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Spinnability of cotton/milkweed blends on ring, compact and rotor spinning systems

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The physical characteristics of cotton/milkweed yarns spun on ring, compact and rotor spinning systems in relation to blend proportion and chemical treatment of milkweed fibres have been studied. During spinning of milkweed fibre blends, greater fibre losses in carding and flies during drafting are observed in further stages. It is observed that amongst the ring, compact and rotor yarns, the compact-spun blended yarns show higher yarn tenacity and elongation values followed by ring and rotor-spun yarns. The rotor-spun blended yarns show lower yarn unevenness, imperfections and hairiness values than compact and ring-spun yarns due to its mechanism of yarn formation. With the increase in milkweed proportion, the yarn quality deteriorates, irrespective of spinning systems due to lack of cohesiveness and brittleness of milkweed fibres, and drastic reduction in yarn quality is noticed for 40/60 cotton/milkweed blend. By considering the effect of chemical treatment of milkweed fibres, it is observed that the alkali-treated milkweed fibre blended yarns show better yarn properties due to improvement in fibre friction and elongation values followed by dyed and untreated milkweed fibres.

Keywords: Compact yarn, Dyeing, Milkweed yarn, Ring yarn, Rotor yarn, Spinning blended yarn

1 Introduction

The textile manufacturers are continuously striving to get new approaches to produce environment-friendly products, such as recyclable and biodegradable textile materials for use in textile goods[1]. After the second world war, the increase in synthetic fibre production considerably decreased the use of natural fibres. With the increase in oil prices and environmental concerns in recent years, there has been a resurgence of natural fibres in textile and automotive industries[2].

The *Pergularia daemia* is a ligno-cellulosic seed fibre obtained from plant, naturally growing drought and pest resistant tree of Indian origin which is well known for its medicinal values[3]. The plant *Pergularia* belongs to the family of *Asclepiadacea* and genus of *pergularia* which is considered under the milkweed fibres[4]. The fibres are hollow, with significantly thin wall relative to their diameter, and are therefore lightweight. Owing to their structure, they posses good insulation or buoyancy properties making them suitable for filler fibres in comforters, life vests and winter jackets[5-8]. One of the major drawbacks of milkweed fibre is difficulty in spinning the fibres into yarn due to its smooth surface. Because of its short length, milkweed floss has been blended with cotton and processed to develop yarns in ring and rotor spinning systems[9,10]. The milkweed generates larger waste when it is processed with cotton in blended form as compared to 100% cotton, presumably due to lack of cohesiveness in milkweed[11]. The breaking strength of yarns and fabrics made from the cotton/milkweed blends were found much lower than that of 100% cotton yarns and fabrics. The processing difficulty increases as the milkweed component increases in the blend. It appears to be impossible to spin a pure milkweed fibre yarn using a classical ring spinning process. The lack of cohesiveness of the milkweed fibres causes extreme difficulties in textile processing[12-14]. It is also used in oil spill clean-up[15] and composite manufacturing[16] because of its light weight and hollow structure. The similar studies were conducted on spinnability of hollow kapok fibres by various researchers and it is concluded that the spinning of 100% kapok fibres beyond lap formation stage is not possible, however, spinning of kapok fibre blended with at least 50% cotton fibre is largely successful[17]. With the increase in kapok content in the blend, the yarn regularity and tenacity decrease while the yarn extensibility increases, with the reduction in the total cost of production[18].

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But still there is a dearth in analysis of influence of chemical treatment of fibres and their influence on spinnability of milkweed fibres. Hence, in the present study, the effect of chemical treatment of milkweed fibres on the spinnability of cotton/milkweed blends in ring, compact and rotor spinning systems has been analysed.

2 Materials and Methods

2.1 Collection of Milkweed Fibres

The matured pods were collected from the plant *Pergularia daemia* for its floss, since immature pods yield floss of inferior quality. After collection, the floss is extracted from the pods and partly dried. The medium grade cotton variety S-4 was used to blend with the milkweed fibres.

2.2 Modification of Milkweed Fibres by Chemical Treatments

Milkweed fibre is a ligno-cellulosic seed fibre and hence possesses the inherent attributes of this class. The fibre is highly brittle and is easily hand-crushable due to high lignin content and has less cohesiveness between the fibres due to smooth rod like fibre profile. Hence, two chemical treatments namely delignification by alkali treatment[19] and dyeing of fibres were done to modify the surface properties of milkweed fibres. Dyeing of fibres modifies the surface characteristics of fibres and increases the fibre friction[20].

2.3 Physical Properties of Fibres

The linear density of the material was measured by gravimetric method using the ASTM test method D1577 at standard atmosphere conditions. The tensile properties of cotton and milkweed fibres were determined as per ASTM D3822-01 standard in an Instron tester. The fibre density determined with a density gradient column having a mixture of xylene (0.866 g/cc) and carbon tetrachloride (1.592 g/cc) as per ASTM D1505-03 standard shows the value in the range of 0.92-0.95 g/cm^3. The moisture regain of fibre samples were calculated by oven drying method using ASTM D2654-89a standard testing method. The fibre-to–fibre frictional coefficients of the cotton and milkweed samples were measured with the help of a friction tester developed by Gowda & Mohanraj[21]. An average of twenty readings was taken as the representative value for each sample.

