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Investigation of Thermo-physiological comfort characteristics of Eri silk knitted Fabrics

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Abstract - Eri, the only non-mulberry domesticated variety of silk, is not reliable and is used for the production of spun yarn only. It has outstanding thermal insulation property. Knitted fabric produced from Eri silk materials is a new avenue in the in the global market. These fabrics are natural, ahimsa, eco-friendly and glamorous. Eri knitted fabrics have better physical, dimensional, thermal and moisture management properties which evidence that the fabric is suitable for suitable for both summer and winter wear. In this study, thermal-related characteristics, such as the thermal conductivity, thermal absorptivity, thermal resistance, wick ability of knitted fabrics were investigated. For this purpose, commonly used knitted structures of single jersey and single pique were produced by using two different yarn linear density and fabric tightness level. The comfort properties of these fabrics were measured using the Alambeta instrument, vertical wicking device and statistical analyses were carried out. Process variables such as yarn linear density, fabric structure and stitch length have significant influence on the comfort properties Eri knitted fabrics.

Keywords: Eri silk, Knitted fabrics, yarn linear density, stitch length, wicking, thermal conductivity, thermal absorptivity, thermal resistance.

I. INTRODUCTION

Eri silk categorized under wild silks, it ranks next to Tassar silk in commercial importance. It is the product of domesticated silk worm, Philosomia ricini that feeds mainly on castor leaves. Eri cocoons are mouth opened and not suitable for reeling, possible to manufacture only as spun yarn . Since these silk can be taken out without killing the pupae, it can be promoted as Ahimsa (non violent) silk. Eri silk is a unique silk with rough appearance, rustic touch and aesthetic appeal. It has the finish of wool, look of cotton and softness of silk. Eri silk fabrics are characterized by strength, durability, less wrinkle and greater elasticity. Eri silk has specific thermal property, which makes its alternative fiber wool. The Eri mill spun yarn can produce from worsted system of spinning. The yarn count ranges from $2/10^s$ Nm to $2/210^s$ Nm [Beera Saratchandra (2003)]. The eri fabric is an excellent material for shirting, suiting, bed spreads, curtains and other furnishings and it posses excellent dimensional and Thermo-physiological comfort properties [Subir Kumar De, 2013].

Knitting structures are important due to several advantages such as comfort, high elasticity, conformity with the shape of the body, softer touches, lightweight, warmth, wrinkle resistance, and ease of care. etc. It is well known that the physical and comfort properties of fabrics are dependent on their yarn properties and fabric construction parameters [Kane CD et al].

Clothing comfort or the sense of coolness/warmth is one of the important parameters for consumers. Comfort in fabrics is related to three main factors, namely thermo-physiological, sensorial and physiological. Thermo-physiological comfort is a general expression of factors such as the thermal properties, moisture transmission and drying ability of fabrics [Onofrei E et al 2011]. Various researchers made investigations in order to increase comfort properties of garments. However, there is hardly any research work on the moisture and thermal comfort characteristics on eri silk knitted fabrics. The aim of this research is to develop the diversified Eri silk products to enhance the marketability and analyze thermo-physiological comfort characteristics of the Eri knitted fabrics made from the mill spun yarns and also to find out the suitability for winter active garments.

II. MATERIALS AND METHODOLOGY

Materials

The mill spun Eri yarn procured from the leading mill in India and the yarn properties as given the table.

Table 1 : Eri Silk Yarn Properties		
Linear Density	Coarse	Fine
Yarn count (IS1315:1977)	**2/80s Nm**	**2/140s Nm**
Count CV%	3.5%	4.2%

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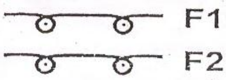
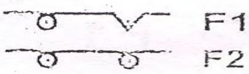
CSP	2900	3350
Single Yarn strength	397gms	347gms
Mean elongation	11.9	12.2
Tenacity (RKM)	15.2	15.0
U% (ASTM D 1425 M:09)	10.8	11.2
Total Imperfection	93	82
Thin (-50%)	21	12
Thick (+50%)	30	32
Neps(+200%)	42	38
Hairiness index	4.62	4.22

Fabric development

Knitting

The above yarns were used to produce single jersey and single pique fabric on Pailung knitting machine of the following details: Single jersey machine, gauge 24 GG, diameter 24”,speed10 rpm,feeders74 ,number of needles 1720; knitting-room atmosphere had a humidity of 60% and a temperature of 32±2°C. Single jersey and single pique structure were produced according to the Fig 1 with two different tightness levels, i.e. slack and tight, with the same machine settings.

