

The Effect of Wet Processing on the Comfort and Mechanical Properties of Fabrics Made from Cotton Fibres and Its Blends with Modal and Tencel Fibres in Weft



Devanand Uttam  and Garima Ahlawat 

1 Introduction

To survive in throat-cutting competitive environment and to satisfy modern customers; the textile manufacturers and researchers are searching some new products which have improved properties. Modern customers consider comfort as one of the most important attributes in their purchase of textile and apparel products [1]. To achieve improved functional textiles; one attempt is to produce cotton/modal blended fabric and cotton/tencel blended fabrics.

Cotton is a natural cellulosic fibre while Modal and Tencel Lyocell are regenerated cellulosic fibres. The Modal[®] and Tencel[®] LF are cellulosic regenerated fibres manufactured by Lenzing Company, Austria. Like viscose, Tencel is produced from wood pulp but the process is chemically much less complex. Modal is a type of high wet modulus rayon and manufactured using cellulose obtained from beech trees [2–4]. The Tencel fibre has highest strength, elongation and moisture regain followed by modal fibre and cotton fibres. Although, wet tenacity reduced in both Modal and Tencel fibres; while it increases in cotton fibre. The cotton fibres show highest wet tenacity followed by Tencel fibres and modal fibres [2, 4]. The cross-sectional shapes of various fibres are shown in Fig. 1.

Mostly all cellulosic fabrics are gone through the two main wet processing stages: scouring and dyeing. These may alter the structure and properties of fabrics. This requires a detailed study. In the present work, three types of plain-woven fabrics are

D. Uttam (✉)

Department of Textile Engineering, Giani Zail Singh Campus College of Engineering and Technology, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab 151001, India
e-mail: d_a_uttam@yahoo.co.in

G. Ahlawat

Department of Fashion Technology, Government Polytechnic, Hisar, Haryana 125001, India
e-mail: garima.ahlawat@rediffmail.com

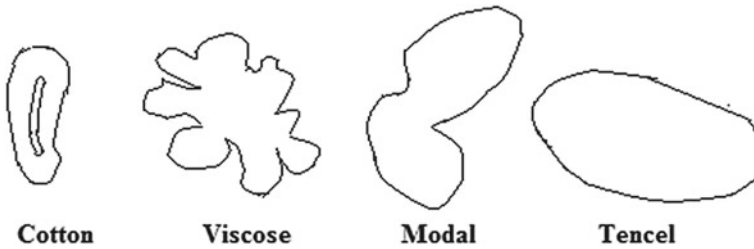


Fig. 1 Schematic diagram showing the cross-sectional view of different fibres

made using cotton yarn, cotton/tencel and cotton/modal blended yarns in weft only. The effect of wet processing on the comfort properties of these fabric samples is studied in three stages, i.e. greige state, after scouring and after dyeing. The fabric physical factors (cover factor, fabric thickness, fabric weight), air permeability, moisture transport properties, fabric stiffness and tensile properties of the fabrics were evaluated. The results are statistically analysed at 95% confidential limits.

2 Materials and Methods

2.1 Materials

Three types of plain-woven fabric samples were made using ring spun weft yarns of 30^s Ne with 100% cotton fibres, 50:50% cotton/modal blend and 50:50% cotton/tencel blend yarn in weft. The warp yarn for all fabric samples is cotton/polyester (60:40 with 2/40^s Ne). These three fabric samples were processed for scouring and then dyeing. Thus, a total of nine fabric samples (three samples each of greige, scoured and dyed stage) produced to study the impact of wet processing on properties.

i. Preparation of yarns

Weft yarn of 30^s Ne was produced by ring spinning technique using 3.5 twist multiplier. Cotton sample was made by two varieties: J-34 and S-6 in 50:50 ratio. These two varieties are mixed in blow room stage. Modal fibres and tencel fibres were blended each with the cotton fibres in 50:50 ratio at drawing stage. The yarns parameters are given in Table 1.

ii. Preparation of greige fabric samples

The plain-woven fabrics were prepared on rapier loom with a warp beam containing cotton/polyester 60:40 (2/40 s count) for all samples. For making fabric samples, three types of yarns: 100% cotton yarn, 50–50% cotton-modal blended yarn and

