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Evaluation of Quality and Assurance Parameters of Mulberry Silk Waste and Viscose Blended Knitted Fabrics by Using 'Fabric Assurance by Simple Testing' (FAST) Technique

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Authors' contributions

This work was carried out in collaboration between both the authors. Authors Shikha Bajaj and Sandeep Bains designed the study. Author Shikha Bajaj performed the statistical analysis. Author Sandeep Bains wrote the protocol. Author Shikha Bajaj wrote the first draft of the manuscript and managed the analyses of the study. Author Sandeep Bains managed the literature searches. Both the authors read and approved the final manuscript.

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ABSTRACT

Fabric handle is one of the influential properties for any fabric and is a guiding factor for optimum selection of textile materials for specific end uses. The paper deals with objective analysis of knitted fabrics for fabric hand. Present attempt was made on four knitted fabrics, blended in proportions of 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose, each in two different counts. Fabric Assurance by Simple Testing (FAST) was utilized for determination of properties which is precisely associated with apparel construction and its lastingness. Fabric samples were subjected to tests for obtainment of dimensional stability, formability, low load extensibility, bending rigidity, compression and shear rigidity. Knitted fabric blended in proportion of 50% mulberry silk: 50% viscose in 20 Nm count was found to be most feasible to large scale production and garment construction.

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1. INTRODUCTION

Textile industry is one of the biggest industry in the world with large textile manufacturing base [1]. The immense progress in the past decades has not only produced high technology textile goods but has also given way to considerable experimentation and testing. Quality has grown into a prime requirement in today's competitive market and can be assessed to a large extent from the performance of the product [2]. Objective evaluation of the textile materials is a indispensible tool in the present textile trade. There is a huge rise in production of quality goods due to mechanization. In order to reap satisfactory performance in the clothing business, an assertive specification in relation to the critical fabric quality has to be retained. Thus determination of these aspects objectively is crucial [3]. The fabric hand is one aspect of importance to the fashion industry and consumers, which plays a vital role in guiding consumer's purchase decision [4]. Customers intuitively examine fabric hand to characterize and determine quality and its applicability for a definite end use. The property can be assessed by mechanical and electronic equipments and by human experts by utilization of psychophysical or psychological methods [5]. Respondents may contradict, however, in their subjective evaluations of properties, even when the specific marking levels are provided, and these contrasts may lead to discrepancies in their judgment [6]. To fill this void, objective evaluations are considered better for assessment of such properties. In the past, Kawabata system of evaluating hand values was developed which measured the fabric handle with accuracy; however, the experimentation is highly cumbersome and time consuming [7]. In this view, FAST system of fabric handle evaluation system has come into picture, which is much simpler than Kawabata evaluation system and experimentation cost is also less. Fabric Assurance by Simple testing (FAST) was developed by CSIRO (Division of Textile Industry, Australia) [3]. The test determines properties which sharply define ease of garment construction and its durability [8]. This test method is based on correlations between a number of subjective evaluations of fabric handle (like smoothness, firmness, fullness, crispiness and hardness) and corresponding mechanically detectable Figures [9]. In the present study, authors have intended to evaluate fabric hand of blended knitted fabrics. Dimensional stability, formability, extensibility, bending rigidity, shear rigidity and compression have been measured by using Fabric assurance by simple testing.

2. MATERIALS AND METHODS

Four types of fabrics were knitted by using blended yarns of two different yarn counts, each in two different blending proportions *viz.* 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose. Blended knitted fabrics were utilized for present course of experimentation.

The property of fabric hand was determined by using Fabric assurance by simple testing (FAST). The process involved use of tensile testing machine called extensometer, which measured the force generated when the fabric specimens passed through a ring [10]. Apart from this, cantilever bending tester and a cloth thickness gauge were also utilized. Fabrics were subjected to FAST in both wale-wise and course-wise directions for all parameters except compression, weight and shear rigidity.

