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A study on the Low Stress Mechanical properties of spun silk sarees woven on Handloom

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Article

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ABSTRACT

The silk handloom industry consumes two-thirds of the raw silk produced domestically in India. It was envisaged to develop a handloom silk saree using spun silk as warp and or weft and study the fabric characteristics in terms of low-stress mechanical properties using Kawabata analysis. Accordingly, a commercially available finer variety of Nm 210/2 spun silk was used as warp and or weft to produce three types of silk sarees and compared with regular reeled silk saree. Two types of spun silk sarees showed significantly lesser bending stiffness when compared to the reeled silk saree that implies, the fabric is less stiff with better drape-ability. The shear rigidity of all the spun silk sarees was significantly lower than that of reeled regular silk saree. It implies that the spun silk fabric can be easily distorted in laying up, marking and cutting. As such it is easy for folding and sleeve insertion during fabric stitching. Also, the spun silk saree possesses tensile, surface and compression properties at par with reeled silk saree. The analysis revealed that the Primary Hand Values (PHV), Koshi (Stiffness), Numeri (Smoothness) and Fukurami (Softness) including the Total Hand Value (THV) for the women's thin dress material were better than that of regular reeled silk saree. The results of thermal properties revealed that the Q-max, CLO and TIV of the spun silk sarees are significantly better than that of regular reeled silk saree.

KEYWORDS

spun silk saree, tensile, bending, shear, comfort, surface properties

INTRODUCTION

The silk handloom industry constantly explores the possibilities of producing new and innovative products to retain its niche market. On the other hand, the spun silk industry is facing acute marketing problems associated with highly fluctuating raw material prices. To explore the possibility of using spun silk in the handloom industry, Central Silk Technological Research Institute, Bangalore initiated a research project to produce spun silk saree on handlooms. Accordingly, the quality parameters of the spun silk should match the present handloom filament silk quality parameters. In the handloom industry, 20/22 denier (den) raw silk is used in the warp, where the individual thread is twisted, doubled and again twisted in the opposite direction to make warp thread, organzine, which is always used as a double-strand as one end. Also, 24/26 den raw silk is used in the weft, where the individual thread is doubled and twisted to make weft thread, tram,

which is always used as a three-fold or four-fold strand as one pick. Moreover, the resultant linear density of the degummed warp end as well as the weft pick are almost equal to the linear density of Nm 210/2 spun silk. Thus, it was envisaged to use a commercially available finer variety of Nm 210/2 spun silk either as warp and or weft to produce the butta silk sarees.

The silk handloom industry consumes two-thirds of the raw silk produced (30000 t/annum) domestically in India. Unfortunately, no literature is available on the quality characteristics of silk saree produced on the handloom, particularly on the low-stress mechanical properties. That is because the silk sarees are classified based on the type of dye/colour, motif, body, border, pallu and type of loom used for production. The manuscript under consideration deals with one such product, the Butta silk saree. Each costs 700 USD, predominantly as a Kanchipuram silk saree that has a geographical indication (GI) tag. A GI application that shows yarn characteristics, fabric construction, and zari thread constituents like gold, silver, copper and silk, but it does not indicate the fabric quality, utility, durability or comfort characteristics. Earlier studies on low-stress mechanical properties of silk fabric revealed that the silk Habutae has high Koshi (stiffness) and Kishimi (scroop) and low Shari (crispness). Silk Dechine shows high Shinayakasa (flexibility with soft feeling) and low Hari (anti-drape stiffness). Silk Georgette has good Shinayakasa (flexibility with soft feeling), but poor Hari (anti-drape stiffness) and Fukurami (fullness). Silk Fujiginu has a slightly high Kishimi (scroop) and a slightly low Shari (crispness). High Koshi (stiffness) and Hari (anti-drape stiffness) with low Shinayakasa (flexibility with soft feeling) are distinctive features of silk Chirimen. Silk Shantung has higher Koshi (stiffness) and Hari (anti-drape stiffness) and lower Shinayakasa (flexibility with soft feeling) [1]. The blended silk fabrics have higher resilience as well as warp-wise extensibility. The union-blended silk fabrics have high bending hysteresis, high tensile energy, lower coefficient of friction, and less geometric roughness. The total hand value (THV) of silk blended fabrics showed its suitability for women's lightweight winter dress material and suiting and the union-blended fabrics were suitable for men's winter suiting [2]. One such study revealed that the gap between the warp and weft threads at their crossover points in woven silk fabrics is responsible for the very low values of shear stiffness and hysteresis of shear force in these fabrics [3].

