron and the diameter of modal fiber was 15.40micron. From the result it was found that Eri silk fiber had maximum diameter followed by modal fiber.

Fiber density (g/cm^3)
Table 1 revealed that fiber density of modal and Eri silk fiber were 1.30g/cm^3 and 1.40g/cm^3 respectively. Results show that modal fiber has slightly less density as compared to Eri silk fiber. This may be due to finer the fibers; finer fiber has lower density (Gupta *et al*., 1999) [6].

Fiber Moisture Content (%)
It is apparent from the Table 1 that moisture content of Eri silk fiber was found to be maximum (10.70per cent) followed by modal fiber had the moisture content of 9.90 per cent.). Thus, the moisture regain per cent was more in the case of silk fiber as compared to modal fiber, it may be due to fiber color, length and strength; as well as other properties, are all impacted by fiber moisture content (Delhom C., 2016) [7].

Table 1: Physical properties of the selected fibres

Physical Parameters	Fibres	
	Eri-silk	Modal
Fibre length(mm)	55.20	55.26
Maximum length	136	128
Minimum length	04	04
Fibre Count(tex)	0.55	0.33
Fibre diameter (microns)	17.45	15.40
Density (g/cm3)	1.40	1.30
Moisture Content (%)	10.70	9.90

Mechanical Properties
Fibre Tenacity (cN/tex)
The fibre length and fineness have effect on tenacity of fibre. The tenacity of modal and Eri silk fibre were 12.55cN/tex, 8.99cN/tex respectively. The high tenacity fibre has high durability, toughness and chemical resistance to withstand extreme environments.

Elongation (%)
Elongation is specified as a percentage of the starting length. The elastic elongation is of decisive importance since textile products without elasticity would hardly be usable. Eri silk had the elongation per cent of 19.14 per cent whereas modal fibre was 8.85per cent. The results indicated that elongation per cent for Eri silk is higher as compared to modal fibre. This may be due to the low tenacity of Eri silk.

Initial Modulus (cN/tex)

Initial modulus is the tangent of angle between the initial curve and the horizontal axis is equal to the ratio of stress and strain. The Initial Modulus of the fibres was observed as maximum in case of modal fibre (787.28cN/tex) and minimum in Eri silk (231.61cN/tex). From the result it was observed that modal had exhibited higher initial modulus, it may be due to modal fibre has higher resistance to stretching (Adusumali *et al.* 2007) [8].

Specific work of rupture (mj/tex.m)

Work of rupture is defined as the energy required breaking a material or total work done to break that material. The Specific work of rupture was recorded as Eri silk and modal fibre 11.04mj/tex.m, 6.69 mj/tex.m respectively. Fibre having maximum work of rupture, it may be due to fibre having least strength and initial modulus offering greater energy to break it.

Table 2: Mechanical Properties of Eri silk, modal and acrylic fibres

Mechanical Parameters	Fibres	
	Eri-silk	Modal
Tenacity(cN/tex)	8.99 (32.15%)	12.55 (17.95%)
Elongation at break (%)	19.14 (47.63%)	8.85 (23.95%)
Initial Modulus(cN/tex)	231.61	787.28
Specific work of rupture (mj/tex.m)	11.04	6.69

Evaluation of Physical and Mechanical Properties of Controlled and blended Yarns

Physical properties controlled and blended yarns

Yarn Average twist (tpi)

Yarn twist is the spiral arrangement of the fibres around the axis of the yarn. The twist binds the fibres together and also contributes to the strength of the yarn. The amount of twist inserted in a yarn defines the appearance and the strength of the yarn. The number of twists is referred to as turns per inch (Banale and Chattopadhyay, 2015) [9]. The results furnished in Table 3 shows that the maximum twist observed in controlled Eri silk (14.54tpi) followed by EM 70:30 (12.85tpi) and minimum was in EM 30:70 yarn (10.25tpi). From the results it was found that controlled Eri silk and higher percentage of Eri silk blended yarn had more twist than controlled modal, acrylic and their blended yarns. It may be due to the effect of twist per inch which depends on the density of the fiber in yarn. Further, a greater number of the twist in yarn means that fibers are more rigid because the fibers are close together. That means no freedom for movement of fiber so the formability is less (Rocco and Maurizio, 2010) [10].

Yarn Density (g/cm^3)

It is evident from Table 3 that the density of yarns were maximum in EM 30:70 (2.67g/cm^3) and minimum in controlled Eri silk yarn (2.08g/cm^3).The density is changing according to the number of twist in the yarn (Rocco and Maurizio, 2010) [10].