Figure 1 Knitted Structure

	
	
Single jersey	Single pique

Wet processing of fabrics

Dyeing was done in an automated Soft flow dyeing machines with material to liquor ratio of 1:10. The dye manufacturers’ recommended processes were followed. The dyed fabrics were washed with normal water, rinsed and then dried. The P^H of dye bath was maintained with acetic acid and sodium carbonate.

Compacting

Compacting is a mechanical finishing process carried out to bring the fabric into dimensionally equilibrium state. Compacting is done with “Tube Tex” compaction calendar machine at 110° C. The fabric is stretched width wise it’s over feed lengthwise. Then it shrunk in length wise in the compressive shrinkage unit.

Testing

The fabric structural and physical fabric properties were evaluated according to international testing standards; weight per unit area (ASTM D 3776), thickness (ASTM D 1777), wales and courses per unit length (WPI & CPI) and stitch length (ASTM D 3887) . The fabrics were measured for their stitch length, aerial density in g/m2 and fabric thickness at different places with the help of Shirley thickness gauge. The aerial density of the knitted fabrics was measured by using the circular GSM cutter of diameter 5.64 cm. The sample was weighed in the electronic balance and the value was multiplied by 100. The loop length was derived by unravelling 50 courses and their total length was measured. The stitch length was calculated using the formula i.e., Total length x No. of wales / 50.

Table 2.The properties of fabric samples

Short code	Yarn linear density	Fabric Structure	Loop length, cm	Tightness Factor, $Tex^{1/2}$, cm	Weight per unit area, g/m^2	Stitch density, $loops/cm^2$	Thickness, mm
CSJ-T	$2/80^s$ Nm	SJ	0.270	18.53	250	16 * 21 = 336	0.92±2
CSJ-S	$2/80^s$ Nm	SJ	0.330	15.16	205	15* 18 = 270	0.81±2

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FSJ-T	2/140^s Nm	SJ	0.250	15.12	140	18*22= 396	0.74±2
FSJ-S	2/140^s Nm	SJ	0.310	12.20	110	17*19=323	0.69±2
CSP-T	2/80^s Nm	SP	0.280	17.86	262	13 *26=338	1.04±2
CSP-S	2/80^s Nm	SP	0.340	14.71	215	12*23=276	0.92±2
FSP-T	2/140^s Nm	SP	0.260	14.54	152	14 *29=406	0.79±2
FSP-S	2/140^s Nm	SP	0.320	11.82	116	13*26=338	0.68±2

T-Tight, S- Slack, SJ –Single Jersey, SP-Single Pique

Thermal Properties

The thermal properties of fabrics evaluated by using computer controlled semi-automatic instrument called ALAMBETA, developed by Technical University in Liberec. Instrument can be measures thermal conductivityλ, Thermal diffusion **a**, thermal resistance **R**, q_{max}, thickness of samples in less than 3 -5 min. The objective measure of warm-cool feeling of fabrics, so called thermal absorptivity b [Ws1/2/m2K] was introduced [2] . In this instrument the fabric is kept between the hot and cold plates according to IS011092. The hot plate comes in contact with the fabric sample at a pressure of 200 Pa. As soon as the hot plate touches the fabric surface, the amount of heat flow from the hot surface to the cold surface through the fabric is detected by heat flux sensors. There is also a sensor, which measures the thickness of the fabric. These values are then used to calculate the thermal resistance of fabric.

Vertical Wicking Testing

Vertical wicking tests were performed on the apparatus shown in Figure 2. Five specimens of 200 mm × 25 mm cut along the wale wise and course wise directions were prepared.

