ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

FUNCTIONAL PROPERTIES OF BAMBOO AND TENCEL UNION FABRICS

MEDAR Renuka[1], MAHALE Geeta[2]

[1, 2] Department of Textile and Apparel Designing, College of Community Science
University of Agricultural Sciences, Dharwad, India

Corresponding author: Geeta Mahale, e-mail: geetmahal@rediffmail.com

Abstract: *This study delves into the concept of union fabric, a textile innovation that involves weaving two distinct yarns in the warp and weft directions. By merging the unique properties of each yarn, union fabric enables weavers to enhance desirable qualities while minimizing drawbacks, resulting in fabrics with superior functional attributes. This research focuses on the application of union fabrics made from Bamboo and Tencel, highlighting their user-friendly and eco-friendly characteristics. Bamboo fibers are renowned for their natural antibacterial properties, breathability, and sustainability, while Tencel fibers are celebrated for their softness, moisture management, and eco-friendly production processes. When combined in union fabrics, these yarns create textiles that are not only comfortable and gentle on the skin but also highly durable and environmentally friendly. Union fabrics represent an innovative approach in textile manufacturing, offering enhanced functionality and performance by integrating the best attributes of different yarns. The synergy between bamboo and Tencel in union fabrics exemplifies the potential of this technique, providing solutions that are beneficial for everyday use and critical in specialized applications, such as medical textiles. This study underscores the promise of these fabrics in medical textiles, suggesting a promising avenue for the development of advanced and sustainable healthcare materials.*

Keywords: *Union fabric, Textile innovation, Warp and weft, Yarn combination, Functional properties, Bamboo, Tencel, User-friendly, Eco-friendly*

1. INTRODUCTION

Clothing nowadays is no longer a material to be draped over human body for protection from extreme weather conditions. Rather it has many more functions like status symbol, beautifying agent, fitness guide, multitasking device and personality developer in an era of smart clothing. In order to enhance the functional features, introducing new fibres like bamboo and tencel improves the quality and durability of the fabrics produced. Bamboo is an evergreen perennial flowering plant belonging to subfamily Bambusoideae and grass family *Poaceae*. Bamboo fabrics are characterized by good hygroscopicity, excellent permeability, softer to feel, easy to straighten and dye. While Tencel is a brand name of Lyocell fibre, which is regenerated from cellulose extracted from eucalyptus wood pulp. The wood used for the purpose is, which is sustainably grown on farms in Europe, on land which is unsuitable for agriculture. Tencel fibre possesses great strength, excellent moisture management properties, and good absorbency and is gentle when worn next to skin. Tencel is soft, breathable, lightweight and comfortable, exceptionally strong fiber, both wet and dry conditions.

The growing emphasis on eco-friendly products in recent years' merits consideration. Institutions, businesses, and society at large are increasingly directing their focus towards organic agriculture [1].

Bamboo fabrics are more prominent in bathrobes and towels, foot mats, bed clothes, intimate garments, Bamboo T-shirts, sanitary napkins and Bamboo socks and many others [2]. Tencel fabrics are widely used as sports wears, home furnishings, toweling materials and many other areas. Thus, with respect to the properties of both Bamboo and Tencel an attempt was made to study the functional properties of Bamboo and Tencel union fabrics.

2.MATERIAL AND METHODS

2.1. Procurement of raw material

2/20s cotton yarns were procured from KHDC Gadag, Karnataka while Bamboo and Tencel yarns of 20s and 30s counts were procured from Pallava textiles, cotton mill, Mangarangam palayam, Tamil Nadu.

2.2. Design and development of union fabrics

Weaving is the method of fabric production wherein, two sets of yarns are interlaced at right angles to each other. Two types of plain woven union fabrics were produced on a pit loom at Malali Village, Ramapur and Karnataka wherein cotton yarns were used as warp and Bamboo and Tencel yarns were used as weft.

2.3. Cloth stiffness (cm):

Cloth stiffness is the resistance of the fabric to bending. Bending length is the length of the fabric that bends under its own weight to a definite extent. It equals half the length of rectangular stripe of fabric that bends under its own weight to an angle of 41.5°. The test samples were tested as directed in BS test method: 3356-1961. A rectangular strip of fabric, 6 inch × 1 inch was mounted on a horizontal platform in such a way that it hangs like a cantilever and bends downwards. Fabric was cut with help of template and then both template and fabric was placed on the platform with the fabric underneath. Both were pushed forward slowly. The strip of fabric was started to a droop over the edge of the platform and the movement of the templates and the fabric was continued until the tip of the fabric viewed in the mirror cuts both index lines. The bending length was read off from the scale mark opposite a zero line engraved on the side of the platform. Five readings were recorded by using Shirley's stiffness tester [3].

2.4. Cloth crease recovery (Degrees°):

Crease recovery is nothing but allowance of the fabric to recover from the crease. The test samples were tested as directed in IS method: 4681-1968 by using Shirley's crease recovery tester. Samples were cut both warp and weft way from the fabric with a template, 2 inch long by 1 inch wide. It was creased by folding into half and placed under a weight of 2 kg for 5 minutes. The weight was removed and the specimen was transferred to the fabric clamp on the instrument using forceps and was allowed to recover from the crease for 5 minutes. As it recovered the dial of the instrument was rotated to keep the free edges of the specimen in line with the knife edge. At the end of the time period as it was allowed for recovery, usually 1 minute the recovery angle in degrees was read on the engraved scale. Readings were recorded for both warp and weft separately [3].

2.5. Tensile strength (kgf) and elongation (%):

Tensile strength is the ability of the material to resist or rupture induced by eternal force. It is expressed as force per unit cross sectional area of the specimen at the time of maximum load. The specimens were tested as directed in ASTM test method: 12616-1989. The method employed to determine the breaking load and elongation of the material by using the 'raveled strip test' in Unistretch 250 tensile tester.

The fabric sample of 20 cm × 5 cm dimensions was gripped between two clamps of the tensile testing machine in such a manner that the same fabric was gripped by both the clamps and a continuous increasing load was applied longitudinally to the specimen by moving one of the clamps until the specimen ruptured. Values of breaking load of the test specimen were recorded from the indicator of the machine.

Elongation is the increase in length of the specimen from its initial length expressed in units of length. The distance that material will extend under a given force is proportional to its original length. Hence elongation is coated as strain or percentage was assessed for the fabrics.