Table 1 The details of yarn parameters

Description	Cotton	Cotton-modal blend	Cotton-tencel blend
Yarn count	30 ^s Ne	30 ^s Ne	30 ^s Ne
Uster %	9.48	9.56	9.51
Imperfections (−50)	0.0	0.0	0.0
(+50)	22	37	30
(+200)	47	79	80
Strength RKM	18.83 cN/tex	20.4 cN/tex	23.82 cN/tex
CV%	7.89	8.7	9.47
Hairiness	5.39	5.14	5.21
Blend	100% Cotton	50:50	50:50
Blending Technique	–	DF Blending	DF Blending
Yarn TM	3.65	3.65	3.65

50–50% cotton-tencel blended yarns were used in weft only. The ends per/inch and picks/per inch were kept about 61.5 and 43.5 respectively.

iii. Preparation of scoured fabric samples

The scouring is done to remove the natural as well as added impurities and make fabric more absorbent. To make scoured samples, all three greige fabric samples were processed in kier for 2 h at boiling temperature using following scouring recipe:

Material to liquor ratio: 1:10.

Caustic soda (alkali): 2% (on the weight of material).

Soda ash: 2%

Detergent: 0.3%

Wetting Agent: 0.1%

Sodium silicate: 0.5%

Sodium sulphite: 0.5%

iv. Preparation of dyed fabric samples

Dyed samples were made by dyeing the scoured samples with reactive dye. The dye is able to react chemically with the substrate to form a covalent dye substrate linkage. The reactive dyes have a reactive group and this group makes covalent bond with fibre polymer and act as an integral part of fibre [5].

2.2 Methods

The fabric samples were tested for its physical factors (EPI, PPI, Cover Factor, GSM and Thickness), air permeability, moisture management properties, strength and stiffness test.

i. Physical factors

Fabric cover factor was calculated using the following formula:

$$\text{Fabric cover factor}(CF_f) = CF_{wrp} + CF_{wft} - \frac{(CF_{wrp} \times CF_{wft})}{28}$$

where, CF_{wrp} = Warp cover factor = n/\sqrt{N} (n = ends per inch and N = thread count).

CF_{wft} = Warp cover factor = n/\sqrt{N} (n = picks per inch and N = thread count).

The fabric weight per square meter (GSM) was measured according to ASTM D 3776–02 standards [6].

Fabric thickness was determined at 100 g/cm² pressure with the help of a precision thickness tester with accuracy 0.01 mm and pressure foot dia 10 mm.

ii. Air permeability test

Air permeability was measured at 185 Pa pressure by using the Digital Air Permeability Tester (YG461E Type) and expressed in mm/s [7] for all samples. The nozzle diameter and test area were 6 mm and 20 cm² respectively.

iii. Moisture management test

The SDL ATLAS Moisture Management Tester (MMT) was used to measure the liquid moisture management capabilities of the samples [8]. The instrument measures, evaluates and classifies liquid management properties of fabrics. It can measure overall moisture management capacity along with five other properties.

iv. Fabric breaking strength

The breaking strength and elongation of textile fabrics may be determined using the strip method test using the Aimil Universal Testing Machine [9].

v. Fabric stiffness test

Fabric stiffness is a property of fabric to keep standing without any support. It is an important factor in the study of handle and drape of fabric. The fabric stiffness was measured by Shirley Stiffness Tester [10] work on cantilever principle as per B.S. 3356:1990 test [11]. A 25 mm wide and 200 mm long rectangular strip of fabric was mounted on a horizontal platform in such a way that it hangs like a cantilever and bends downwards. The length of the fabric required to bend to a fixed angle is measured. This is known as bending length.

The stiffness of a fabric in bending is very dependent on its thickness, the thicker the fabric, the stiffer it is if all factors remain same [10]. The bending modulus is independent of the dimension of the strip tested.

$$\text{Bending Modulus} = \frac{12 \times G \times 10^3}{T^3} N/m^2$$

where,

G Flexural rigidity = $M \times C^3 \times 9.807 \times 10^{-6} \mu Nm$,

C Bending length (mm) and dependent on weight of the fabric.

M fabric mass per unit area (GSM).