2.4 Yarn Production

The spinning trials were conducted on a micro-spinning line (Trytex, India)[22,23]. Since 100% milkweed (M) fibres cannot be processed on the machine due to its lack of cohesiveness and low elongation-at-break, it was blended with the cotton (C) fibres at three different blend ratios of C/M 80/20, 60/40, and 40/60. Due to processing difficulties such as web falling in carding and roller lapping, the maximum milkweed proportion was limited to 60% in the blend. Three types of blended yarns such as ring, compact and rotor were produced. The process parameters in carding and draw frame were kept constant for all the three spinning systems. The process parameters in speed frame (spindle speed 1000 rpm, TM 1.0, roving hank 1.1), ring frame (spindle speed 10000 rpm, TM 4.4) and rotor frame (opening roller speed 8000 rpm, opening roller wire type OS21, rotor speed 40000 rpm) were kept constant for the production of 20^s Ne in ring, compact and rotor-spun yarns.

2.5 Testing of Yarn Properties

The yarn characteristics, such as single yarn strength (ASTM D 2256-02), yarn evenness, imperfections (ASTM D 1425-09) and hairiness frequency (Zweigle hairiness - ASTM D 5647-07) were tested as per standard method. All the tests were carried out after conditioning the samples at the standard temperature (21.0 ± 0.1°C) and relative humidity (65±2%). The wrapper fibres were evaluated by their rate of recurrence and arrangement in the yarn surface. The average number of loosely wrapped fibres per metre of yarn was observed in rotor-spun yarns.

3 Results and Discussion

3.1 Tensile Properties of Single Fibres

The linear density of cotton and milkweed fibres was found to be 1.25 and 1.05 denier respectively. The tensile properties of single fibres measured in Instron tester is given in Table 1.

Table 1—Tensile properties of cotton and milkweed fibres

Fibre property	Cotton	Milkweed fibre		
		Raw	Alkali treated	Dyed
Fibre denier	1.25 (12.7)	1.05 (18.6)	1.04 (16.2)	1.04 (17.5)
Breaking strength, gf	5.1 (35.72)	3.92 (44.63)	4.02 (57.13)	3.96 (39.22)
Tenacity, g/den	4.1 (34.1)	3.73 (37.6)	3.87 (53.5)	3.81 (42.1)
Breaking elongation, %	8.1 (23.2)	3.05 (33.7)	4.83 (39.6)	3.1 (35.4)
Initial modulus, gf/den	91.87 (42.33)	210.89 (33.7)	140.8 (45.38)	197.3 (52.2)

Values in parentheses represent CV%.

It is observed from Table 1 that the cotton fibres have higher tenacity and elongation values as compared to raw and chemically treated milkweed fibres, and these fibres are coarser than milkweed. The initial modulus of raw milkweed fibres is significantly higher than the cotton fibres, which could be due to the low elongation-at-break of milkweed as compared to cotton. The tenacity and elongation of alkali-treated milkweed fibre slightly increase as compared to the raw fibre. This may be due to re-arrangement of molecular chains and formation of convolutions after alkali treatment[19]. Such lower elongation values could result in fibre breakage during opening in blow room and carding processes. The dyed milkweed fibre sample does not show a significant difference in tensile properties than in raw fibres.

3.2 Effect of Chemical Treatments on Frictional Property of Milkweed Fibres

The fibre-to-fibre friction coefficient (μ) measured on the fibre friction tester shows a value of 0.33 for cotton fibre and 0.16, 0.22, 0.28 for raw, dyed and alkali-treated milkweed fibres respectively. The values for milkweed are relatively lower than that for cotton, indicating a smooth surface without convolutions or crimps. The alkali-treated fibre shows higher friction co-efficient followed by dyed fibre. This is due to the irregular collapse of hollow structure and formation of convolution like structure in the milkweed fibres[19].

3.3 Influence of Carding on Sliver Properties

The carded slivers were tested for their properties like 5% length, nep count and short fibre content in AFIS instrument. The AFIS results of the carded slivers are given in Table 2. It is observed that, the 5% length of C/M blended slivers is lesser than 100% cotton slivers due to more number of shorter milkweed fibres in the blend. The short fibre content and nep count of C/M blended sliver increase with the increase in milkweed fibre proportion, irrespective of chemical treatments. This could be due to milkweed fibre breakage during opening and stationary flat arrangement in the carding machine respectively.

