Studies on Red eri silk -wool blended spun Yarns and their fabrics

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Red Eri silk long staple fibres were blended with wool fibre in different proportion for producing ring spun yarn on worsted system of spinning and the yarns produced were converted into plain woven fabrics on power loom. Various fabric properties viz., functional, aesthetic, thermal including low-stress mechanical properties and hand values were determined on Kawabata fabric evaluation system. Blending of eri with wool improve the fabric durability, aesthetic and wear comfort performance. Fabrics produced from 70:30 and 60:40 eri wool blended fabrics are suitable for summer and winter dress material respectively.

Key words: Red eri, Wool, Low-stress mechanical properties, blend spun yarn, Thermal properties, Total hand value.

1. Introduction

Red Eri silk is one of four varieties of silk produced in India[1], in eri silk two types one is red eri and other is white eri silk, both the silk have distinct fibre characteristic. The eri silk is extruded from silk worm which feeds on Castor/tapioca plant leaves. Wool is animal fiber which is sheared from the sheep and both are protein fibre[2].

Eri fiber fineness (14-16 microns) is very close to wool fiber which can be blended easily with wool. Finer wool fibre (14- 16 microns) is not available in India to produce fine and soft qualities of woolen fabrics. Indian Woolen industry is importing 14-16 microns wool fibre from foreign countries and fetches costly[3]. Cost of 16 microns wool is about Rs. 900-1000 per kg compares to Rs 700-750 per kg of eri cocoons. By blending eri with wool fibre in spinning reduces the cost of the blended yarn. In place of finer micron Wool, Eri fibre may be alternative. By blending of Eri with wool, fabric properties like smoothness, luster, durability, dimensional stability, pilling properties, crease resistance, improved as Eri has better above properties than wool. Thermal properties of Eri are close to wool fabric[4-5].

The both eri fibre are finer fibre fabric made from these fibre are more comfort to wear[6]. The comfort is more active state of pleasure in wear. The clothing comfort is divided into three groups such as physiological, tactile and thermal comfort. Physiological comfort is mainly related to latest fashion trend and acceptable in the society. The tactile comfort has relationship with fabric surface and mechanical properties. The thermal comfort is related to the ability of fabric to maintain temperature of skin through transfer of heat and perspiration generated within the body[7].

In the present work, red eri silk – wool blended yarn were produced using different blend ratios. The blends were deliberately selected as eri silk rich to produce the fabric will have better hand value. The properties of eri-wool blended yarn were tested and yarns were converted into plain woven fabrics on power loom. These fabrics of were tested for various conventional fabric properties including thermal as well as for hand value on Kawabata fabrics evaluation system to examine the changes in hand value by addition of eri silk fibre to wool.

2. Materials and methods

2.1 Eri silk and wool fibre having the following specifications were used for the study given in table 1

2.2 Methods

2.2.1 Yarn preparation

Four eri- wool (70:30, 60:40, 50:50, 30:70) blended yarns (2/68^s) , one 100 % eri yarn and 100 % wool yarn were prepared on worsted system of spinning

2.2.2 Yarn quality Evaluation

2.2.2.1 Unevenness and Imperfections

The measurement of yarn unevenness and imperfection was done on Uster-4. The yarn irregularity in terms of Um% and the imperfections in terms of tick places, thin places and neps were evaluated.

2.2.2.2 Yarn count

The yarn count was measured with help of wrap reel and electronic balance

2.2.2.3 Breaking strength, elongation %, young's modulus, Tenacity and work of rupture

The Breaking strength, elongation %, young's modulus, Tenacity and work of rupture were measured on Instron tester using the standard procedure in accordance with ASTM D 2256.

2.2.3 Fabric preparation

The plain woven fabrics were made on power loom using same yarn in warp and weft with parameter of ends per inch 60, Picks per inch 42 and width of fabric 54 inches.