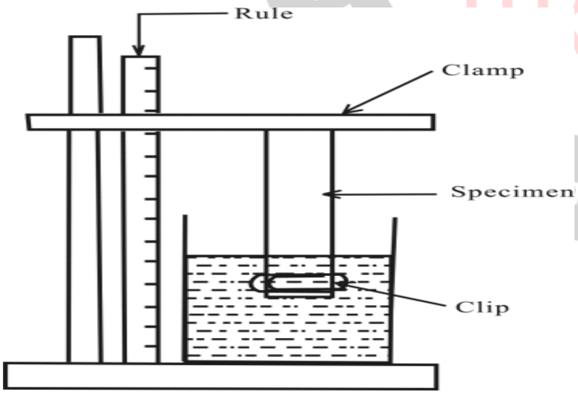

Fig2: Vertical wicking

The specimen was suspended vertically with its bottom end dipped in a reservoir of distilled water. In order to ensure that the bottom ends of the specimens could be immersed vertically at a depth of 30 mm into the water, the bottom end of each specimen was clamped with a 1.2 g clip, as shown in Figure 2. The wicking heights, measured every minute for 10 min, were recorded for a direct evaluation of the fabric's wicking ability.

All measurements were performed under the standard atmospheric conditions 20°±2°C and 65±2% RH. Five readings were taken for each of the knitted fabrics and then the averages were calculated.

III. RESULTS & DISCUSSION

Structural and Physical Properties of the Knitted Fabrics

The properties of fabric samples are given in table 2. It can be seen that the fabrics differed in terms of the knitted structure, the number of courses and wales per cm and Stitch length. The thickness of the fabrics varied with the yarn linear density, stitch length and course density. This is in accordance with established understanding of knitted fabric behaviour. The dimensional, weight and comfort-related properties of knitted fabric are determined by the yarn count and stitch length.

Sample code	Thermal conductivity (W/mK)X 10^{-3}	Thermal absorptivity ($Ws^{0.5}/m^2K$)	Thermal resistance (m^2 K/W) X 10^{-3}
CSJ-T	28.5	78.0	33.7
CSJ-S	24.9	74.2	32.8
FSJ-T	23.4	66.5	28.7
FSJ-S	21.2	57.2	27.9
CSP-T	29.6	86.8	35.1
CSP-S	26.8	78.1	38.2
FSP-T	26.2	63.8	31.5
FSP-S	24.2	54.2	32.4

Table 3. Thermal comfort characteristics of Eri knitted fabrics

Thermal conductivity

Thermal conductivity is defined as the heat transmitted through a unit area at a temperature gradient per unit length. Thermal conductivity is an intrinsic property of a fabric which indicates its ability to conduct heat. It is the flux of heat divided by the temperature gradient. It is observed from the Figure 3 that the thermal conductivity of pique fabrics is higher than those of single-jersey fabrics, which may be due to the air amount inside the fabrics. It is also observed that the fabric structures and yarn linear density have the great influence. The fiber/air proportion in the

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fabric increases with increasing thickness / weight of the fabrics, contributing to the thermal conductivity.

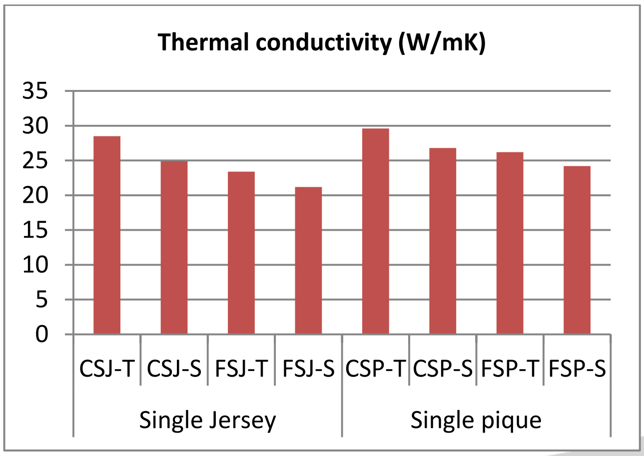

Fig 3 Thermal conductivity of Eri knitted fabrics

Thermal absorptivity

Thermal absorptivity is an objective measurement of the warm–cool feeling of fabrics, introduced by Hes[1987] to characterize the thermal feeling during instant contact of the human skin with the fabric surface. Low absorptivity values indicate a warm feeling, which is desired for winter fabrics, whereas high absorptivity values indicate cool feeling, which is desired for summer fabrics. The thermal absorptivity of pique fabrics is, in general, slightly higher than that of single-jersey fabrics, which can be related with the fabric weight /thickness.