The Central Silk Board, a government body in India (the second largest country in the world to produce all varieties of silk next to China), is all along emphasized quality and productivity improvement and drudgery reduction. Of late, projects are initiated to address product development and consumers' requirement. Thus, it was envisaged to develop a handloom silk saree using spun silk as warp and or weft. The handloom industry aspired to develop products with subdued colours that are preferred by the younger generation in silk saree. The prominent handloom silk saree varieties are dyed either using the basic or direct class of dyes to have more lustre. The spun silk after dyeing is not as lustrous as that of filament silk.

EXPERIMENTAL

Materials and Methods

Materials

Initial discussion with the silk weavers on the possibility of using Nm 210/2 spun silk (tenacity of 23 cN/tex and elongation of 8%) having the twist level of 1420 twist/m as a replacement to the reeled silk (tenacity of 28 cN/tex and elongation of 16%) that has the twist level of 630 twist/m revealed that the finer variety of spun silk yarn selected may not be suitable as warp and weavers suggested to insert an additional twist to the spun silk. Thus, Nm 210/2 spun silk was again twisted to have an additional twist to the level of 870 twist/m to use as warp or weft. Accordingly, it was finalized to use reeled silk, spun silk with a standard twist and spun silk with an additional twist either as warp or weft to produce nine possible combinations of fabrics for subjective analysis. Three yarns were dyed in a single bath in small quantities to ascertain the dyeing behaviour of the spun silk using acid dye (Crymson Special; Nitin dyes) at 85 °C for 30 min using the standard dyeing method [4-8]. It was found that the spun silk dye absorption was not at par with the filament silk and was found to be lighter. Moreover, the spun silk with a standard twist was darker than that of spun silk with an additional twist. The inner portion of additionally twisted spun silk was not dyed to the core. Thus, it was decided to use higher shade depth for spun silk with better exhaustion techniques.

Initial weaving trials were conducted to weave 12.7 cm x 30.5 cm fabric sample bits by using three types of warp silk namely reeled filament silk (organzine), spun silk with a standard twist (single) and spun silk with an additional twist (single) and three types of weft namely reeled filament silk (tram; 4 fold), spun silk with a standard twist (2 fold) and spun silk with an additional twist (2 fold) [9]. Thus, nine combinations of silk fabric bits were prepared. The subjective analysis of all the 8 nos. fabrics in comparison with the control fabric (organzine x tram) was carried out for its appearance, feel, lustre and drape with the help of 10 master weavers/experts, who unanimously agreed that three combinations:

- (1) reeled filament silk (organzine) and spun silk with a standard twist (2 fold),
- (2) spun silk with a standard twist (single) and reeled filament silk (tram; 4 fold) and
- (3) spun silk with an additional twist (single) and reeled filament silk (tram; 4 fold)

were similar to the control sample and recommended conducting a larger trial to produce 5.5 m silk saree with butta design. Accordingly, four silk sarees were produced with butta design as per the details mentioned in Table 1.

Table 1. Butta silk saree fabric specification

Specification	Sample A	Sample B	Sample C	Sample D (control)
Warp	Spun silk, additional twist (single warp)	Mulberry silk (double warp)	Spun silk, standard twist (single warp)	Mulberry silk (double warp)
Weft	Mulberry silk (4 Fold)	Spun silk, standard twist (2 Fold)	Mulberry silk (4 Fold)	Mulberry silk (4 Fold)
Warp colour	Tomato red (red SRS: 7%)	Tomato red (red SRS: 5%)	Tomato red (red SRS: 6%)	Tomato red (red SRS: 5%)
Weft colour	Rose (red 3BN :6%)	Rose (red 3BN :8%)	Rose (red 3BN :6%)	Rose (red 3BN :6%)

The objective analysis of the three spun silk sarees so produced in comparison with that of the regular reeled silk butta handloom saree was carried out by testing the low-stress mechanical properties, hand values and thermal properties using Kawabata evaluation system for fabrics [10-15].