The procedure included four steps of examination. FAST-1 provided a figure for fabric thickness with micrometre resolution. FAST-2 calculated the values for fabric bending length and bending rigidity. FAST-3 measured fabric extensibility at low loads and shear rigidity. FAST-4 was utilized for measurement of dimensional stability, involving relaxation shrinkage and the hygral expansion [8]. Three readings were obtained for each sample, while testing individual criterion. Mean was calculated for three readings for the final value. Below mentioned methods were utilized for judgement of various parameters.

1. Dimensional stability: Extent of dimensional deformation of knitted fabrics was evaluated by computation of parameters like relaxation shrinkage and hygral expansion.

- **Relaxation shrinkage: D**imensional change in fabric was measured by calculating the percentage change in dimensions after relaxation of fabric after knitting. Relaxation was carried out at room temperature.
- **Hygral expansion:** It was measured by calculating the reversible change in dimensions of fabric after moisture content is altered.

$$\text{Relaxation shrinkage} = \frac{L1-L3}{L1}$$

$$\text{Hygral expansion} = \frac{L2-L3}{L3}$$

Where;

L1 = Length of dry relaxed fabric. *L2* = length of wet fabric after relaxation in water and *L3* = length of dry unrelaxed fabric [11].

2. Bending rigidity: Bending lengths were calculated and converted into bending rigidities (BS 3356-1961). FAST 2 instruments worked on cantilever principle.

3. Formability: Compression was applied on the fabric and its ability to withstand the same in its own plane was measured. It was obtained from both FAST 2 and FAST 3 equipments.

4. Extension percentage: Extension in the fabric was measured by applying various loads viz. 5 gf/cm, 20 gf/cm and 100 gf/cm. It was computed by using extension meter. The property is associated with looseness of fabric.

5. Compression: Under this parameter, thickness of the fabric was calculated under various loads. Compression meter was used for this purpose.

- **Surface thickness:** Surface thickness is defined as the difference between the values of thickness at the two predetermined loads viz 2 gf/cm^2 and 100 gf/cm^2. The pressure at which thickness was measured was controlled by adding weights to the measuring cup [11].
- **Relaxed surface thickness**: The values of surface thickness when viewed against the values of relaxed surface thickness carries higher significance in terms of fabric hand [12].

6. Weight: Weight of the fabrics per meter square was measured by using weighing balance.

7. Shear rigidity: The parameter was judged by using tensile extension. Duration of the study was 2 years.

3. RESULTS AND DISCUSSION

The knitted fabric construction was carried out by yarn blends of 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose, in both 15 Nm and 20 Nm yarn counts. Amount of twist was kept constant for all the yarns (10 twists per inch). All the fabrics were knitted in plain jersey structure.

Developed knitted fabrics were assigned codes for ease of discussion and understanding (Table 1). Fabric knitted in 50% mulberry silk: 50% viscose yarn and 15 Nm count was called S_1 and fabric made in 40% mulberry silk: 60% viscose in the same count was assigned code S_3. In case of 20 Nm yarn count, codes S_2 and S_4 were the assigned to fabrics with 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose respectively.

Table 1. Coding of developed fabric proportions

Blending proportion	Yarn count Nm	Code assigned
50% mulberry silk: 50% viscose	15	S_1
50% mulberry silk: 50% viscose	20	S_2
40% mulberry silk: 60% viscose	15	S_3
40% mulberry silk: 60% viscose	20	S_4

Dimensional stability

i) **Relaxation shrinkage:** It is evident from Table 3 that highest values for relaxation shrinkage were calculated for fabrics S_2 and S_3, however, there was not much difference found among the figures of four knitted fabrics. Relaxation shrinkage in the direction of wales was found to be significantly higher than that of course direction. Since the gap between two crossing points in the direction of wales was much greater than in course direction, the fabrics found extra capacity to repose. Apart from this, course density was also found to be greater than wales density for the blended knitted fabrics (Table 2), so there was very less space available for further shrinkage [13]. Fletcher and Roberts [14] mentioned that shrinkage in areas of all of the grey fabrics and of the finished viscose fabrics increased with knitting stiffness.