2.6. Cloth drapability (%):

Drape is the ability of the fabric to assume a graceful appearance in us. Fabric drape may be explained as the extent to which a fabric deforms when it is allowed to hung under its own weight. A circular specimen about 10-inch diameter was supported on a circular disc about 5-inch diameter and upper supported area drapes over the edge. On switching the lamp of the drape meter, it gave the shadow of the draped area, which was taken on a paper and was weighed. Similarly draped shadow area of the template and supporting disc was also taken. Drape coefficient is the ratio of the projected area of the draped specimen to its undraped area after deduction of the area of the supporting disc [4], [5].

2.7. Cloth thermal insulation value (Tog):

Thermal resistance is the ability of a material to resist the flow of heat. Thermal resistance is the reciprocal of thermal conductance *i.e.,* lowering its value will raise the heat conduction and vice-versa. The specimens were tested manually. The experiment was carried out by cooling method. In this method, a hot body is wrapped with the fabric and its rate of cooling is measured. The outer surface of the fabric is exposed to the air. The experiment consists in finding the time taken by a hot body covered with the fabric sample without the sample to cool through a particular temperature range under identical atmospheric conditions. The experiment was started when temperature of the water was exactly 48°C. A stop watch was used to find the time taken for the temperature to fall at 38°C.

2.8. Cloth Air permeability ($cm^3/cm^2/sec$)

Air permeability is defined as the volume of air measured in cubic centimeter passed per second through 1 cm^2 of the fabric at a pressure of 1 cm of water. All the samples were tested as directed by ASTM D-737 test method. Air at standard atmosphere was drawn from labrorartry through the test specimen by means of a suction pump, the rate of flow being controlled by means of the pass valve and service valve at the definite pressure. The rate of flow was adjusted until the required pressure drop across the fabric and is indicated on a draught gauge. The rate of flow of air was then recorded by rotameter from the instrument.

2.9. Cloth abrasion resistance (Ratings)

Cloth Abrasion is the rubbing away of component fibres and yarns of the fabric [3]. Abrasion resistance was carried out in **digitized** ‘Martindale abrasion tester ‘using IS 12673-1989 test method. Fabric specimens of 13.5 cm diameter were cut according to the size of template. The specimens were abraded using zero emery paper and determination of end point was visualized until a hole was formed and number of cycles to create a hole and readings were recorded.

2.10. Visual evaluation of Bamboo and Tencel union fabrics

Visual assessment of the developed fabric was carried out by a panel of textile experts. Weighted average ranking (WAR) was done in order to study the preference of developed union fabrics based on rakings (5-Excellent, 4- Very good, 3-Good, 2- Fair and 1-Poor).

The cost of the yarns and developed bamboo and tencel union fabrics per meter were calculated for comparison of bamboo and tencel union fabrics.

2.11. Statistical analysis

The experimental data obtained from present experiment was subjected to two-way ANOVA using two and three factorial designs using WINDOSTAT software developed by INDOSTAT services.

3. RESULTS AND DISCUSSIONS

Table 1, highlights the physical properties of Cotton, Bamboo and Tencel yarns. It was observed that Cotton yarn obtained maximum **yarn twist** (16.84) compared to Bamboo (3.84) and Tencel (9.24) yarns of 30s counts which is due to the fibre content, the crysatllinity of Cotton fibre which enhances the yarn to twist more, further adding strength. Similar results with respect to twist of Cotton yarns were obtained in a study on Effect of blend ratio on quality characteristics of Bamboo/Cotton blended ring spun yarn by Prakash *et al* [6].

Table 1: *Physical properties of Cotton, Bamboo and Tencel yarns*

Sl.No	Type of Yarn	Yarn parameters							
		Count	Twist	Unevenness (%)	Hairiness (No. of hairs/km)	Count Strength Product	Single yarn Strength (kgf)	Elongation (%)	Lea yarn strength (lbs)
1	Cotton	20	**16.84**	8.0	246	**2954**	**556.5**	4.5	**152.6**
2	Bamboo	20	3.26	8.0	**922**	1540	166.4	**9.1**	78.2
		30	**3.84**	**8.2**	303	1373	132.6	8.4	46.5
3	Tencel	20	4.84	7.6	307	2948	447.4	6.6	143.2
		30	**9.24**	**8.4**	340	2611	287.7	6.1	87.78

Similarly, Bamboo (8.2%) and Tencel (8.4%) yarns of 30s count possessed greatest amount of **unevenness percentage** (Thick, thin places and neps) which may be due to the presence of water in varying amounts or an uneven blend of two or more fibres will alter the relative permittivity (dielectric constant) in parts of the yarn and hence appear as unevenness. The results are on par with the study conducted by Majumdar *et al.* [7] who concluded that, 100 per cent Cotton and Bamboo yarns have comparable yarn unevenness percentage. However, while in case of 30s bamboo yarn, the unevenness percentage was higher than that of 20s bamboo yarn.

Bamboo 20s (922 no of hairs/km) yarn possessed highest **yarn hairiness** and length of hairs ranging from 3mm to 15 mm which may be due to the yarn manufacturing, yarn production techniques. Higher yarn hairiness leads to faulty and poor quality of yarns that affects the thermal insulation and other apparel characterstics. Majumdar *et al.* [7] reported that yarn hairiness of Bamboo was found to be higher than Cotton as Bamboo fibres are longer in length when compared to Cotton fibres.

Likewise, the **count strength product** was also seen higher in Cotton yarn (2954) because yarn count and yarn twist contributes to strength of the yarn which ultimately enhances the count strength product.

Single yarn strength of Cotton yarns (556.5kgf) were found to be maximum when compared to Bamboo and Tencel yarns as the elastic nature of the cellulosic yarns makes them resistant to break when subjected to certain load applied. While **Elongation** was fond to be higher in case of Bamboo 20s yarn (9.1%) compared to other yarns as Bamboo itself possessed good amount of waviness which makes a yarn to take more time to rupture as it lacks the plastic nature.

Lea yarn strength means the amount of pressure required to break a hank of yarn. Cotton yarn hank (152.6lbs) noticed greater lea yarn strength compared to Bamboo and Tencel yarns due to the friction of the pulleys on which the hanks were mounted and also the yarn friction. Yarn friction may alter the fibre constituent of the yarn and also the force at which the yarn initiates to break which depends on the type of instrument used. As the braking elongation of cotton fibres/yarn are expected to reach the rupture point earlier resulting in collapsing the entire yarn structure which makes the yarns unstable to take the load applied.