Data sources

The objective analysis test data of the Kawabata evaluation system of the three spun silk sarees and one regular reeled silk saree was considered for the study.

Experimental design

All four sarees were tested at the Central Institute for Research on Cotton Technology (CIRCOT), Indian Council of Agricultural Research, Mumbai, India for their low-stress mechanical properties namely tensile, bending, shear, surface and compression characteristics using a tensile tester (KES-FB1A), pure bending tester (KES-FB2), shear tester (KES-FB1), surface tester (KES-FB4) and compression tester (KES-FB3A) respectively. Also the primary hand values namely Koshi (stiffness), Numeri (smoothness) and Fukurami (softness), Total Hand Value, thermal properties (Q-max, CLO and TIV value) as well as fabric weight and thickness were also assessed using the Kawabata evaluation system. The tests were conducted at standard atmospheric conditions ($65 \pm 2\%$ relative humidity and 27 ± 2 °C temperature) and the average value of 3 reading as prescribed in the standards have been compared. The test data in respect of three spun silk sarees and one regular reeled silk saree was statistically analysed using Minitab software and compared to ascertain the qualitative improvement [16,17].

RESULTS AND DISCUSSION

Fabric geometry of the saree

The fabric geometry and weight of the three spun silk handloom sarees along with the regular silk saree are given in Table 2. Besides the mass per unit area (g m^{-2}), other qualitative characteristics do not differ significantly and are comparable.

Table 2. Fabric geometry

Particulars	Test method	Saree - A	Saree – B	Saree - C	Saree – D
		Spun silk,	Reeled silk x	Spun silk,	Reeled silk x
		additional twist x reeled silk	spun silk, standard twist	standard twist x reeled silk	reeled silk (control)
End per cm	IS 1963 1981	41	40	41	41
Picks per cm	IS 1963 1981	25	27	28	28
Mass, (g m^{-2})	IS 1964 2006	79	83	80	80
Silk weight (g)		540	620	540	540
Warp weight (g)		240	240	240	240
Weft weight (g)		300	380	300	300
Zari weight (g)		240	240	240	240

Low-stress mechanical properties

Two sample t-test results of the Kawabata data on low-stress mechanical properties of the three spun silk handloom sarees along with the regular silk saree, analysed using Minitab software are discussed below [18].

Tensile property

The linearity of load extension curve (LT), tensile energy (WT) tensile resilience (RT) and fabric extensibility (EMT) test data namely descriptive statistics, student's t-test (t) for control sample and probability (p) associated with that particular student's t-test, of all the three spun silk sarees along with the control silk saree in the warp as well as weft direction are given in Table 3.

Table 3. Tensile property

Statistics	Saree - A		Saree – B		Saree - C		Saree – D	
	Spun silk, additional		Reeled silk x spun silk,		Spun silk, standard		Reeled silk x reeled	
	twist x reeled silk		standard twist		twist x reeled silk		silk (control)	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
LT – Linearity of the load-extension curve								
n	3		3		3		3	
$\bar{x}$	0.870	0.914	0.850	0.925	0.895	0.879	0.772	0.902
s	0.104	0.051	0.035	0.069	0.066	0.089	0.096	0.117
t	1.21	0.16	1.33	0.29	1.84	0.27		
p	0.29	0.88	0.26	0.79	0.14	0.80		
WT – Tensile energy (g.f.cm/cm ²)								
$\bar{x}$	0.607	1.000	0.307	1.090	0.983	0.617	0.657	0.813
s	0.064	0.111	0.087	0.122	0.104	0.042	0.090	0.140
t	0.79	1.81	3.97	2.58	4.11	2.33		
p	0.48	0.15	0.02	0.06	0.02	0.08		
RT – Tensile resilience (%)								
$\bar{x}$	56.63	61.14	47.24	55.95	61.93	70.82	73.45	73.52
s	7.34	8.15	18.52	13.17	17.93	15.06	6.35	10.21
t	3.00	1.64	2.32	1.83	1.04	0.26		
p	0.04	0.18	0.08	0.14	0.36	0.81		
EMT – Fabric extension at (500 g/cm) (%)								
$\bar{x}$	1.117	0.910	1.157	1.177	1.463	0.880	1.063	0.820
s	0.029	0.053	0.229	0.060	0.075	0.050	0.040	0.085
t	1.86	1.55	0.69	5.91	8.13	1.05		
p	0.14	0.20	0.53	0.00	0.00	0.35		