ii) **Hygral expansion:** Hygral expansion percentage has been measured highest in case of fabric S_1 in the direction of wales. In the direction of courses, fabric S_2exhibited highest change in dimensions. The figures show a similar pattern as seen

Table 2. Constructional parameters of knitted fabrics

Fabric code	Knitted structure	Yarn density (WPI x CPI)	Tightness factor	Fabric thickness (mm)
S_1	Single jersey	14 x 19	$4.533^a \pm 0.002$	$0.763^b \pm 0.012$
S_2	Single jersey	14 x 20	$4.532^a \pm 0.002$	$0.663^a \pm 0.012$
S_3	Single jersey	14 x 20	$4.534^a \pm 0.003$	$0.883^c \pm 0.024$
S_4	Single jersey	14 x 18	$4.529^a \pm 0.000$	$0.703^b \pm 0.003$
		Critical difference	NS	0.102

a,b,c Significant at 5 % level of significance, same alphabet= no significant difference, different alphabet= significant difference, CD= Critical difference, NS= Not significant

for relaxation shrinkage in which higher dimensional changes were witnessed in the direction of wales. Cookson [15] found a high correlation between relaxation shrinkage and hygral expansion. According to the CSIRO Wool research laboratories, Ballard [16] found that in fabric having composition of viscose rayon, high levels of moisture regain percentages lead to higher figures for hygral expansion. This mostly occurs in the atmospheres of high humidity only. In the present case, moisture regain values for the yarns used for knitting of fabrics were found as below (Table 4).

In the areas of high humidity, the swelling shrinkage of fabrics may occur which will be in equilibrium with high relative humilities. Mostly, larger values of hygral expansion cause puckering problems [17], However, values thus obtained for fabrics under investigation fall in the safe region and were advisable for clothing purpose.

Bending rigidity

Bending rigidities were calculated for knitted fabrics. Findings reveal that fabric S_1 was most rigid in the direction of wales. A significant difference was found among the values during statistical calculations at 95% confidence level. Highest rigidity values were shown by fabric S_3 in coursewise direction. Bending rigidity of fabric S_2 has been found less than fabric S_1, in both the directions, as its knit structure is less dense because of finer count. The stiffness of a fabric in bending is dependent on its thickness, the thicker the fabric, the stiffer if all other factors remain the same [18]. Fabric S2 with lowest thickness exhibited lowest bending rigidity in coursewise direction. In the direction of wales, fabric S_2 and S_4 were found least rigid with no significant difference. Hence fabric S_2 and S_4 can be called as suitable for apparel use.

Formability

High formability values were obtained for all the fabrics with significantly high ($p \leq .05$) figure for fabric S_1 in the direction of wales, and that of fabric S_3 in the direction of courses. Since, low formability give rise to problem of puckering [4], having present figures for the property, the chances of crunch were not foreseeable. According to Hooputra et al. [19], the ability to bear compression or formability is an outcome of bending property of the material. Results thus produced for the knitted fabrics were tested for correlation with bending rigidities of the same (Fig. 1). A moderate positive correlation was found between the two properties clearly depicting that rise in bending rigidity increases formability of fabrics.

Extension percentage

Fabric extension of knitted fabrics was calculated on various loads. Fabric S_4 extended the most both in waleswise and coursewise directions. Fabric S_2 and S_3, however, also achieved suitable extension percentages for garment construction. Knitted fabrics tend to develop high extensions [20]. Low figures of fabric S1 can be explained by mentioning that bending rigidity values for the same were found to be highest which led to lower extension figures under loads. For all the fabrics, much higher extension was witnessed in coursewise direction than in waleswise direction. According to Gordon and Hsieh [21], when tensile loading is applied to the fabric, the yarn within the structure moves until it jams and then the yarn elongates until it breaks. Under an applied load, plain knitted fabric has lesser elongation in the walewise direction than in coursewise direction because waleswise jamming occurs sooner than coursewise jamming. Horizontal extension is seen after flattening of curvature of lower portion of sinker loops in plain knitted fabrics. As the load is increased, curved areas tend to straighten [20].