Table 2: *Loom particulars of Bamboo and Tencel union fabrics*

Sl. No.	Particulars	Union fabrics (CC/ $CB_1/CB_2/CT_1/CT_2$)
1.	Type of loom	Pit loom (Handloom)
2.	Reed width	72’’
3.	Cloth width	36’’
4.	Denting order	2 Threads/dent

Weaving is a technique of fabric construction wherein two sets of yarns *viz.*, warp (lengthwise) and weft (filling) yarns are interlaced at right angle to each other to form a mesh like structure called as a woven fabric. In the present research five different types of union fabrics were woven on a traditional handloom also called as ‘pit loom’ using 2/20s Cotton yarn were used as warp while Bamboo and Tencel yarns of 20s and 30s as weft. One control sample and four union fabrics were woven on a handloom with 72’’ reed width, cloth width of 36’’ with 2 threads/dent denting order (Table 2).

Table 3: *Constructional details of Bamboo and Tencel union fabrics*

Sl. No.	Union fabrics	Direction	Fiber Content	Yarn type	Twist Direction	Threads per inch	Weave
1	Cotton × Cotton	Warp	Cotton	2 Ply	Z	48	Plain
		Weft	Cotton		Z	26	
2	Cotton × Bamboo 20s	Warp	Cotton		Z	51	Plain
		Weft	Bamboo		Z	23	
3	Cotton × Bamboo 30s	Warp	Cotton		Z	50	Plain
		Weft	Bamboo		Z	26	
4	Cotton × Tencel 20s	Warp	Cotton		Z	50	Plain
		Weft	Tencel		Z	23	
5	Cotton × Tencel 30s	Warp	Cotton		Z	50	Plain
		Weft	Tencel		Z	27	

Table 3 explains the constructional details of bamboo and tencel union fabrics wherein Cotton × Cotton (CC), Cotton × Bamboo 20s (CB_1), Cotton × Bamboo 30s (CB_2), Cotton × Tencel 20s (CT_1), Cotton × Tencel 30s (CT_2) 2 ply yarns possessing Z twist were utilized to weave plain woven fabrics on a pit loom following a traditional style of weaving by master weaver in Malali Village, near Hubli.

Table 4. *Cloth stiffness of Bamboo and Tencel union fabrics*

Sl. No.	Union fabrics	Cloth stiffness (cm)	
		Warp	Weft
1.	Cotton × Cotton	**4.24**	1.82
2.	Cotton × Bamboo 20s	**5.92**	1.74
3.	Cotton × Bamboo 30s	2.64	**1.86**
4.	Cotton × Tencel 20s	**6.40**	**1.86**
5.	Cotton × Tencel 30s	4.04	**1.92**

ANOVA Table

Factors	S.Em. ±	C.D. (5 %)
A- (Union fabrics)	0.04	0.12
B- (Warp and weft)	0.02	0.07
A × B- (Union fabrics) × (warp and weft)	0.06	0.17

* CD- Critical difference

Table 4, Figure 1 disclose the **cloth stiffness** was slightly higher in union fabrics *viz.*, Cotton × Tencel 20s (6.40 cm) and Cotton × Bamboo 20s (5.92 cm) fabric compared to Cotton × Cotton (4.24 cm) fabric in warp direction which is due to the sizing applied to warp yarns (Cotton yarns) prior to weaving thus imparting stiffness in warp direction. Whereas, due to the variation in the linear densities of the yarns, as tencel obtained greater single yarn strength (table 1) resulted in higher stiffness which means if the fabric is stiffer, thus, it will take greater time to bend against gravity hence Cotton × Tencel fabrics had higher cloth stiffness in weft direction.

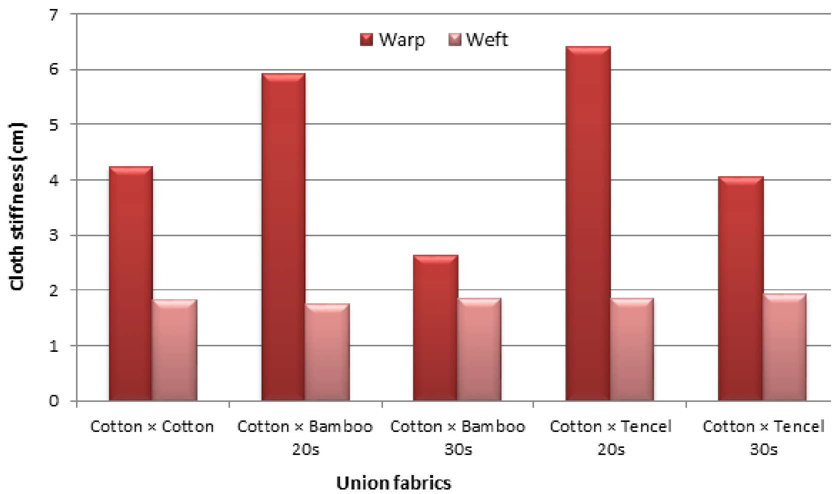

***Fig. 1**. Cloth stiffness of Bamboo and Tencel union fabrics*

Rashmi [8] quoted warp way cloth stiffness was signific antly lower than the weft way cloth stiffness as presence of cotton yarns which possessed finer yarn count and more evenness of the yarn.

Table 5: Cloth crease recovery of Bamboo and Tencel union fabrics

Sl. No.	Union fabrics	Cloth crease recovery (degrees)	
		Warp	Weft
1.	Cotton × Cotton	82.40	84.20
2.	Cotton × Bamboo 20s	83.40	**108.20**
3.	Cotton × Bamboo 30s	**85.80**	93.00
4.	Cotton × Tencel 20s	56.40	106.20
5.	Cotton × Tencel 30s	83.60	99.20

ANOVA Table

Factors	S.Em. ±	C.D. (5 %)
A- (Union fabrics)	1.24	3.55
B- (Warp and weft)	0.78	2.24
A × B- (Union fabrics) × (warp and weft)	1.75	5.02

* CD- Critical difference

It is perceived from table 5, fig 2 that, among the fabrics Cotton × Bamboo 30s union fabric (85.80°) had highest **crease recovery angle** when compared to Cotton × Bamboo 20s (83.40°) and Cotton × Tencel 30s (83.60°) union fabric due to the combination of Cotton, Bamboo and Tencel yarns in union fabrics, more unevenness of the yarns, type of weave all alters the crease recovery angle in warp way. Weft way crease recovery was higher in Cotton × Bamboo 20s union fabric (108.20°) when compared to Cotton × Cotton fabric. This may be due to the stiffness of the union fabrics makes them more stiff and pliable than the control sample. The results were on par with the study on value addition to silk floss by Rashmi [8].