2.2.4 Fabric properties

2.2.4.1 Functional properties

- Weight per square meter of the fabric was measured as per IS 1964-2001.
- Thickness of fabric was measured as per IS 7702-1975.
- Air permeability of the fabric was measured as per IS 11056-1984 PROLIFIC air permeability tester.
- Bursting strength was measured as per IS 1966-1975
- Tearing strength of the fabric was measured as per IS 6489-1993
- Tensile strength and elongation of the fabric was measured as per IS 1969-1985, Instron 50x 200 mm strip 300 m/min.
- The drape of sample was measured as per IS 8357 ,1977.
- The Abrasion resistance of fabric was measured as per IS 12673- 1989 Martindale abrasion tester.
- The Crease recovery of fabric was measured as per IS 4681- 1981
- The Bending length and flexural rigidity was measured as per IS 6490-1971.
- The Water repellency of fabric was measured as per IS 390 1975.
- The Pilling resistance of fabric was measured as per IS 1097-1964
- TIV was measured in (guarded hot plat method)-Thermolabo-II Wind speed -1m/sec.

2.2.4.2 Low stress mechanical properties

The fabrics were tested for low-stress tensile, bending, shear, surface and compressional properties on Kawabata fabric evaluation system. The primary hand value and total hand value (THV) were estimated from these results using Kawabata system of equations. For the evaluation of hand values, 16 Low stress mechanical fabric attribute were determined (Table 1 A).

3. Results and discussion

3.1 Yarn properties

2- Yarn unevenness, imperfections, hairiness and tensile properties

3.1.1 Unevenness, Imperfection, hairiness properties

The values of unevenness, imperfections and hairiness and index of irregularity are given in table From Table 2. The absolute unevenness, imperfections, hairiness and index of irregularity appears to be at higher side in 100 % wool spun yarn. The addition of eri silk fibre in spun silk yarn there is significant improvement in evenness and reduction of imperfections, hairiness and index of irregularity. The improvement in quality of blended spun silk yarn is due to more evenness, and longer fibre of eri silk fibre[8].

3.1.2 Tensile properties

The table 2 shows that values of Breaking force, tenacity, elongation percentage, young modulus and B-work significantly improves with increases of eri silk component in the blended yarn. The improvement in tensile properties of blended yarn due to tenacity and elongation percentage of eri fibre is higher than wool fibre which influences the yarn properties. The Higher strength of eri silk fibre is due to silk fibre composed of linearly folded, beta configuration and very crystalline polymers have more hydrogen bonds formed in regular manner. The low tensile strength of wool is due to relatively few and shorter hydrogen bonds are formed. The higher elongation percentage of eri silk fibre due to polymer structure of eri silk fiber has high visco-elastic, more bulky side group in nature compared to wool polymer. The eri silk polymer segment in the amorphous regions will flow more easily[9].

3.1.3 Optical properties

The values of optical properties are presented in table 2. The optical properties like whiteness index, yellowness index and brightness index improves with increase of eri silk component in blended yarn. This is due to fact that light falls on the silk fibre is uniformly reflected form triangular cross section of silk fibre, where as in wool light falls on circular cross section of fibre scatter the light rays as a result reduced optical properties .

3.2 Fabric properties

3.2.1 Breaking strength, tearing strength and elongation percentage

Breaking strength and tearing strength and elongation percentage are given in table 3. These values are higher in warp way fabric than weft way fabric in all varieties of fabrics. This is due to warp density in fabric is higher than weft density. These values are significantly increases with increases of eri component in blended yarn. These values are higher in 70:30 eri wool blend fabrics because of this fabric has higher thickness value.

These values are least in 100% wool fabric. Eri fibre has higher strength and elongation percentage than wool which reflects in the fabrics.

3.2.2 Air permeability (m3/m2/min):-

Air permeability is reciprocal of the air resistance. The resistance of the fabric to the flow of air is a measure of the initial warmth/ cool feeling when the garment is wear. The higher the air flow value, the greater the intensity of warm/cool feeling will be. The effect of air permeability on comfort properties is much greater when the speed of air is high. The amount of air pass through a unit fabric area per unit time is given in table 3. The results show that blending of eri wool fibre is significantly influencing the air permeability of blended fabric.

Higher air permeability noticed in 70:30eri wool blended fabric as compared to other fabrics due to this fabric has lower cover factor and lower hairiness in the yarn due to longer length of eri fibre used. The air permeability results shows that the fabrics made from 70:30 eri wool blended yarn are most suitable for summer wear.