Table 3. Findings of 'Fabric assurance for simple testing parameters' for blended knitted fabrics

Parameters		S_1		S_2		S_3		S_4		CD	CD
		Wales wise	**Course wise**	**Wales wise**	**Course wise**	**Wales wise**	**Course wise**	**Wales wise**	**Course wise**	**Wales wise**	**Course wise**
Dimensional stability (%)	Relaxation shrinkage	13.4^{a}	3.8^{c}	14.8^{b}	2.1^{b}	14.2^{b}	0.0^{a}	13.1^{a}	5.8^{d}	0.33	0.09
	Hygral expansion	4.2^{c}	2.6^{a}	3.4^{b}	3.0^{b}	0.9^{a}	2.1^{a}	0.9^{a}	7.4^{c}	0.12	0.16
Formability (mm^2)		9.36^{c}	3.26^{b}	3.26^{a}	2.73^{a}	5.30^{b}	7.37^{c}	3.12^{a}	3.06^{b}	0.23	0.1
Extension (%)	Extension at 5 gm load	0.0^{a}	1.3^{a}	1.0^{b}	6.5^{b}	1.4^{b}	10.1^{c}	4.3^{c}	10.4^{c}	0.15	0.4
	Extension at 20 gm load	5.4^{a}	19.3^{a}	7.0^{b}	21.0^{b}	8.4^{c}	21.0^{b}	11.8^{d}	21.0^{b}	0.3	0.14
	Extension at 100 gm load	18.6^{a}	21.0^{a}	19.1^{b}	21.0^{a}	20.4^{c}	21.1^{b}	21.1^{d}	21.1^{b}	0.48	0.35
	Extension at 5 gm load Bias	4.7^{c}		6.2^{d}		1.7^{a}		3.8^{b}		0.29	
Bending Rigidity (µN.m)		9.0^{d}	7.6^{c}	6.7^{b}	3.3^{a}	8.4^{c}	7.2^{c}	6.0^{a}	4.3^{b}	0.25	0.34
Compression (mm)	Surface Thickness	0.457^{a}		0.607^{c}		0.652^{c}		0.583^{b}		0.02	
	Relaxed surface Thickness	0.452^{a}		0.645^{c}		0.586^{b}		0.587^{b}		0.02	
Weight (g/m^2)		187^{c}		172^{b}		175^{b}		136^{a}		6.49	
Shear Rigidity (N/m)		26.4^{b}		19.9^{a}		71.0^{d}		32.5^{c}		3.4	

Results significant at 5 % level of significance, CD: Critical difference

Table 4. Findings of moisture regain of yarns used for knitting

	Moisture regain (yarns used for knitting)			
	Yarn used for fabric S1	**Yarn used for fabric S2**	**Yarn used for fabric S3**	**Yarn used for fabric S4**
Moisture regain (%)	8.517	8.524	9.960	8.614