***Table 6:** Cloth tensile strength and elongation of Bamboo and Tencel union fabrics*

Sl. No.	Union fabrics	Tensile strength (kgf)		Elongation (%)	
		Warp	Weft	Warp	Weft
1.	Cotton × Cotton	**38.00**	25.24	**12.33**	11.51
2.	Cotton × Bamboo 20s	30.02	18.76	9.66	16.76
3.	Cotton × Bamboo 30s	36.72	**27.32**	12.01	8.23
4.	Cotton × Tencel 20s	37.1	21.70	10.44	**17.28**
5.	Cotton × Tencel 30s	34.66	**39.1**	12.10	11.33

ANOVA Table

Factors	S.Em. ±	C.D (5 %)
A- (Union fabrics)	0.22	0.63*
B- (Tensile strength and elongation)	0.14	0.39*
C- (Warp and weft)	0.14	0.39*
A × B - (Union fabrics) × (tensile strength and elongation)	0.31	0.89*
A × C- (Union fabrics) × (warp and weft)	0.31	0.89*
B × C- (Tensile strength and elongation) × (warp and weft)	0.20	0.56*
A × B × C- (Union fabrics) × (tensile strength and elongation) × (warp and weft)	0.44	1.32*

*- CD- Critical difference; Significant at 5 % level of significance

Maximum **tensile strength** was observed in Cotton × Cotton fabric (38kgf) when compared to union fabrics which may be due to the presence of good amount of crysatllinity in the polymer system of both Cotton and Tencel which makes them to withstand the force applied to tear the fabric. However, Cotton × Tencel (39.10 kgf) and Cotton × Bamboo (27.32kgf) 30s union fabric attained highest tensile strength in weft direction may be due to the combination of bamboo and tencel yarns with cotton yarns together influences the cloth tensile strength (Table 6 and Figure 3).

Further, Cotton × Cotton fabric (12.33%) possessed highest **elongation** percentage in warp direction on the other hand, Cotton × Tencel 20s union fabric (17.28%) obtained highest elongation percentage in weft direction which as in case of cotton × cotton fabric both set of yarns are cotton which makes the fabric double times stronger while in case of Cotton × Tencel 20s union fabric both Cotton and Tencel yarn possess high amount of crysatllinity thus making the fabric stronger and sustain more pressure. Similar results were quoted by Rashmi [8] in a study on value addition to silk floss and stated that in general warp way tensile strength of the designed fabric samples depicted higher tenacity.

Table 7: *Cloth drapability of Bamboo and Tencel union fabrics*

Sl. No.	Union fabrics	No of nodes	Drape coefficient (%)
1.	Cotton × Cotton	3	**105.44**
2.	Cotton × Bamboo 20s	3	97.30
3.	Cotton × Bamboo 30s	4	95.24
4.	Cotton × Tencel 20s	4	101.31
5.	Cotton × Tencel 30s	4	**104.11**

ANOVA Table

Factors	S.Em. ±	C.D. (5 %)
A- (Union fabrics)	0.55	1.58*
B- (No of nodes and drape coefficient)	0.35	1.00*
A × B- (Union fabrics) × (no of nodes and drape coefficient)	0.78	2.23*

*- CD- Critical difference; Significant at 5 % level of significance

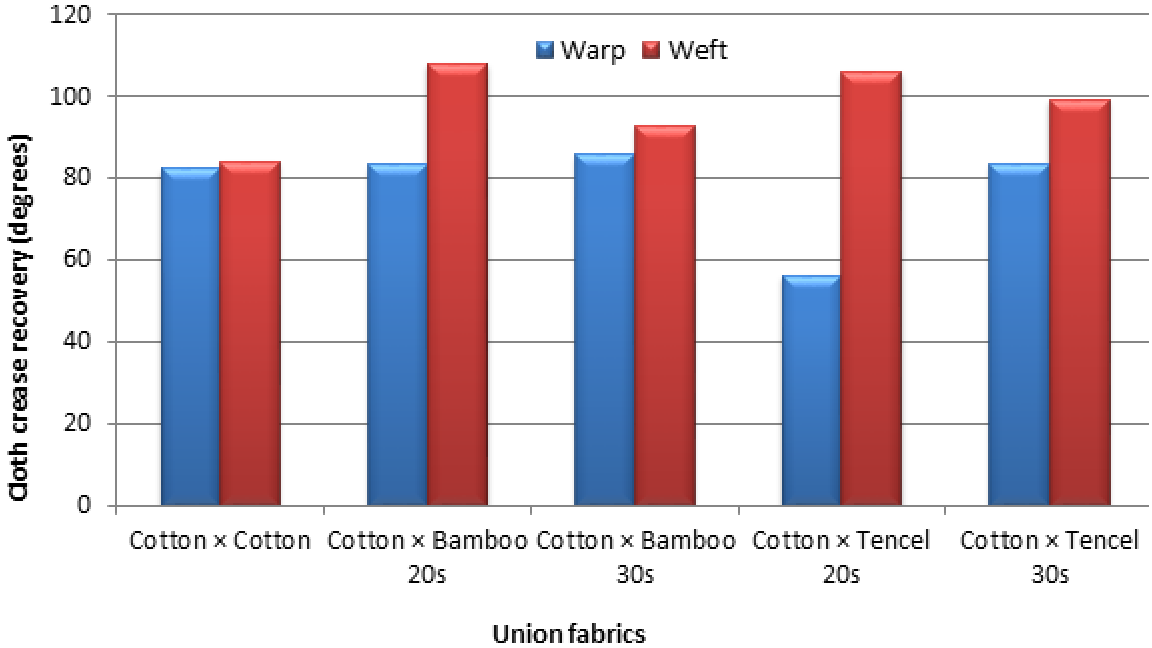

Fig. 2. *Cloth crease recovery of Bamboo and Tencel union fabrics*

Cloth drapability and stiffness are interrelated and are influenced by various properties *viz.*, fabric set ratio, weave, cloth count and cloth thickness. Thus Table 7, Figure 4 illustrates that, cloth drape coefficient was found to be higher in cotton × cotton fabric (105.44%) and cotton × tencel 30s union fabrics (104.11%) which may be because of as cloth stiffness and cloth crease recovery of the fabrics were found to be on par when compare to cotton × bamboo union fabric resulting in higher stiffness ultimately making a fabric stiffer and coarser.