T Thickness (mm).

3 Result and Discussion

Fabric physical factors (EPI, PPI, Cover factor, GSM and fabric thickness), comfort properties (air permeability and moisture management properties) and mechanical properties (tensile strength, stiffness) are evaluated and results are tabulated in Table 2.

Table 2 Test results

Weft yarn component in fabric	CF	Fabric weight (GSM)	Thickness (mm)	AP (mm/s)	OMMC index	Breaking strength (Newton)	Bending Modulus (N/m ² × 10 ⁻³)
100% C, Gr	17.16	1.29	0.37	117	0.70	185	9.69
50:50 C/M, Gr	17.16	1.28	0.36	145	0.75	166	9.84
50:50, C/T, Gr	17.33	1.28	0.36	129	0.78	196	8.50
100% C, Sc	17.96	1.33	0.39	84	0.81	216	6.62
50:50 C/M, Sc	18.07	1.34	0.38	92	0.78	174	6.31
50:50, C/T, Sc	17.90	1.37	0.38	100	0.79	244	5.86
100% C, Dy	17.80	1.39	0.43	92	0.82	213	6.78
50:50 C/M, Dy	18.22	1.39	0.42	97	0.79	157	6.07
50:50, C/T, Dy	18.19	1.43	0.44	94	0.80	174	4.34

C = Cotton, M = Modal, T = Tencel, Gr. = Greige Stage, Sc. = Scoured, Dy = Dyed, CF = Cover Factor, AP = Air permeability, OMMC = overall moisture management capacity index

3.1 Fabric Physical Properties

i. Cover factor

The results of cover factor are tabulated in Table 2 and the impact of wet processing is shown in Fig. 2. Result shows that after scouring, the cover factor increases in all fabrics samples due to fabric shrinkage and further increases slightly in cotton/modal (C/M) and cotton/tencel (C/T) samples after dyeing while in cotton (C) samples, it decreases slightly. There is a very slight difference in cover factor of all the samples.

ii. Fabric weight (GSM)

Fabric weight has been analysed and results are tabulated in Table 2 and the impact of wet processing is shown in Fig. 3.

Figure 3 shows that the fabric weight (GSM) of all the three types of fabrics has increased significantly after scouring and further increases in dyeing perhaps due to shrinkage of samples in each step of wet processing.

From the graphical result, it is found that in greige stage, all fabric having nearer same GSM value. After wet processing steps, i.e. in scouring and dyeing, the cotton/tencel blend has highest GSM value followed by cotton/modal blend fabrics and 100% cotton fabric.

iii. Fabric thickness

Thickness of a fabric plays important role in its comfort properties as well as handling and drape properties. The data of thickness is tabulated in Table 2 and the impact of wet processing is shown in Fig. 4.