Yarn Hairiness (-)/km

Hairiness is characterized by the quantity of freely moving fibre ends or fibre loops projecting from a yarn. Hairiness is an important quality parameter of spun yarns. It not only affects the quality of yarns, but also the weaving and knitting performance of yarns as well as the quality of the resultant fabrics (Haleem and Wang, 2015) [11].

From the Table 3, it can be observed that the hairiness was more in the two controlled yarns *i.e.* acrylic and Eri silk. Blending of all the fibres resulted in reduced hairiness (-) of controlled yarns. Controlled modal (4.648/km) exhibited less hairiness as compared to controlled controlled Eri silk. The lowest hairiness was observed EM 30:70 (4.086/km) which was least among all the blended as well as controlled yarns. From the result it was observed that all the acrylic blended yarns showed higher hairiness than modal blended yarns, it may due to density of the yarn, inadequate drafting and orientation and spinning triangle.

Yarn Crimp

The results registered in Table 3 shows that the maximum crimp mean value was observed in controlled Eri silk (0.38 per cent) and the lowest in case of controlled Modal (0.28 per cent). Yarn crimp was more in Eri due to its higher twist per inch. The abrasion resistance of a fabric will be more, if the crimp in the yarns is more. The yarns with high crimp take the brunt of abrasion action (Tyagi, 2004) [12].

Table 3: Physical and Mechanical properties of controlled and blended yarns

Physical Parameters	Yarns					Mechanical Parameters	Yarns				
	Eri 100%	Modal 100%	EM 70/30	EM 50/50	EM 30/70		Eri 100%	Modal 100%	EM 70/30	EM 50/50	EM 30/70
Average twist (tpi)	14.54	12.06	12.85	11.85	10.25	Elongation (%)	15.95	11.30	11.58	11.06	10.72
Density (g/cm^3)	2.08	2.35	2.38	2.58	2.67	Yarn strength (gf)	196.05	198.85	221.25	223.00	224.05
Hairiness (-/km)	5.696	4.648	4.442	4.156	4.086						
Yarn Crimp (%)	0.38	0.28	0.36	0.33	0.32						

EM-= Eri- Modal

Mechanical Properties of Controlled and Blended yarns

Elongation

Table 3 shows that controlled Eri silk had the highest elongation with a mean value of 15.95 per cent followed by EM 70:30 (11.58 per cent). Lowest elongation was seen in EM 30:70 yarn (10.72 per cent). However in controlled Eri-silk high elongation is due to higher resistance to torsion and low yarn strength of Eri-silk fibre. Also, the elongation of the silk yarn, to a certain extent depends on its source. The innate nature of silk *viz.* the elongation increases from the internal layers to the external layers of the cocoon. Since the elongation as well as strength is the primary properties of fibre, the elongation is very much necessary for spinning quality, which enhances the cohesiveness of the fibre during spinning process (Doorthy, 1980) [13].

Yarn Strength (gf)

Yarn strength was lowest yarn strength was found in controlled Eri silk yarn196.05gf. From the result (Table 3) it was observed that all the blended yarns exhibited maximum yarn strength than controlled yarns, it may be due to testing yarn with shorter gauge length which in turn enhance the apparent yarn strength. This effect is known as 'weak link effect'. For more irregular yarn, the "effect" is more. It was evident from the table that blends of Eri and modal fibre produce the strongest yarn as compared to controlled yarn. Yarn strength is one of the most significant parameters to be controlled during yarn spinning process (Furferi and Gelli, 2010) [14].

Conclusion

Eri silk has a potential of emerging as "A silk of the new millennium", providing excellent dimension of scope in design development and produced fashionable dresses with special properties to produce abundant finished products. Eri is known as the softest and warmest amongst all the silk and has immense potential for commercial exploitation by making finest quality blankets, sweaters, ties and knitwear for suiting. Besides, there is a good scope for Eri to be used as a blending material.

The experimental finding provides information on physical and mechanical properties of Eri silk with modal blended yarns. Eri with Modal blended yarns were found to be better quality in respect of physical and mechanical properties than pure Eri/Eri fabric. Thus special properties of Eri silk could be utilized for production of diversified finished products to venture world market of craze for natural silk and mark it as an export commodity. Eri silk or Ahimsa silk is natural and a eco-friendly fibre, where user friendly and non-toxic dyes can be used to obtain wide range of shades and cross dyed effect.

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