However, irrespective of counts, least cloth drape coefficient was found in cotton × bamboo/tencel union fabrics contributing to lower bending length and cloth thickness, thus making the fabric suppler and soft. Least cloth drape coefficient attributed to low cloth stiffness thus making it soft and pliable, according to Kulkarni *et al.*, [9].

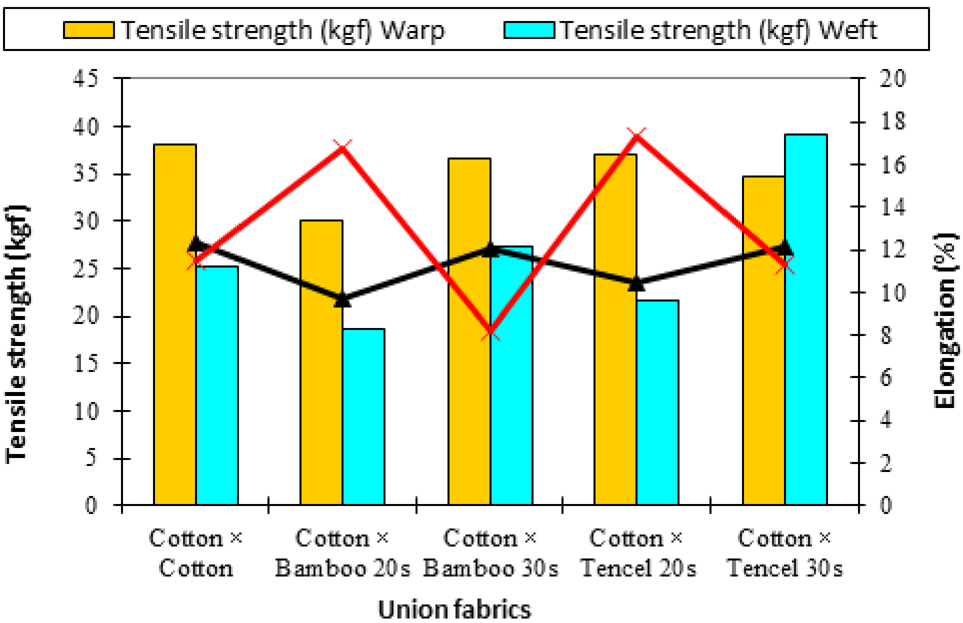

Fig. 3. *Cloth tensile strength and elongation of Bamboo and Tencel union fabrics*

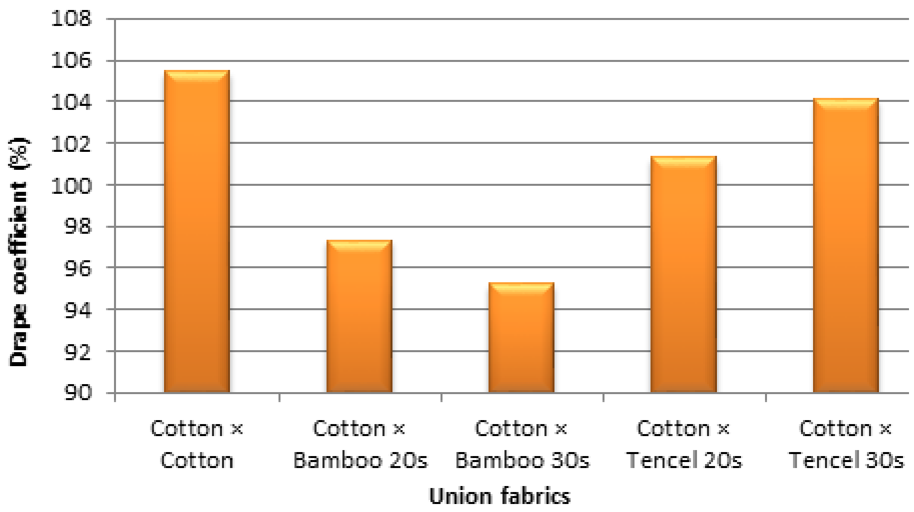

Fig. 4. *Cloth drape ability of Bamboo and Tencel union fabrics*

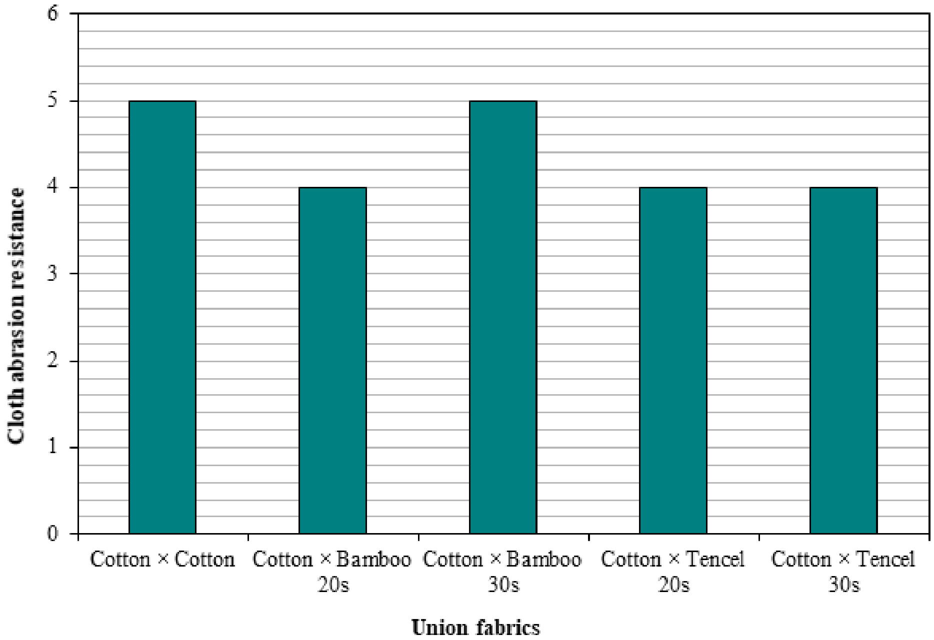

Fig. 5. *Cloth abrasion resistance of Bamboo and Tencel union fabrics*

Table 8. *Cloth abrasion resistance of Bamboo and Tencel union fabrics*

Sl. No.	Union fabrics	Total revolution	Cloth abrasion resistance
1.	Cotton × Cotton	100 Revolutions/ Sample	**5**
2.	Cotton × Bamboo 20s		4
3.	Cotton × Bamboo 30s		**5**
4.	Cotton × Tencel 20s		4
5.	Cotton × Tencel 30s		4