3.2.3. Water repellency and Pilling resistance (rating)

High and uniform absorbency of water is desirable quality of the fabric. Absorbency of fabrics is influenced by their wicking ability. The absorbency is very important in quick evaporation of perspiration in under garment, absorption of water by towel, cleaning cloth, diapers, gauge and bandages. Pilling is tufts of entanglement of fibers are attached to the surface of the cloth and they look like small pills. The value of water repellency and pilling resistance rating are given in table 3. These values remain same for all blended and pure fabrics due to that all varieties of fabrics are hydrophilic in nature. The polymers of both fibres have hydroxyl groups in the polymer structure are polarity in nature which attract more water molecules, hence fabrics are more comfortable to wear. The results shows that sever piling noticed owning to their yarn hairiness, yarn content and their fibre type.

3.2.4 Abrasion resistance (no of rubs) and bursting strength (Kgf/cm^2)

Abrasion is just one aspect of wear and is rubbing away the component fibers and the yarn of the fabric during usage. Bursting strength is measure of fabric resistance to multidirectional force. The results of abrasion resistance and bursting are given in the table 3. It is observed from table that abrasion resistance and bursting strength increases significantly with increases eri component in the blended yarn. Abrasion resistance and bursting strength of 70:30 eri: wool fabric has highest value compared to other fabrics due this fabric has higher component of eri fibre and higher thickness value. The Pure wool fabric has low value of these values due to wool fibre has lower strength and elongation percentage than eri fibre is reflecting in the fabric.

3.2.5 Drape coefficient (%)

Drape is the ability of the fabric to assume a graceful appearance in use. It is an important factor of textiles materials, which allows fabric to orient itself into graceful folds or pleats as results of force of gravity. The results of drape coefficient of blended fabrics are given in table 3. The result indicates that the drape coefficient of blended fabric is significantly decreases with increase of eri component in the blended yarn. Among the blended fabric 70:30 eri wool blended fabric shows lower value of drape coefficient and 100% pure wool fabric shows higher value. Fabric having smaller values of drape coefficient are considered to hang down well and cling to a curved surface easily. This is due to combined fabric thickness and weight and fibre fineness affects the drape properties of blended fabrics.

3.2.6 Flexural rigidity (Stiffness (mg-cm)

Fabric stiffness indicates the resistance of the fabric to bending key factor in the study of hand and drape. The results of flexural rigidity of blended fabrics are given in table 3. The results show that flexural rigidity of weft is higher than warp in all six varieties of fabrics. This is because of warp density in the fabric is higher than weft density. Among the blended fabric 70:30 eri wool blended fabric shows lower value of flexural rigidity and 100% pure wool fabric shows higher value. Fabric having smaller values of drape coefficient are considered to hang down well and cling to a curved surface easily. This is due to combined fabric thickness and weight and fibre fineness affects the flexural rigidity of blended fabrics.

3.2.7. Thermal Insulation value (TIV)

Thermal insulation value provided by fabrics depends on fibre type, fabric thickness, bulk density of, fibre arrangement and the compressibility of fabric structure. The mechanism of heat transfer involves dry heat transmission through conduction, convection and radiation. Latent heat transfer due to water vapor transport and liquid water transport also determines the thermal property so fabric[10]. The thermal insulation properties of various fabrics measures on thermo lobo (KE-FB5) are shown in the table 3. The results show that thermal insulation value significantly influenced by blending of eri silk with wool. Thermal insulation value depends upon type of fibre air permeability and thickness of fabric. Among the blended fabric 50:50 eri wool blend fabric has higher thermal insulation value this is due to the fabric has higher thickness and low air permeability. It maybe concludes that eri wool blended fabric can provide desired protection to the human body against climatic fluctuations. Flatness of eri fibre will cling and trap air between the fibre results in higher thermal insulation value in blended fabric.

4. Low stress mechanical properties

4.1 Low stress tensile properties

The results show that low stress mechanical properties are given in table-4-7. Table 4 shows various blended fabrics attributed to tensile properties. EMT is tensile strain biaxial extension. The large value EMT the greater will be the wear comfort[11]. EMT of fabric increases with increase of eri component in blended yarn. Among the blended fabric 60:40 eri shows higher value wool due this fabric higher areal density and higher eri component. This implies that that the heavy fabrics might be better handle due to their extensibility at low stress deformations.