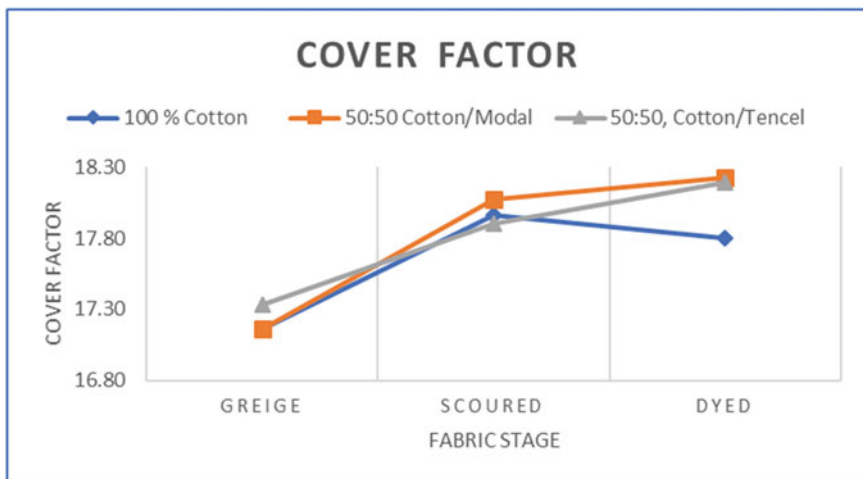


Fig. 2 Fabric cover factor

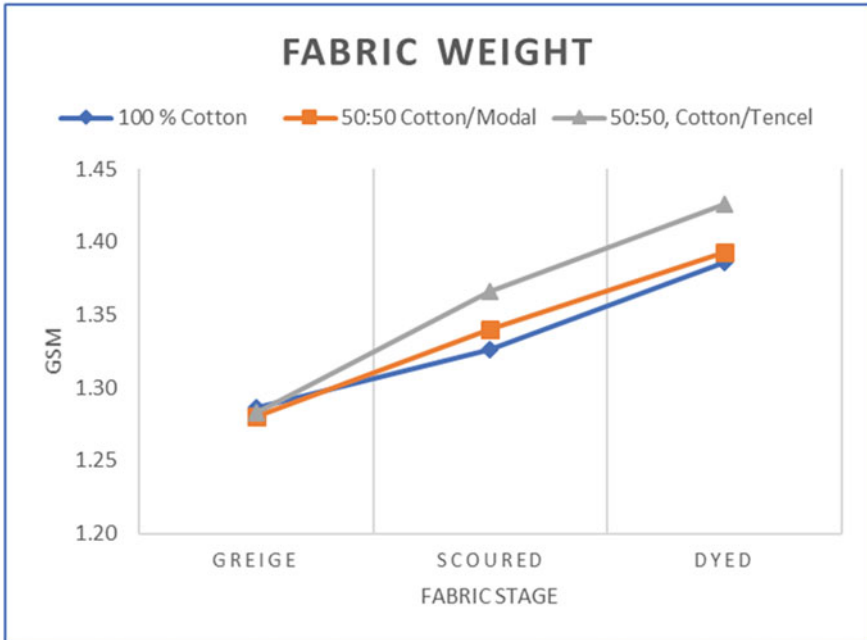


Fig. 3 Fabric weight (GSM)

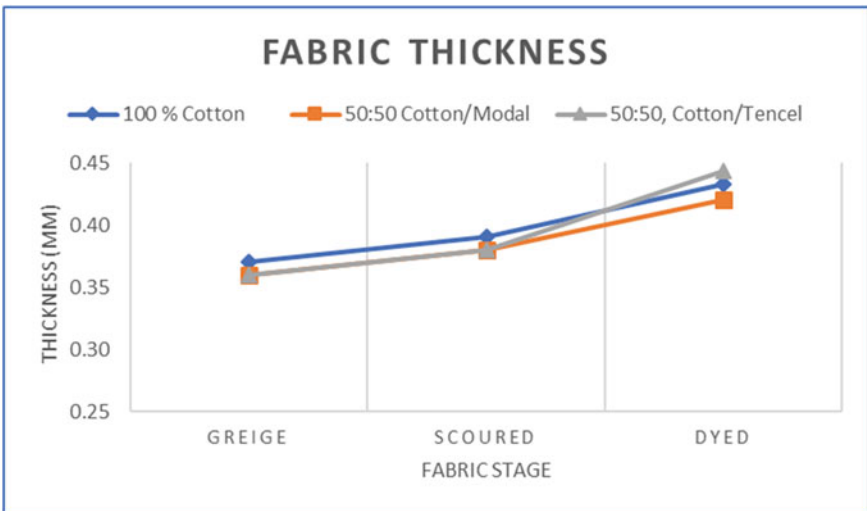


Fig. 4 Fabric thickness

After scouring the fabric thickness increases in all fabric samples significantly and further increases after dyeing. This may be due to shrinkage in process of wet processing. There is a very slight difference in between the different fabric sample in each stage.

3.2 Comfort Related Properties

i. Air permeability

The results of air permeability of the samples are tabulated in Table 2 and the effects of wet processing on various materials were shown in Fig. 5.

The air permeability decreases after scouring in all samples but there is no any significant changes in after dyeing. This may be perhaps due to mostly all shrinkage takes place at scouring and very little alteration in shrinkage after dyeing. After scouring, the resultant effect of shrinkage and fibre swelling take place and the yarns come closer resulting in decreasing of the gaps to let the air pass and this result in decrease of air permeability after scouring.