5- No pilling, 4- Slight pilling, 3- Moderate Pilling, 2- Severe pilling, 1- Very severe pilling

Table 8, Figure 5 indicated that, Cotton × Cotton (5) and cotton × bamboo 20s union fabric exhibited no pilling, indicating excellent durability of the fabric thus increasing its life for longer usage. The factors contributing to abrasion resistance are yarn count, cloth count, cloth thickness and the amount of friction between the abradent used and the fabric surface. The results of value addition to silk floss by Rashmi [8] were on par with present research stating that union fabrics with cotton×cotton/silk floss depicted higher abrasion resistance due to the higher percentage of cotton fibre also depends on yarn count, thickness, cloth count and highest contact with abradent and fabric surface.

Table 9. *Cloth thermal insulation value of Bamboo and Tencel union fabrics*

Sl. No.	Union fabrics	Cloth thermal insulation value (tog)
1.	Cotton × Cotton	27.34
2.	Cotton × Bamboo 20s	**29.60**
3.	Cotton × Bamboo 30s	23.84
4.	Cotton × Tencel 20s	27.42
5.	Cotton × Tencel 30s	26.34
S.Em. ±		0.01
C.D. 5 %		0.03*

*- CD- Critical difference; Significant at 5 % level of significance

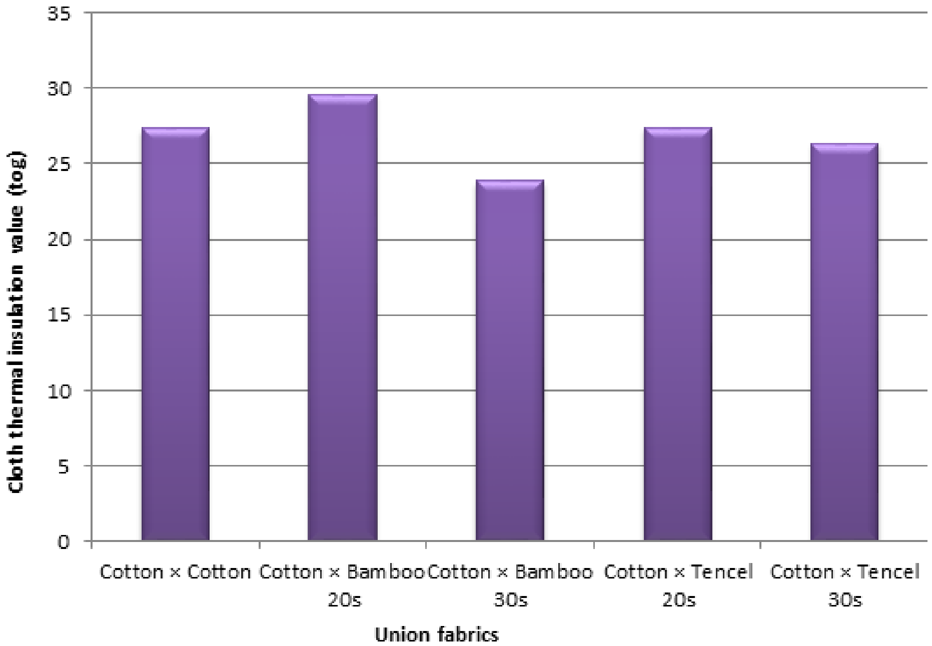

Fig. 6*. Cloth thermal insulation value of Bamboo and Tencel union fabrics*

Table 9, Figure 6 expresses that the **cloth thermal insulation value** depicted higher in cotton × bamboo 20s union fabric (29.60 tog) when compared to the cotton × cotton fabric (27.34 tog) because as cotton is a good conductor of heat, cotton and bamboo both being cellulosic in nature have the tendency to retain heat energy and combining the properties of both cotton and bamboo results in good thermal insulation value of the union fabrics. The results of value addition to silk floss by Rashmi [8] were on par, stating that, maximum thermal insulation value was observed in union fabrics which were due to the combined effect of cotton and silk floss resulting in higher thickness.

Table 10. Cloth air permeability of cotton × bamboo/tencel union fabrics

Sl. No.	Union fabrics	Cloth air permeability ($cm^3/cm^2/sec$)
1.	Cotton × Cotton	58.32
2.	Cotton × Bamboo 20s	43.38
3.	Cotton × Bamboo 30s	**76.26**
4.	Cotton × Tencel 20s	69.28
5.	Cotton × Tencel 30s	**75.28**
S.Em. ±		0.01
C.D. 5 %		0.03*

*- CD- Critical difference; Significant at 5 % level of significance;