LT represents linearity of stress-strain curve. It has some correlation handle of the fabric. A higher value of LT is suppose to b better from this point of view 100 % eri fabric has highest values.

WT represents tensile energy (i.e. area under the load elongation curve). It is strongly related with the movement of the boy parts in particular garment and fabric handle Lower value of WT is better in the respect. It is observed from the table that 70: eri wool fabric is the best among the blended fabric. The value is decreasing with increase of eri component in blended yarn due to different loading of fibre in the yarn cross section.

RT represents the recovery from tensile deformation. The higher value of RT makes the fabric more elastic. Among the blended fabric 50: 50eri wool bend shows highest value of RT values increase with increase of eri component in blended yarn.

4.2 Shear properties

Shear rigidity (G) of blended fabric is lowest for 70:30 eri wool blended fabrics is given table 4. The shear rigidity of fabric depends mainly on the mobility of warp/weft threads in the fabrics, while the mobility depends upon the frictional property of constituent fibre, yarn dia. and surface properties of yarn. The lower value of G is prepared for better handle of the fabric[12]. Therefore 70:30 eri wool blended fabric is the best in comfort to wear.

2HG and 2HG5 are the hysteresis of shear force at 0.5° and 5° respectively. s. The hysteresis of blended fabrics significantly reduces with in increase eri component in the bled yarn. Among the blended fabrics, the results shows that the hysteresis is the lowest (recovery is better from shear deformation) for 70:30 eri wool blended fabric. The high value of hysteresis gives trouble in tailoring and also shows wrinkling during wear.

4.3 Bending properties of the blended fabric

Bending is a measure of how easily fabric bends can bend, bending rigidity (B) of fabric depends upon the bending rigidity of fibre, yarn and the mobility of warp and weft threads within the fabric. Table 5 shows that bending rigidity is lowest for 70:30 eri wool fabric, this fabric should give a superior Koshi (primary hand value) and highest for 100% pure wool fabric. This is due fact that eri fibre are finer than wool and 70:30 eri wool fabric is lowest thickness and weight value. The finer fibre of eri silk is more flexible than wool fibre. The hysteresis of bending moment 2HB shows same trend shown by bending rigidity.

4.4 Surface properties

Table 5 shows the coefficient of friction (MIU) is the lowest for 70:30 eri wool blended fabric and is higher in 50:50 eri wool blended fabric. The geometric roughness (SMD) is highest for 70:30 and least in 50:50 eri wool blended fabric. This may be due to fineness of eri silk fibre and evenness of blended yarn influences the MIU. The coefficient of friction depends upon contact area of the fabric with that of the body. MMD is a measure of the Variation of MIU.

4.5 Compressional properties

There is no clear trend noticed in compressional properties are given in table 6. However Linearity of compression (LC) is slightly higher for the fabrics prepared from for 70:30 eri wool blended fabric and lowest 50:50 eri wool blended fabric. The compressional energy (WC) is slightly lower for 70:30 eri wool blended fabric and is slightly higher in 50:50 eri wool blended fabric. The value of compressional resilience (RC) is slightly higher for 100% wool fabric. The compressional property of fabrics mainly depends on compressional behavior of fibre, yarn and fabric thickness.

5. Fabric hand value

From the above low stress mechanical properties, the primary hand value, total hand value (THV) were estimated using Kawabata system equation considering the fabric for summer wear, THV was estimated using primary hand value such as KOSHI(Fabric hardness),SHARI(fabric crispness), HARI (fabric hardness) and FUKURAMI (fabric fullness) [7]. For the THV of winter wear three primary hand values (KOSHI, NUMERI (fabric surface smoothness) and FUKURAMI) were used. The calculated primary and total hand vales for winter and summer are given in the table 7. Total hand value is the measure of tactile comfort provided by the clothing. THV is found to be higher for 70:30 eri wool blended fabric in summer wear and higher for 60:40 eri wool blended fabric in winter wear.