In greige stage, the air permeability of cotton-modal blend was the highest followed by cotton-tencel blend and 100% cotton weft yarn fabric samples. After scouring, air permeability of cotton/tencel is highest followed by cotton/modal and 100% cotton fabric. After dyeing, the cotton/modal blended fabric shows highest air permeability followed by tencel/cotton blended fabric and 100% cotton fabric.

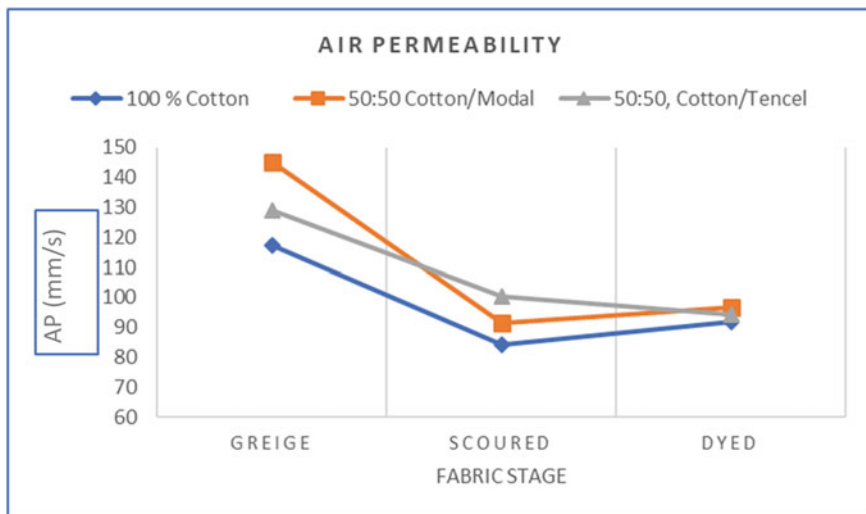


Fig. 5 Air permeability of fabrics

The air permeability of the fabrics depends on structure of the fabric, i.e. size of the pores, fabric thickness and tortuosity of the pores. Most of the air passes through the pores between the yarns but when the fabric is denser, the air also passes through the micro-voids inside the yarns (i.e. the pores between the fibres). There is good correlation (Table 3) between air permeability and fabric cover factor ($R = -0.86$) and GSM ($R = -0.72$) and fabric thickness ($R = -0.66$).

ii. **Moisture management capacity**

The overall moisture management capacity (OMMC) as measured by the Moisture Management Tester are furnished in Table 2 and the effect of wet processing illustrated in Fig. 6.

The overall moisture management capacity (OMMC) is based on three factors, the moisture absorption rate at the bottom of the fabric (ARB), the spreading speed at the bottom (SSB) and accumulative one-way transfer rate of liquid moisture from top to the bottom of the fabric. Higher value of OMMC is associated with higher capillary action.

Table 3 Correlation (R-value)

	Air permeability	OMMC	Breaking strength	Bending modulus
Cover factor	-0.859	0.716	0.016	-0.948
GSM	-0.720	0.651	0.025	-0.906
Thickness	-0.663	0.605	-0.089	-0.753