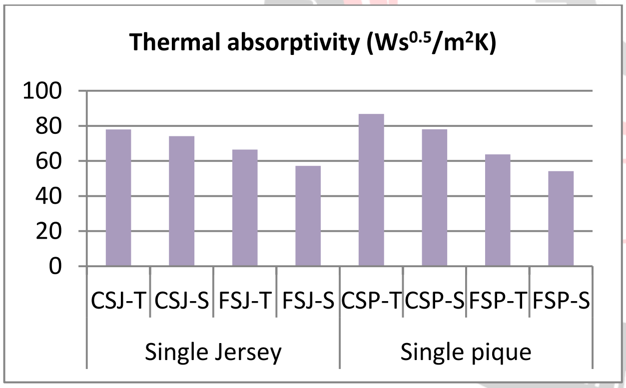

Fig4 Thermal absorotivity Eri knitted fabrics

Thermal Resistance:

Thermal resistance is a measure of a material's ability to prevent heat from flowing through it. Thermal resistance is a very important parameter and is greatly influenced by fabric structure. Increase in fabric thickness will effects in increase in thermal insulation, as there will be a decrease in heat losses for the space insulated by the fabric structre.

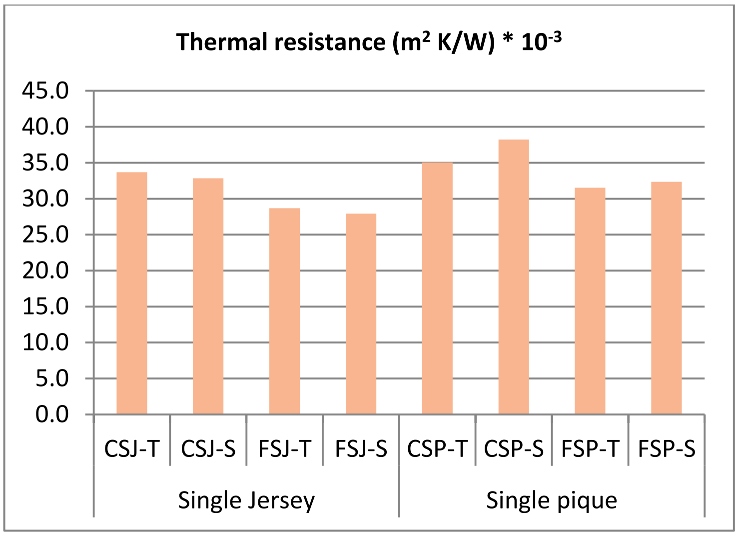

Fig5 Thermal resistace of Eri knitted fabrics

Vertical wicking test results

Figures 6, shows vertical wicking test results for wale and course-wise directions, respectively. The knitted structures, yarn linear density, structure tightness have significant effects on the vertical wicking ability; single jersey has better wicking in nature than single pique fabric. Coarser yarn varieties good wicking property than finer yarn varieties; It is, basically, because of fabric properties such as fabric thickness, tightness factor, pore size, stitch length and density. Benltoufa et al [2007] , indicated that liquid absorbency are closely related to pore size and distribution. Wong [2001] reported that according to the capillary principle, small pores are packed first and, the liquid then moves to the larger pores. The higher pore size of single pique structure attributed for poor wicking.

Dependent-independent Variables	Pearson Correlation coefficient
Wicking height-yarn linear density	0.798
Wicking height-Stitch density	-0.792
Wicking height-Thickness	0.465
Wicking height- Fabric Weight per unit area,	0.613