Conclusion:-

From the study it is revealed that by blending of eri silk with wool fibre in spinning helps in improving, evenness, imperfections, hairiness, tensile strength, young modulus, elongation and work rupture. The improvement in yarn properties is clearly reflected in fabric properties like increase in fabric tensile, extensibility, tearing and bursting strength, air permeably, thermal properties, reduction in drape coefficient and flexural rigidity, Blended fabrics are good moisture absorbent and pilling resistant, From this it is concluded that fabrics made from eri wool blended yarn are durable, soft, good aesthetic, tactile and thermal comfort properties. From the Kawabata analysis it is noticed that fabric made from 70:30 eri wool blend has higher these properties and is most suitable for summer garments and more comfortable and fabric made from 60:40 eri wool blended is more comfortable in winter wear and as this fabric has higher hand value in winter, higher thermal and low air permeability value.

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Table 1- Fabric mechanical attributes

Fibre parameter			
Sl. No.	Property	Eri	Wool
1	Fibre dia. (microns)	16	25
2	Breaking Tenacity(g/tex)	29.4	12.5
3	Elongation%	11	10
4	Effective mean length (Hmm)	54.5	45.6

Table 1 A - Fabric mechanical attributes

Instrument and parameter	Symbol	Characteristic value	Units	Test method
KES –FB1 Tensile (using shear and tensile tester)	LT	Linearity load – Extension Curve	None	1. Sense : 5x 5 2. Velocity :0.2 mm/sec 3. Elongation: 25 mm/10V 4.Tensile force 500gf/cm 5. sample Size : 5 cm x 20 cm
	EMT	Extensibility	%	
	WT	Tensile energy	gf.cm/cm^2	
	RT	Tensile resilience	%	
KES –FB1 Shear (using shear and tensile tester)	G	Shearing Stiffness	gf.cm/deg	1. Sense : 2x 5 2. Rate of sharing 0.417 mm/sec 3. Angle 8 deg 4. weight 200 g 5. Size : 5 cm x 20cm
	2HG	Hysteresis of Shear force at 0.5^0 of share angle	gf/cm	
	2HG5	Hysteresis of Shear force at 5^0 of share angle	gf/cm	
KES –FB2 Bending (using pure bending tester)	B	Bending rigidity	gf.cm^2 /cm	1. Sense : 2x 1 2. rate of bending 0.5 cm^{-1}/s 3. B K=0.5- 1.5 cm^{-1} 4. 2HB K=1.0 cm^{-1} 5. Size : 20 cm x 1 cm
	2HB	Hysteresis of Bending moment	gf.cm /cm	
KES –FB3 Compression (using compression tester)	LC	Linearity of compression –thickness Curve	None	1. Sense : 2x 5 2. Velocity : 50 sec/ mm 3. Stroke : 5mm/10V 4. Area : 2 cm^2 5. Maximum compression load 50 gf /cm^2
	WC	Compression energy	gf.cm /cm2	
	RC	Compression resilience	%	
	T	Thickness	mm	
	Wt	Fabric weight	mg/ cm^2	
KES –FB4 Surface (using surface tester)	MIU	Coefficient of friction	None	1 sense : 2 x 5 for both MIU & SMD 2.Fabric tension 20g 3.Load on roughness detector 10g 4.Load on surface friction detector 10g 5. Fabric speed 1mm/second Maximum sweep 3 cm.
	MMD	Mean deviation of MIU	None	
	SMD	Geometrical roughness	Micron (μm)	

Table 2- Yarn unevenness, imperfections, hairiness and tensile properties

Blended yarn quality parameter has been studied							
Per / 400 km	**100% Eri (67.6)**	**30% wool: 70% Eri (74)**	**40% wool: 60% ERI (65.8)**	**50% wool: 50% Eri (78.4)**	**70% wool: 30% Eri (76)**	**100% Wool (61.2)**	**C.D at 5%**
Um %	10.16	13.30	14.21	15.35	15.64	16.59	1.206
Cv m %	12.99	18.06	19.07	19.52	19.89	21	1.509
Cvm (1m) %	4.76	5.78	6.28	6.84	8.25	8.96	1.728
Thin Places (-50%)/km	2	118	131	225	347	372	60.42
Thick Places (+50%)/km	46	161	180	248	252	292	42.418
Thick Places (+100%)/km	1	5	8	12	12	14	4.036
Neps (+ 140 %)/km	150	240	395	408	524	613	61.591
Neps (+ 200 %)/km	42	59	78	128	131	163	25.59
Neps (+ 280 %)/km	14	24	28	53	72	98	14.027
Neps (+ 400 %)/km	7	8.00	11	23	25	61	8.243
Hairiness (-)/km	2.19	2.65	3.05	3.09	3.11	5.55	0.183472
Index of irregularity	1.09	2.49	2.52	2.52	2.59	3.04	0.2007
Mechanical properties							
Breaking Force (gf)	726.66	424.40	411.60	319.00	260.10	191.10	18.78
Elongation (%)	16.530	16.400	15.330	14.650	13.650	12.17	1.91
Tenacity (gf / den)	2.24	1.57	1.39	1.38	0.96	0.57	0.0780
Young modulus	382.283	287.432	282.87	245.488	245.488	231.02	20.7
B-Work(Kgf.cm)	35.444	20.329	19.864	15.611	10.359	9.488	2.449
Yellowness	21.993	21.6	21.263	21.112	21.11	19.423	
Whiteness Index	46.285	44.663	43.713	43.489	43.299	42.688	
Brightness index	49.935	46.451	44.834	44.039	43.735	43.084	