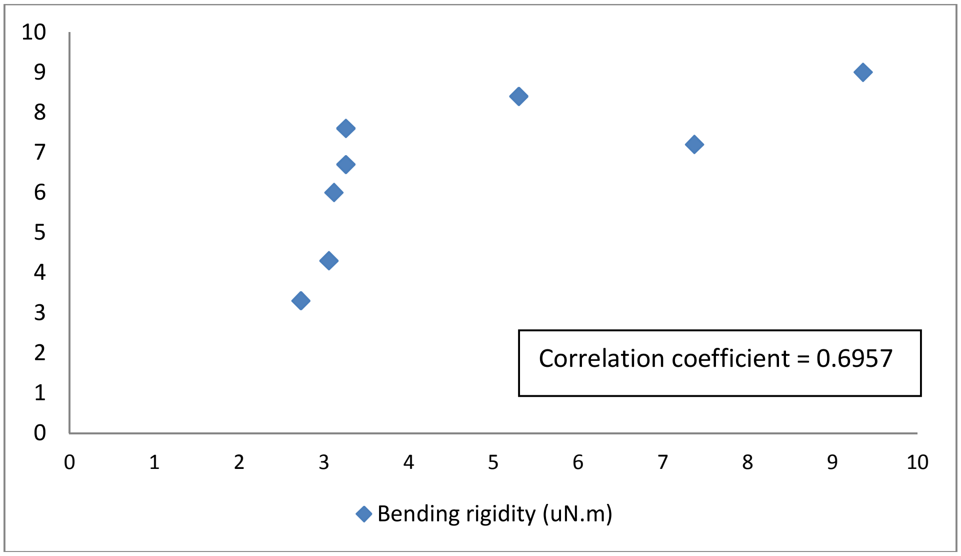

Fig. 1. Correlation between Formability and bending rigidity of blended knitted fabrics

Compression

Under this, surface thickness of the fabric was calculated along with thickness under various loads.

a) **Surface thickness:** Surface thickness measures the difference in thickness of a fabric measured at pressures of 2 gf/cm^2 and 100 gf/cm^2**.** Fabric S_1 was found to have the least bulky surface in this case. Fabric S2, S3 and S4 were found to obtain similar figures for surface thickness with no significant difference among them. The higher the surface thickness, higher will be the surface hairiness or bulk of the fabric [22].
b) **Relaxed surface thickness:** Figures for this property were found to be lowest for fabric S_1, and highest for fabric S_2. Behery[5] was of the opinion that contrast of the original surface thickness and the released surface thickness determines the stability of the finish on the fabric while garment construction. For the present investigation, comparison of both the parameters shows a gap of less than 0.1 mm for all the fabrics, which shows high stability for finishes. Fabrics S_1, S_2 and S_3 exhibited highest ability to handle finish with least disparity between original surface thickness and relaxed surface thickness.

Weight

Table 3 depicts that weight of fabric S_1 and S_3 was higher than that of fabric S_2 and S_4. This was due to the difference in yarn counts of yarns used for the fabrics. Fabric S_1 and S_3, having the higher count yarn were found to have significantly more weight than fabric S_2 and S_4 at 95 % confidence level.

Shear rigidity

Shear rigidity is the measure of performance of fabrics in terms of ability to drape, and handle while garment construction and usage. Fabric S_3 demonstrated highest amount of shear rigidity which can be understood by considering the higher yarn density and tightness factor for the same. Wang et al. *[*23] established the relationship between shear rigidity and tightness factor and it was observed that high tightness factor gives rise to larger figures for shear rigidity. Fabric S_2 was found least rigid in this case and hence was considered most drapable.

4. CONCLUSION

The investigation of FAST parameters for blended knitted fabrics provides data for comparative analysis of significant properties and to figure out the dependencies of fabric performance on its constructional properties. The results obtained indicate that fabric S_2, proved to be better in performance than fabrics S_1, S_3 and S_4, exhibiting low bending and rigidities in both wale-wise and course-wise directions. Regarding formability, fabric S_2 scored satisfactory value and chances of crinkling were eliminated. Fabric S_2, however, showed dimensional changes during testing for relation shrinkage and hygral expansion. Findings for compression test depict that fabric S_2 was highly suitable for handling finishes. Analyzing the relationship between performances of blended knitted fabrics during Fabric Assurance by Simple Testing (FAST), it can be concluded that fabric thickness, yarn density and tightness factor were found as influential parameters in deciding hand properties of fabrics. Keeping in view the unequaled characteristics of 50% mulberry silk: 50% viscose in 20 Nm yarn count and lower fabric weight, it is therefore recommended as best suitable apparel use and commercial production.

5. RESEARCH LIMITATION

Laboratory tests like (FAST) can only imitate wear and durability conditions.

6. FOLLOW UP RESEARCH RECOMMENDATIONS

1. Subjective evaluation for quality and durability of blended knitted fabrics may be carried out in order to judge the actual fabric in use.
2. Comparison of findings of both objective and subjective quality tests can be done.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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