(n) - No. of readings, ($\bar{x}$) - Average value, (s) – Standard deviation, (t) – Student's t-test value to control sample and

(p) – probability associated with Student's t-test

It is evident from the results of the analysis that there is no significant improvement/deterioration in the overall tensile properties of the three types of spun silk saree when compared to the reeled silk saree (except 1). The tensile energy of warp in saree B ($\bar{x}$ -0.307; p-0.02) as well as in saree C ($\bar{x}$ -0.983; p-0.02) have shown significant difference when compared to that of reeled silk saree D (control sample; $\bar{x}$ -0.657). It can be inferred that saree B and C have shown quality improvement and deterioration respectively in terms of tensile energy (WT). The tensile resilience of warp in saree A ($\bar{x}$ -56.63; p-0.04) has shown significant quality deterioration when compared to reeled silk saree D (control sample; $\bar{x}$ -73.45). As tensile resilience (RT) measure fabric recovery process and

the fabric extension, the saree B in weft direction ($\bar{x}$ -1.177; p -0.00) and saree C in warp direction ($\bar{x}$ -1.463; p -0.00) have shown significant difference when compared to that of reeled silk saree D (control sample; $\bar{x}$ (Warp) – 1.063; $\bar{x}$ (Weft) – 0.820). It can be inferred that saree B and C have shown quality improvement in terms of fabric extension (EMT).

Surface property

The coefficient of friction (MIU), mean deviation of coefficient of friction (MMD) and geometrical roughness (SMD) test data of all the three spun silk sarees along with the control silk saree in the warp as well as weft direction are given in Table 4.

Table 4. Surface property

Statistics	Saree - A		Saree – B		Saree - C		Saree – D	
	Spun silk, additional twist x reeled silk		Reeled silk x spun silk, standard twist		Spun silk, standard twist x reeled silk		Reeled silk x reeled silk (control)	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
MIU – Coefficient of friction								
n	3		3		3		3	
$\bar{x}$	0.217	0.197	0.176	0.206	0.173	0.219	0.181	0.189
s	0.027	0.007	0.008	0.009	0.014	0.009	0.033	0.023
t	1.47	0.60	0.25	1.23	0.35	2.15		
p	0.21	0.58	0.81	0.29	0.74	0.10		
MMD – Mean deviation of coefficient of friction (m)								
$\bar{x}$	0.129	0.043	0.085	0.038	0.095	0.029	0.079	0.058
s	0.016	0.010	0.007	0.004	0.014	0.004	0.049	0.009
t	1.69	1.85	0.21	3.51	0.55	5.04		
p	0.17	0.14	0.84	0.03	0.61	0.01		
SMD – Geometrical roughness								
$\bar{x}$	10.468	9.382	9.830	3.423	8.932	4.610	10.623	3.230
s	0.430	0.269	0.723	0.293	0.898	0.899	0.957	0.088
t	0.26	37.59	1.15	1.10	2.23	2.65		
p	0.81	0.00	0.32	0.34	0.09	0.06		

It is evident from the analysis that there is no significant improvement/deterioration in the overall surface properties of the three types of spun silk saree when compared to the reeled silk saree except 1). The mean deviation of coefficient of friction of weft in saree B ($\bar{x}$ -0.038; p -0.03) as well as in saree C ($\bar{x}$ -0.029; p -0.01) have shown significant difference when compared to that of reeled

silk saree D (control sample; $\bar{x}$ -0.058). It can be inferred that saree B and C have shown quality improvement in terms of the mean deviation of coefficient of friction (MMD) and the geometrical roughness of weft in saree A ($\bar{x}$ -9.382; p -0.00). It has shown significant quality deterioration when compared to reeled silk saree D (Control sample; $\bar{x}$ -3.230) as geometrical roughness (SMD) measure fabric resistance/drag.