Table 4. Correlation coefficients for wicking height

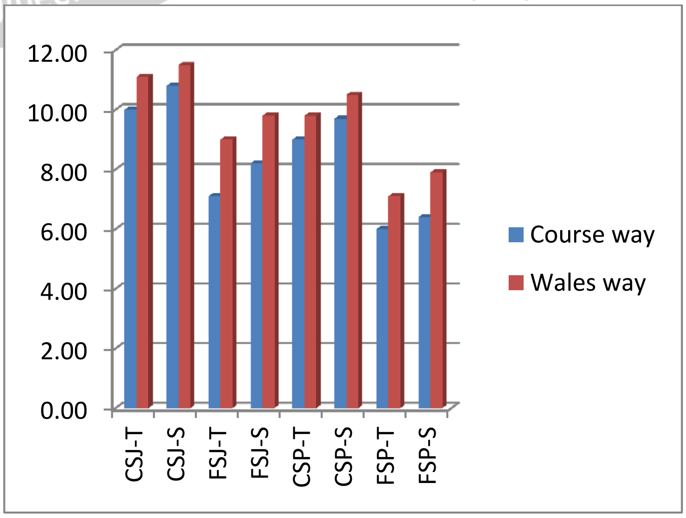

Fig 6 Wicking height at 10 min, mm

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From the Fig 7 and 8, it is observed that the rate of wicking was rapid in the first five minutes. Beyond this, wicking continued to rise but at a significantly lower rate. As explained by Zhuang et al [2002], the initial rapid wicking rate could be due to gravitational forces that interfered with the capillary rise of the liquids through the fabric.

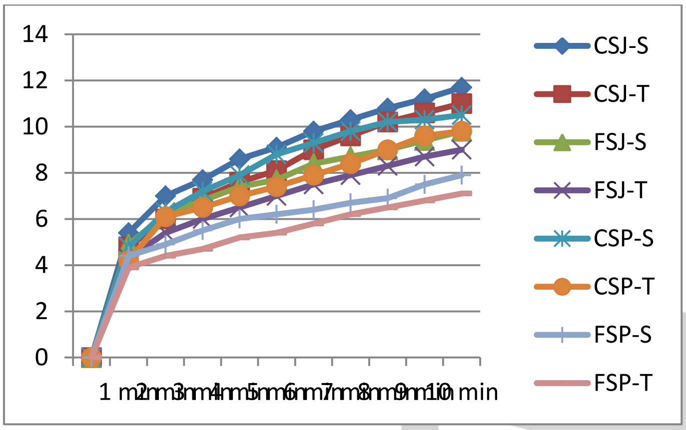

Fig 7 Vertical wicking curves for Course-wise directions.

From Fig 7 and 8, it shows that the slack forms of the different knitted structures show better wicking ability than their tight forms in both directions. The samples also show shorter wicking heights in course-wise direction than for wale-wise direction for all knit structures. It might be related to different loop shapes and densities of the structures for wale-wise and course-wise directions.

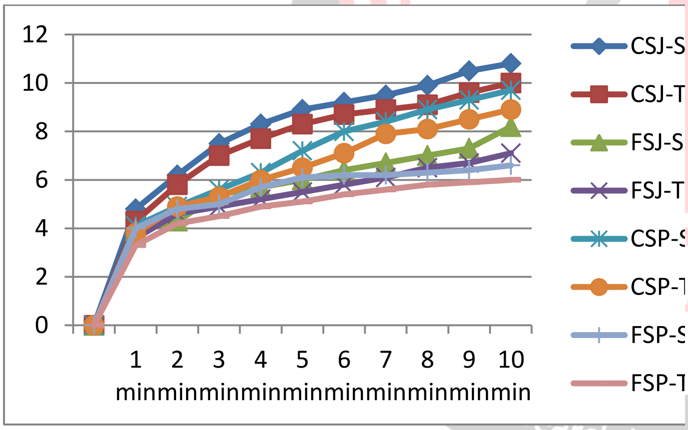

Fig 8Vertical wicking curves for wales-wise directions.

IV. Conclusion

The studies revealed that the Eri spun yarn fabric has good Physical, structural and comfort Properties. It confirms the suitability of Eri silk knit materials for performance based garments. The Knitted fabric produced from these yarns has good demand in international market because Eri spun silk fabric is produced by non violence and is stiffer, has good wicking, thermal insulation properties and warmth. The fabric is soft to wear, is good in all season. Production of Eri Knit Wear and other fashion products out of Eri material provides a better value addition which ultimately increases the price of eri cocoon and yarn; thereby improve the income of poor tribal producers. Eri Silk is skin friendly and it can be used for production of light weight thermal garments.

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