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Table 3- Mechanical properties of Eri/wool blended Fabric properties

Sl.No	**Character**		**E100%**	**W/E(30:70)**	**W/E(40:60)**	**W/E(50:50)**	**W/E(70:30)**	**W 100%**
1	Linear Density(Ne)	warp	22.0	22.2	21.1	23.1	21.6	17.6
		weft	22.9	20.6	21.5	22.2	20.9	22.6
2	Threads	Ends/dm	248	244	246	247	247	252
		Picks/dm	202	176	209	201	178	176
3	**Fabric mass(g/m2)**		131.2	122	139.3	125.1	124	136.4
4	**Thickness(mm)**		0.357	0.407	0.359	0.332	0.392	0.377
5	Cover factor		19	18.4	**19.5**	18.9	18.5	19.6
6	**Tensile strength**							
A	Breaking strength(kg)	warp	39.1	**53.6**	42.4	33.7	44.1	29.1
		weft	31.2	48.5	36.5	27.3	31.3	23.9
B	Elongation%	warp	29.2	30.9	**32.1**	29.2	28.5	23.8
		weft	22.2	21.9	22.4	18.2	20.2	21.5
7	**Tearing strength(g)**	warp	5453	5568	**5018**	4813	3686	3763
		weft	4646	5325	**4070**	4582	2675	2765
8	Water repellency (rating)		0	0	0	0	0	0
9	**Air Permeability(m3/m2/min)**		71.4	**94.6**	**38.3**	62.6	**85.9**	52.6
10	Pilling resistance(rating)		4	4	4	4	4	4
11	**Abrasion resistance(no of rubs)**		355	472	344	270	263	275
11	**Drape coefficient (%)**		43.2	**42.5**	48.3	48.5	45.9	51.8
12	**Bursting strength(kgf/cm2)**		8.0	10.8	9.0	8.5	8.4	7.5
13	**Stiffness(mg-cm)**	warp	141.6	122.6	207.4	129.9	150.9	188.6
		weft	157.6	150.2	305.8	168.7	193.8	213.1
		overall	**149.4**	**135.7**	**251.8**	**135.7**	**171**	**200.5**
14	**Thermal Insulation Value (TIV)**		**23.60**	23.90	**28.00**	**27.402**	**27.30**	**26.90**

Table 4 – Low stress Tensile and shear properties

			Tensile properties				**Shear properties**		
Sl. No.	**Particulars**		**LT**	**WT**	**RT**	**EMT**	**G**	**2HG**	**2HG5**
1	W 100%	Warp	0.78	7.35	62.22	3.76	1.37	4.55	5.31
		Weft	0.71	8.92	51.54	5.06	1.29	4.09	5.00
		Avg	0.74	8.14	56.88	4.41	1.33	4.32	5.16
2	WE (70:30)	Warp	0.34	10.65	50.84	5.81	0.96	6.19	6.54
		Weft	0.68	5.15	62.68	3.05	0.98	5.53	6.22
		Avg	0.71	7.90	56.76	4.43	0.97	5.86	6.38
3	WE (50:50)	Warp	0.76	10.2	58.82	5.36	1.30	5.16	5.94
		Weft	0.68	5.00	65.01	2.95	1.26	4.29	5.19
		Avg	0.72	7.60	61.92	4.16	1.28	4.72	5.56
4	WE (40:60)	Warp	0.78	11.20	50.78	5.72	1.68	8.31	9.01
		Weft	0.70	4.82	61.14	2.76	1.52	7.69	8.65
		Avg	0.74	8.01	55.96	4.24	1.60	8.00	8.83
5	WE (30:70)	Warp	0.70	9.55	48.60	5.45	0.91	5.69	6.88
		Weft	0.70	4.50	63.91	2.59	0.80	4.26	5.63
		Avg	0.70	7.03	56.26	4.02	0.85	4.98	6.25
6	E 100%	Warp	0.76	10.65	53.44	5.61	1.35	6.54	7.35
		Weft	0.75	5.28	61.14	2.82	1.41	6.15	7.19
		Avg	0.75	7.96	57.29	4.22	1.38	6.34	7.27