Bending property

The bending stiffness (B) and bending hysteresis (2HB) test data of all the three spun silk sarees along with the control silk saree in the warp as well as weft direction are given in Table 5

Table 5 – Bending property

Statistics	Saree - A		Saree – B		Saree - C		Saree – D	
	spun silk, additional twist x reeled silk		reeled silk x spun silk, standard twist		spun silk, standard twist x reeled silk		reeled silk x reeled silk (control)	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
B – Bending stiffness (g.f.cm ² /cm)								
n	3		3		3		3	
$\bar{x}$	0.118	0.212	0.045	0.265	0.091	0.349	0.081	0.295
s	0.0026	0.010	0.0009	0.005	0.0009	0.016	0.0008	0.004
t	23.78	12.97	54.38	7.57	14.02	5.61		
p	0.00	0.00	0.00	0.00	0.00	0.01		
2HB – Bending hysteresis, (g.f.cm/cm)								
$\bar{x}$	0.063	0.110	0.031	0.137	0.049	0.183	0.049	0.179
s	0.001	0.011	0.001	0.011	0.002	0.019	0.001	0.011
t	19.00	7.67	20.13	4.61	0.303	0.31		
p	0.00	0.00	0.00	0.01	0.78	0.77		

It is evident from the analysis that there is a significant difference in the overall bending properties of the three types of spun silk saree when compared to the reeled silk saree. The bending stiffness (B) of saree A has shown significant quality improvement in the weft direction and quality deterioration in the warp direction, saree B has shown significant quality improvement in both directions where saree C has shown significant quality deterioration in both the directions. Also, the bending hysteresis (2HB) of saree A has shown significant quality improvement in the weft direction and quality deterioration in the warp direction whereas saree B has shown quality improvement in both warp and weft directions.

Shear property

The shear stiffness (G), the hysteresis of shear force at 0.5° (2HG) and the hysteresis of shear force (2HG) at 5° (2HG5) test data of all the three spun silk sarees along with the control silk saree in the warp as well as weft direction are given in Table 6.

Table 6. Shear property

Statistics	Saree - A		Saree – B		Saree - C		Saree – D	
	Spun silk, additional twist x reeled silk		Reeled silk x spun silk, standard twist		Spun silk, standard twist x reeled silk		Reeled silk x reeled silk (control)	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
G – Shear stiffness, (g. f/cm. deg)								
n	3		3		3		3	
$\bar{x}$	0.787	0.973	0.993	0.877	1.240	0.953	1.180	1.320
s	0.015	0.121	0.015	0.032	0.026	0.045	0.036	0.035
t	17.40	4.77	8.26	16.25	2.32	11.17		
p	0.00	0.01	0.00	0.00	0.08	0.00		
2HG – Hysteresis of shear force at 0.5° (g. f/cm)								
$\bar{x}$	1.207	0.683	3.050	1.693	2.630	1.620	2.307	1.173
s	0.032	0.126	0.180	0.060	0.069	0.096	0.121	0.025
t	15.22	6.61	5.93	13.79	4.02	7.76		
p	0.00	0.00	0.00	0.00	0.02	0.00		
2HG5 – Hysteresis of shear force at 5° (g. f/cm)								
$\bar{x}$	3.733	3.283	5.597	3.827	6.983	4.200	6.523	6.033
s	0.115	0.172	0.448	1.176	0.293	0.020	0.286	0.333
t	15.68	12.70	3.02	10.15	1.95	9.52		
p	0.00	0.00	0.04	0.00	0.12	0.00		

It is evident from the analysis that there is a significant difference in the overall shear properties of the three types of spun silk saree when compared to the reeled silk saree. The shear stiffness (G) of saree A and saree B have shown significant quality improvement in both warp and weft directions whereas saree C has shown significant quality improvement in the weft direction only. Also, the shear hysteresis at 0.5° (2HG) of 1) saree A has shown significant quality improvement in both warp and weft directions where saree B and saree C have shown quality deterioration in both warp and weft direction. Moreover, the shear hysteresis at 5° (2HG5) of saree A and saree B have shown significant quality improvement in both warp and weft directions while saree C has shown quality improvement in the weft direction and quality deterioration in the warp direction.