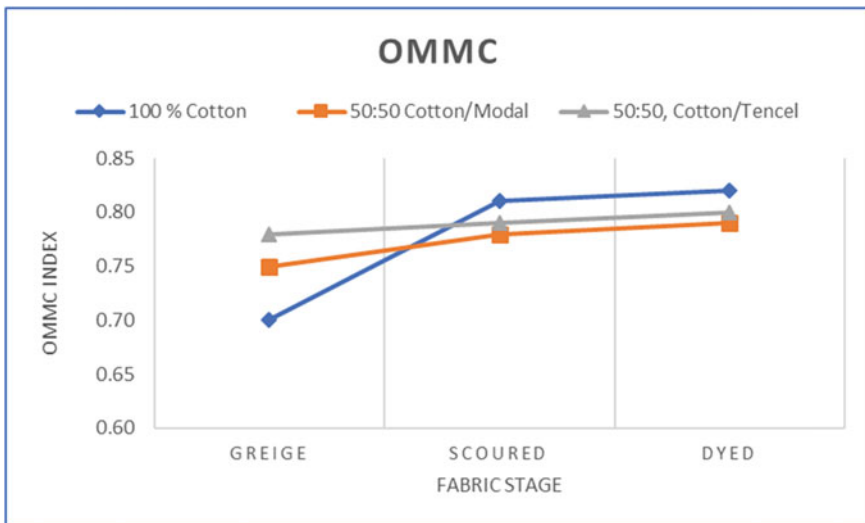


Fig. 6 Overall moisture management capacity

The overall moisture management capacity increases significantly in all samples after scouring and further increases after dyeing. This may be due to removal of cotton wax/spin finish from the cuticle/outer surface of the fibres resulting in improved water transport from the fibrous material. In the greige stage, cotton/tencel blended fabric has the highest value of OMMC followed by cotton/modal blended fabric and 100% cotton fabric. After scouring and dyeing, 100% cotton fabric has highest value of OMMC followed by cotton/tencel and cotton/modal fabric.

There is fair correlation has been found (Table 3) in between OMMC and fabric cover factor ($R = -0.72$) and GSM ($R = 0.65$) and fabric thickness ($R = 0.61$).

3.3 Fabric's Mechanical Properties

i. Breaking strength

Fabric breaking strength was tested using ravelled strip method test in weft direction and the results are tabulated in Table 2 and Fig. 7.

Figure 7 shows that the fabric strength increases after scouring and decreases after dyeing in all samples (100% cotton fabric, cotton/modal blended fabric and cotton/tencel blended fabric). In both greige stage and scoured stage, the breaking strength of cotton/tencel blended fabric is highest followed by 100% cotton fabric

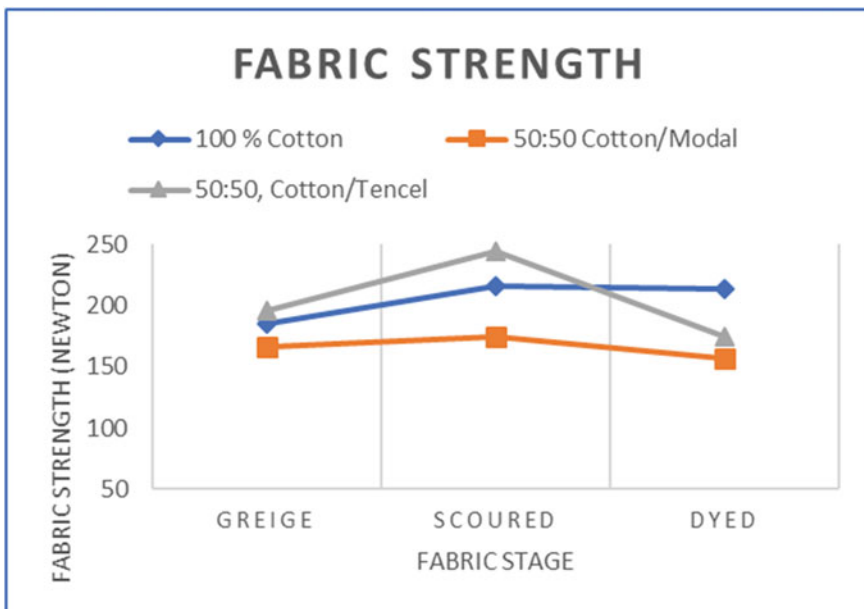


Fig. 7 Fabric breaking strength in weft-wise direction (in Newton)

and cotton/modal blended fabric. More strength of tencel is attributed to crystalline arrangement of its cellulose units which are extremely greatly oriented in the longitudinal axis of the fibre [12]. After dyeing, the breaking strength of 100% cotton fabric is highest followed by cotton/tencel blended fabric and cotton/modal blended fabric. Fabric strength is not good correlated with cover factor, GSM and fabric thickness.

ii. **Stiffness**

Stiffness of fabric was measured in terms of bending modulus. It has impact on fabric handle. As the bending modulus increases, the fabric will be stiffer. More stiff fabric will have less drape thus will not fall freely in a garment. The results are tabulated in Table 2 and the effect of wet processing in weft direction is shown in Fig. 8.

Figure 8 shows the bending modulus of fabrics in various stages, i.e. greige stag, scoured stage and dyed stage predicting the stiffness of samples. The fabric bending modulus decreases after scouring and there is no any significant change has been found after dyeing in mostly all samples.