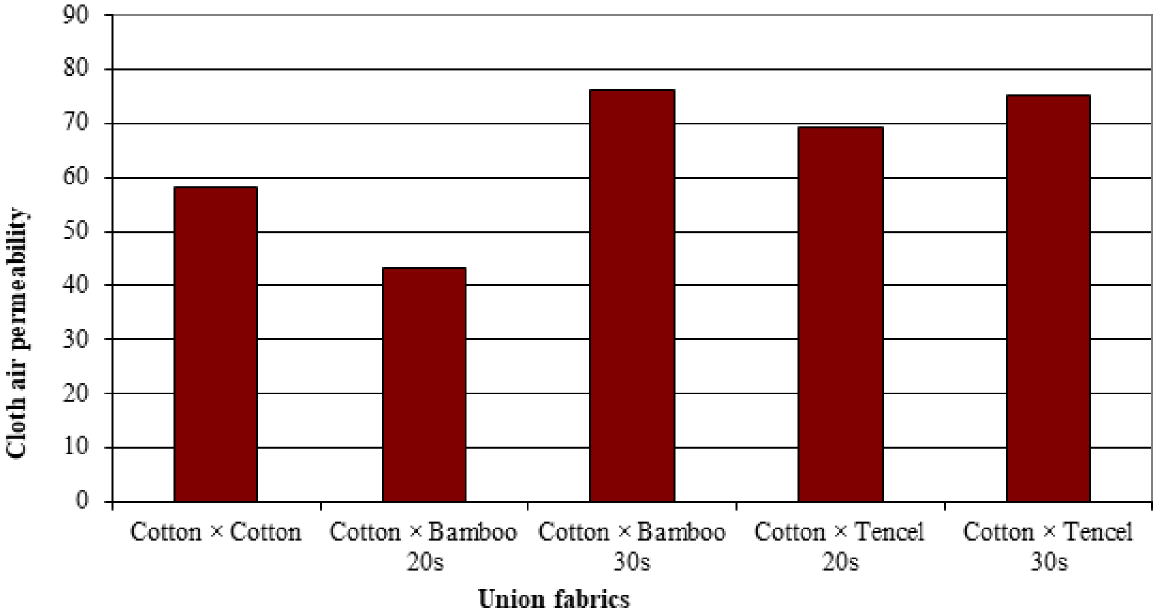

Fig. 7*. Cloth air permeability of cotton × bamboo/tencel union fabrics*

The results presented in Table 10, Fig 7 depicted that, cotton × bamboo 30s (76.26 $cm^3/cm^2/sec$) and cotton × tencel 30s (75.28 $cm^3/cm^2/sec$) union fabrics attained highest **cloth air permeability** which may be due to the count (30s) and compactness of the weave. It can be stated that, higher the yarn count, finer the yarn thus allowing more air to pass through the interstice spaces of the fabrics. Further, loosely woven fabric creates more spaces for air to pass through the fabric structure thereby increasing the air permeability. On the other hand, union fabrics of 20s count were less permeable to air because of the use of coarser yarns and compactly woven fabric structure.

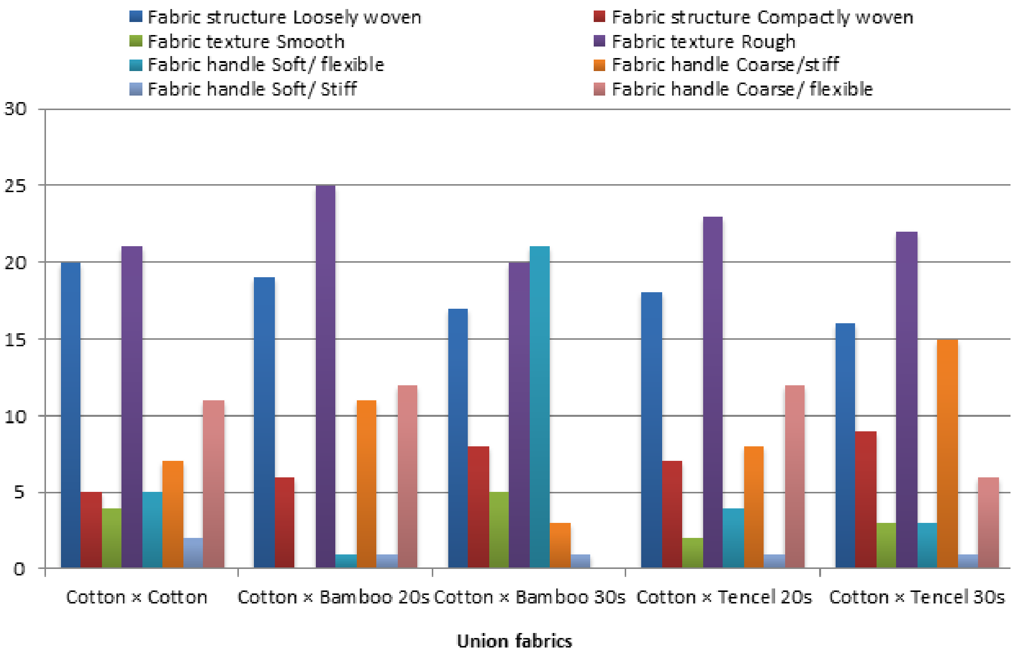

Fig. 8*. Textile expert's opinion on fabric structure and tactile properties of developed union fabrics*

Table 11. *Textile expert's opinion on fabric structure and tactile properties of developed union fabrics*

Sl. No	Samples	Fabric structure		Fabric texture		Fabric handle			
		Loosely woven	Compactly woven	Smooth	Rough	Soft/ flexible	Coarse/stiff	Soft/ Stiff	Coarse/ flexible
1	Cotton × Cotton	**20 (80.00)**	5 (20.00)	4 (16.00)	**21 (84.00)**	5 (20.00)	7 (28.00)	2 (8.00)	11 (44.00)
2	Cotton × Bamboo 20s	19 (76.00)	6 (24.00)	-	**25 (100.00)**	1 (4.00)	11 (44.00)	1 (4.00)	**12 (48.00)**
3	Cotton × Bamboo 30s	17 (68.00)	**8 (32.00)**	**5 (20.00)**	20 (80.00)	**21 (84.00)**	3 (12.00)	1 (4.00)	-
4	Cotton × Tencel 20s	**18 (72.00)**	7 (28.00)	2 (8.00)	23 (92.00)	4 (16.00)	8 (32.00)	1 (4.00)	**12 (48.00)**
5	Cotton × Tencel 30s	16 (64.00)	**9 (36.00)**	3 (12.00)	22 (88.00)	3 (12.00)	**15 (60.00)**	1 (4.00)	6 (24.00)

It was found in Table 11, fig 8 that majority of the respondents opined that, the cotton × cotton fabric (80%) was loosely woven with a rough texture. This may be because of the coarser yarn count and maida starch applied to warp yarns before weft insertion in order to avoid entanglement of yarn and making the yarns to easily pass through the dent. Based on the fabric structure and texture, it was observed that the union fabrics were attributing a soft/flexible, coarse/stiff and coarse/flexible fabric handle property. This may be due to the loom on which the fabric was woven and the different yarn count of bamboo and tencel yarns which also contributes to the fabric handle.