Table 5 – Bending and surface properties

			Bending properties		Surface properties		
Sl. No.	**Particulars**		**B**	**2HB**	**MIU**	**MMD**	**SMD**
1	W 100%	Warp	0.1509	0.1256	0.148	0.013	11.23
		Weft	0.1236	0.2744	0.193	0.030	8.49
		Avg	**0.1373**	**0.2000**	**0.171**	**0.026**	**9.86**
2	WE (70:30)	Warp	0.0930	0.1723	0.146	0.025	13.22
		Weft	0.1180	0.2080	0.186	0.034	10.06
		Avg	**0.1055**	**0.1901**	**0.166**	**0.030**	**11.64**
3	WE (50:50)	Warp	0.1104	0.1326	0.170	0.097	9.84
		Weft	0.1088	0.1426	0.184	0.034	7.33
		Avg	**0.1096**	**0.1411**	**0.177**	**0.065**	**8.58**
4	WE (40:60)	Warp	0.1132	0.1706	0.158	0.071	8.861
		Weft	0.1643	0.2596	0.181	0.033	8.728
		Avg	**0.1388**	**0.2151**	**0.170**	**0.050**	**8.794**
5	WE (30:70)	Warp	0.0730	0.1217	0.148	0.020	13.26
		Weft	0.0816	0.1360	0.157	0.033	15.11
		Avg	**0.0773**	**0.1288**	**0.152**	**0.026**	**14.19**
6	E 100%	Warp	0.1104	0.1737	0.161	0.105	11.25
		Weft	0.1394	0.2116	0.178	0.030	9.93
		Avg	**0.1249**	**0.1927**	**0.170**	**0.068**	**10.59**

Table 6 – Compressional properties

		Compressional properties				
Sl. No.	**Particular**	**LC**	**WC**	**RC**	**Thickness (T)**	**Fabric (wt)**
1	W (0:100)	0.311	0.248	59.28	0.721	14.77
2	E:W(30:70)	0.345	0.255	44.70	0.726	13.38
3	E:W(60:40)	0.267	0.273	48.38	0.824	13.73
4	E:W(50:50)	0.340	0.271	50.13	0.725	14.82
5	E:W (70:30)	0.327	0.231	43.27	0.694	11.62
6	E (100:0)	0.276	0.255	49.82	0.767	13.82

Table 7- Hand and Total hand value of fabrics (summer and winter)

	Hand value				THV (summer)	Hand value			THV (winter)
Variety	**KOSHI**	**SHARI**	**FUKURAMI**	**HARI**		**KOSHI**	**NUMARI**	**FUKURAMI**	
Wool	5.70	5.16	3.83	7.19	3.01	4.80	0.44	3.42	2.11
W/E70:30	4.75	5.52	3.85	6.44	3.31	4.41	2.13	5.02	2.18
W/E50:50	5.02	4.83	3.86	6.60	3.02	4.51	3.13	4.96	2.22
W/E40:60	6.02	5.32	3.72	7.74	2.90	4.72	2.12	3.87	**2.55**
W/E30:70	3.81	5.83	3.73	5.56	**3.53**	4.28	3.48	4.39	2.16
ERI	5.69	5.82	3.42	7.53	3.05	4.80	0.44	3.42	2.11

Primary hand expressions and their meaning

Koshi: Stiffness/firmness

Shari: Crispiness

Hari: Anti drape stiffness/hardness

Fukurami : Fullness/softness

Numeri: Smoothness