There is no significant difference that has been found in cotton fabric and cotton/modal blended fabric samples but the cotton/tencel blended fabric has lesser bending modulus in all three stages, i.e. in greige stage, scoured stage and dyed samples.

There is very good correlation (Table 3) of bending modulus with cover factor ($R = -0.95$), with GSM ($R = -0.91$) and with thickness ($R = -0.75$).

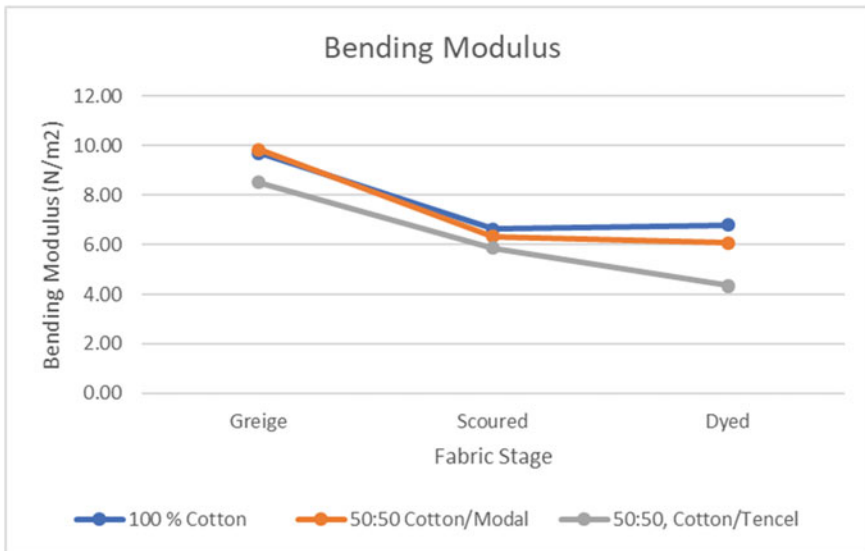


Fig. 8 Bending modulus in weft-wise direction

4 Conclusions

Results are concluded as under:

1. The air permeability decreases significantly after scouring but after dyeing the air permeability alter slightly and this difference is not significant. Air permeability was highest in cotton/modal blend followed by cotton/tencel blend and 100% cotton plain woven fabric in greige stages. After scouring the cotton/tencel blended fabric having the highest value followed by cotton/modal blend and 100% cotton. After dyeing the cotton/modal blend has highest air permeability values followed by cotton/tencel and 100% cotton fabric. In all cases the air permeability of cotton/tencel blend and cotton/modal blend was higher than 100% cotton fabric. There is good correlation between air permeability and fabric cover factor ($R = -0.86$) and GSM ($R = -0.72$) and fabric thickness ($R = -0.66$).
2. After scouring, the OMMC value increases sharply and further increases slightly after dyeing. In greige fabrics, cotton/tencel blend has the highest value of OMMC followed by cotton/modal and 100% cotton fabric. After scouring and dyeing the 100% cotton fabric has highest OMMC followed by cotton/tencel and cotton/modal blend fabric. There is fair correlation has been found in between OMMC and fabric cover factor ($R = -0.72$) and GSM ($R = 0.65$) and fabric thickness ($R = 0.61$).
3. In all fabric samples, the fabric breaking strength increases after scouring and decreases after dyeing. In greige stage and scoured stage, the breaking strength of cotton/tencel blended fabric followed by 100% cotton fabric and cotton/modal blended fabric. After dyeing the 100% cotton fabric shows highest strength followed by cotton/tencel blended fabric and cotton/modal blend fabric. Fabric strength is not good correlated with cover factor, GSM and fabric thickness.
4. In all samples, fabric bending modulus decreases abruptly after scouring and no further change after dyeing significantly. There is no significant difference has been found in cotton fabric and cotton/modal blended fabric samples but the cotton/tencel blended fabric has lesser bending modulus in all three stages, i.e. in greige stage, scoured stage and dyed samples. There is very good correlation of bending modulus with cover factor ($R = -0.95$), with GSM ($R = -0.91$) and with thickness ($R = -0.75$).

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