Table 12. *Preference of the developed union fabrics by textile experts*

Sl.No	Samples	Bamboo and Tencel union fabrics						
		Excellent	Very good	Good	Fair	Poor	Average	WAR
1	Cotton × Cotton	6 (24.00)	5 (20.00)	7 (28.00)	-	7 (28.00)	3.12	III
2	Cotton × Bamboo 20s	11 (44.00)	-	8 (32.00)	4 (16.00)	2 (8.00)	**3.56**	**II**
3	Cotton × Bamboo 30s	4 (16.00)	12 (48.00)	5 (20.00)	3 (12.00)	1 (4.00)	**3.60**	**I**
4	Cotton × Tencel 20s	2 (8.00)	6 (24.00)	3 (12.00)	11 (44.00)	3 (12.00)	2.72	IV
5	Cotton × Tencel 30s	2 (8.00)	2 (8.00)	2 (8.00)	6 (24.00)	13 (52.00)	1.96	V

5 - Excellent 4 - Very good 3- Good 2- Fair 1- Poor
*Figures in parenthesis indicate percentages *Higher the average values higher the rank

Table 12, Figure 9 depicts the preference of textile experts for cotton union fabrics based on the fabric structure, texture and handle properties. It is noticed cotton × bamboo 30s union fabric was highly preferred as it was woven with coarser cotton yarn thus adding weight and making it more usable.

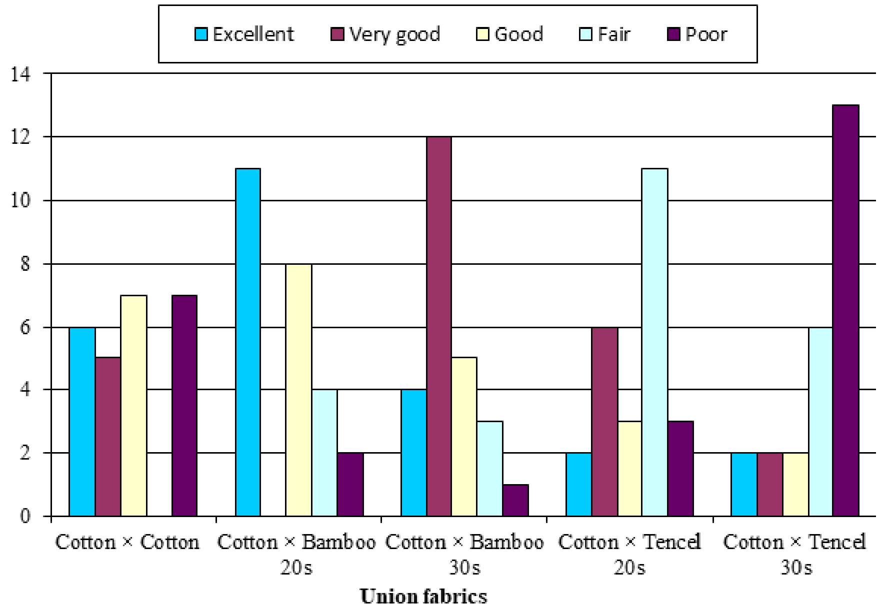

Fig. 9. *Preference of the developed union fabrics by textile experts*

Table 13. *Cost of production of developed union fabrics (Rs./mt)*

Sl. No.	**Particulars**	Cotton × Cotton	**Union fabrics**			
			Cotton × Bamboo 20s	Cotton × Bamboo 30s	Cotton × Tencel 20s	Cotton × Tencel 30s
I. a	Variable Cost (Raw material) Warp	**400.00**				
	Weft	400.00	250.00		280.00	
Total		800.00	650.00		680.00	
b	Pre preparatory process	66.60				
c	Weaving	80.00				
II.	Total cost of production	**946.6**	796.6		826.6	

- Cost of cotton yarn /kg (warp): Rs. 400.00/-
- Cost of bamboo yarn (20s and 30s) kg (weft): Rs. 250.0/-
- Cost of tencel yarn (20s and 30s) /kg (weft): Rs.280.00/-

A perusal of Table 13 indicates that, variable cost of Cotton yarns was found to be higher in cotton × cotton (400.00/-) fabrics in comparison to Bamboo (250.00/-) and Tencel (280.00/-) union fabrics as rate of cotton yarns per kg was higher when compared to Bamboo and Tencel yarns. Total cost of production of one meter of cotton x cotton fabric (946.6/-) was maximum when compared to bamboo and tencel union fabrics as cotton yarns were the costliest yarns among the five types of yarns used in the study.

4.CONCLUSIONS

A union fabric is a textile fabric, which is woven using two different yarns in warp and weft direction to get a new fabric having the properties of both the yarns. Union fabric enables the weavers to combine two different sets of yarns so that good qualities are emphasized and poor qualities are minimized, thereby having the fabrics with better functional properties. Bamboo and Tencel union fabrics being user friendly, ecofriendly is of great use in medical textiles too.

5.REFERENCES

[1]. Yarkova, Y., Atanasova, P. (2020). Leading innovative practices in the thematic area "Healthy living industry and biotechnologies" at a regional level. Trakia Journal of Sciences, 18(1): 451-459. DOI:10.15547/tjs.2020.s.01.074

[2]. Sarvanan,K. and Prakash, C. (2008). Bamboo fibres and their application in textiles. *Indian Textile Journal.*, 15(3): 137-140.

[3]. Booth, J. E. (1996). Principle of textile testing: An introduction to physical methods of testing textile fibres, yarns and fabrics. *CBS Pub. Distri*., New Delhi, pp. 209-253.

[4] Indrie, L., Zlatev, Z., Ilieva, J., Oana, I.P., An algorithm for the analysis of static hanging drape, In: Industria Textila, 2023, 74, 2, 154–162 http://doi.org/10.35530/IT.074.02.202247,

[5] Zlatev, Z., Indrie, L., Ilieva, J., Secan, C., Tripa, S., Determination of used textiles drape characteristics for circular economy, In: Industria Textila, 2023, 74, 1, 57–66, http://doi.org/10.35530/IT.074.01.202241

[6]. Prakash, C., Ramkrishnan, G. and Koushik, V. C. (2011). Effect of blend ratio on qualitycharacteristics of bamboo/cotton blended ring spun yarn. *J. Sci. Tech.,* 6 (2): 67-71.

[7]. Majumdar, A., Mukhopadhyay, S., Yadav, R. and Mondal, K. A. (2011). Properties of ring-spun yarns made from cotton and regenerated bamboo fibres. *Ind. J. Fib. Tex. Res.,* 36 (1), 18-23.

[8]. Rashmi, P. (2016). Value addition to silk floss. *M.Sc. Thesis*, Univ.Agric. Sci. Dharwad, Karnataka (India)

[9]. Kulkarni, A., Mahale, G. and Kariyappa (2011). Physical properties of developed viscose rayon and eri silk union fabrics. *Karnataka J.Agric Sci.,* 24(4): 506-509.