Compression property

The linearity of the compression curve (LC), compression energy (WC) and compression resilience (RC) test data of all the three spun silk sarees along with the control silk saree in the warp as well as weft direction are given in Table 7.

Table 7 – Compression property

Statistics	Saree - A Spun silk, additional twist x reeled silk	Saree – B Reeled silk x spun silk, standard twist	Saree - C Spun silk, standard twist x reeled silk	Saree – D Reeled silk x reeled silk (control)
LC – Linearity of compression curve,				
n	3	3	3	3
$\bar{x}$	0.240	0.272	0.281	0.344
s	0.054	0.062	0.102	0.040
t	2.94	1.69	1.34	
p	0.04	0.19	0.23	
WC – Compression energy (g.f./cm)				
$\bar{x}$	0.088	0.073	0.129	0.050
s	0.013	0.007	0.061	0.002
t	6.05	5.54	3.12	
p	0.01	0.03	0.03	
RC – Compression resilience (%)				
$\bar{x}$	55.69	55.08	45.00	64.50
s	2.05	1.66	4.16	4.96
t	2.89	3.12	5.85	
p	0.10	0.08	0.01	

It is evident from the analysis that there is a significant difference in the overall compression properties of the three types of spun silk saree when compared to the reeled silk saree. The linearity of compression (LC) of saree A has shown a significant difference in better resistance to expansion, saree B and saree C have performed at par with that of the reeled silk saree. Also, the compression energy (WC) of all the spun silk sarees is higher when compared to that of reeled silk saree. Moreover, the compression resilience (RC) is less for the saree C and saree A and saree B have performed at par with that of the reeled silk saree.

In general, the overall analysis revealed that the spun silk sarees showed significantly lesser bending stiffness when compared to the reeled silk saree which implies the fabric is less stiff with better drape-ability. The shear rigidity of the spun silk sarees is significantly lesser than that of

reeled silk saree which implies the spun silk fabric can easily be distorted in laying up, marking and cutting thus easy for folding and sleeve insertion during fabric stitching. It is also inferred that the spun silk saree possess the tensile, surface and compression properties at par with that of reeled silk saree.

Primary and Total Hand Value

The analysis revealed that the Primary Hand Values (PHV) for the women's thin dress material namely Koshi (Stiffness), Numeri (Smoothness) and Fukurami (Softness) are better than that of regular reeled silk saree. The Total Hand Value (THV) of the spun silk sarees is better than that of the regular reeled silk saree. The results are given in Table 8 as well as Figure 1.

Table 8. Primary and Total Hand Value

Parameter	Scale	Saree - A Spun silk, additional twist x reeled silk	Saree - B Reeled silk x spun silk, standard twist	Saree - C Spun silk, standard twist x reeled silk	Saree - D Reeled silk x reeled silk (control)
Koshi (stiffness)	1 Supple and 10 Stiff	7.54	7.68	7.87	8.18
Numeri (smoothness)	1 Harsh and 10 Smooth	3.43	4.14	4.04	3.24
Fukurami (softness)	1 Rough and 10 Soft	6.39	6.41	6.87	5.88
Total hand value (kn-302 winter)	1 Poor and 5 Excellent	2.26	2.23	2.09	1.50

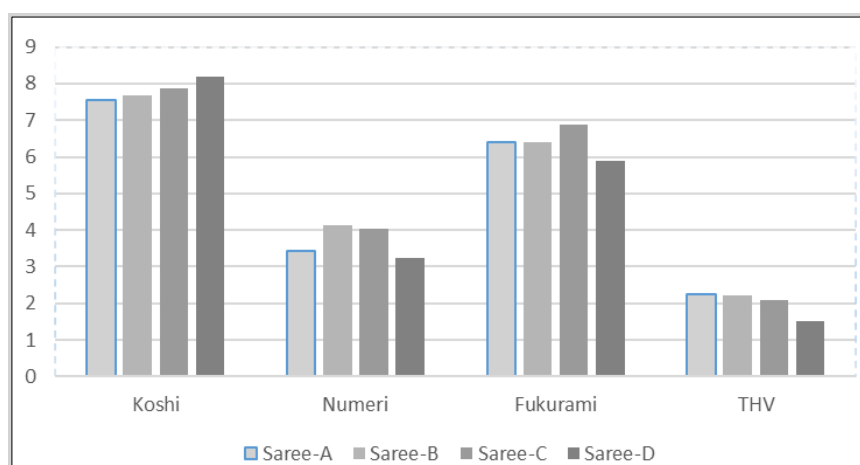


Figure 1. Primary and Total Hand Value of silk saree

Thermal properties

Two sample t-test results of the Kawabata data on Q-max, CLO and Thermal Insulation value (TIV) of the three spun silk handloom sarees along with the regular silk saree, analysed using Minitab software are given in Table 9. It is evident from the analysis that the Q-max, CLO and TIV of the spun silk sarees are significantly better than that of regular reeled silk saree.

Table 9. Thermal properties

Parameter	Saree - A Spun silk, additional twist x reeled silk	Saree – B Reeled silk x spun silk, standard twist	Saree - C Spun silk, standard twist x reeled silk	Saree – D Reeled silk x reeled silk (control)
Q-max (W/cm ²) – Higher values are better				
n	3	3	3	3
$\bar{x}$	0.090	0.110	0.110	0.089
s	0.001	0.001	0.001	0.001
t	0.87	18.19	9.53	
p	0.45	0.01	0.02	
CLO (m ² K/W) – Lower values are better				
$\bar{x}$	0.490	0.500	0.480	0.510
s	0.010	0.010	0.010	0.010
t	3.15	1.57	4.72	
p	0.75	0.25	0.03	
TIV (%)– Lower values are better				
$\bar{x}$	23	25	21	26
s	0.29	0.34	0.48	0.56
t	17.86	5.08	18.00	
p	0.00	0.02	0.01	

Fabric Thickness

Two sample t-test results of the Kawabata data on fabric thickness (To) and fabric thickness at maximum pressure (Tm) of the three spun silk handloom sarees along with the regular silk saree, analysed using Minitab software are given in Table 10. It is evident from the analysis that there is no significant difference in any of the parameters tested.

Table 10. Fabric Thickness

Parameter	Saree - A	Saree – B	Saree - C	Saree – D
	Spun silk, additional twist x reeled silk	Reeled silk x spun silk, standard twist	Spun silk, standard twist x reeled silk	Reeled silk x reeled silk (control)
To – Fabric thickness at (0.5 gf/cm ²), mm				
n	3	3	3	3
$\bar{x}$	0.368	0.295	0.350	0.293
s	0.025	0.008	0.027	0.059
t	2.02	0.05	1.52	
p	0.11	0.96	0.20	
Tm – Fabric thickness at (50 gf/cm ²), mm				
$\bar{x}$	0.226	0.186	0.204	0.235
s	0.017	0.008	0.017	0.065
t	0.22	1.30	0.80	
p	0.84	0.26	0.47	

CONCLUSION

This study on low-stress mechanical properties has paved the way for the qualitative analysis of the spun silk sarees in comparison with the regular reeled silk saree. The study revealed that the spun silk sarees performed better in most of the characteristics, particularly the bending and shear characteristics that have been confirmed through Primary and Total Value test results. Thus, the findings in unequivocal terms recommend the commercial production of the spun silk saree that has better comfort properties for which fine counts spun silk namely 210/2, 240/2 and Nm 280/2 can be used as warp or weft along with reeled silk for better comfort properties.

Author Contributions

Conceptualization – Kadhar A; methodology – Kadhar A; formal analysis – Kadhar K and Naik S.; investigation – Kadhar A; resources – Kadhar A and Naik S; writing-original draft preparation – Kadhar A; writing-review and editing – Kadhar A; visualization – Kadhar A and Naik S; supervision – Naik S. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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