3.4 Fibre Loss in Carding

Since the milkweed fibres possess less cohesiveness because of its smooth rod like surface, it is necessary to blend them with cotton to make their yarn. The raw milkweed fibres have been mixed with carded cotton fibres in desired weight ratios to produce three different blended yarns. The blending process is rather easy, but a significant fibre loss is noticed while carding. Figure 1 shows the

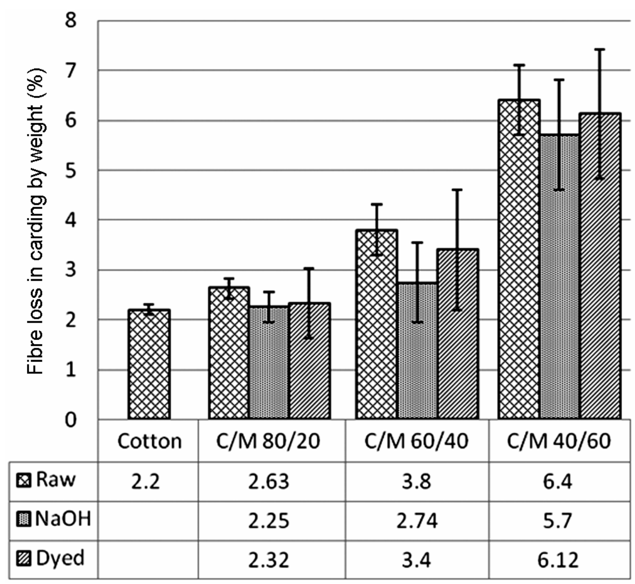


Fig. 1—Influence of blend ratio and nature of fibre treatment of milkweed on card fibre loss

Table 2—AFIS results of cotton and cotton/milkweed blended card slivers

Fibre particulars	Chemical treatment	5% Length, mm	Nep count/g	Seed coat, Nep/g	Short fibre content (n), %
100% Cotton	Raw	30.4 (2.6)	90 (12.2)	2 (16.3)	28.6 (9.2)
C/M 80/20	Raw	29.6 (4.7)	111 (18.2)	2 (12.3)	39.8 (14.1)
	Alkali	29.9 (3.9)	102 (16.9)	1 (8.3)	34.3 (13.9)
	Dyed	29.6 (3.6)	99 (16.6)	1 (10.2)	37.4 (13.7)
C/M 60/40	Raw	29.7 (6.3)	139 (15.6)	1 (7.3)	58.9 (17.2)
	Alkali	29.8 (5.3)	126 (16.2)	2 (6.9)	47.7 (15.8)
	Dyed	29.8 (5.2)	132 (16.7)	1 (9.2)	53.3 (16.3)
C/M 40/60	Raw	29.8 (6.9)	171 (23.5)	1 (6.3)	73.7 (21.3)
	Alkali	29.7 (6.6)	156 (22.4)	1 (3.2)	58.8 (19.7)
	Dyed	29.7 (6.3)	175 (21.6)	1 (7.2)	60.6 (20.9)

Values in parenthesis indicates CV%.

fibre loss during carding with various milkweed proportions. With increase in the blend ratio of milkweed, there is further increase in fibre loss. While carding, the short and finer milkweed fibres are preferentially absorbed as flat strips in the stationary flat arrangement of miniature carding. The increase in fibre loss with milkweed proportion could be attributed to low friction coefficient and brittle nature of milkweed fibres. The lickerin droppings and micro dust generation also increase with the increase in milkweed proportion.

3.5 Influence of Process Parameters on Yarn Tenacity and Elongation

The influence of milkweed blend proportion and chemical treatments on ring, compact and rotor yarn tenacity is shown in Fig. 2. It is evident that the yarn tenacity decreases as the milkweed content increases in ring-, compact- and rotor-spun C/M blended yarns, irrespective of nature of chemical treatments. The yarn tenacity is found higher for the compact yarns followed by ring and rotor yarns for all combinations of C/M. This is due to the technological advantages of compact spinning process. With increase in milkweed fibres in the blend, the tenacity drops due to more number of relatively less stronger and less cohesive fibres in the yarn cross-section.

The rotor-spun yarns have lowest yarn tenacity values as compared to ring- and compact-spun yarns due to its mechanism of yarn formation. The less prominent, less frictional, parallelization of fibres in the yarn surface as compared to that in ring-spun yarn are also the reason for its lower yarn tenacity[24]. From the analysis of frequency of wrapper fibres in the rotor-spun yarns, it is noticed that number of loosely bound wrapper fibres increases with the increase in milkweed proportion. The increase in bend proportion of finer and less cohesive milkweed fibres leads to clumping of fibres at the exit of transport tube, causing an uneven deposition of fibres inside the rotor groove which could result in wrapper fibre formation. The number of wrapper fibres per metre of yarns is found to be 57, 62, 64 and 79 for 100% cotton, C/M 80/20, C/M 60/40 and C/M 40/60 respectively. The loosely wrapped fibres do not contribute much to the yarn tenacity positively as these fibres will not hold the yarn structure tightly. This could be a reason for lower yarn tenacity with increasing milkweed proportion in the blend.

Considering the influence of chemical treatments of milkweed fibres on the tenacity of C/M blended yarns, it is observed from Fig. 2 that the alkali-treated yarns give better results, followed by dyed and raw yarn samples in all spinning systems. The increase in yarn tenacity of alkali-treated yarns is mainly because of the increase in inter-fibre friction and elongation-at-break of milkweed fibres. In case of dyed yarns, the surface friction of fibre increases moderately, thereby increasing the tenacity as compared to untreated (raw) samples. The change in inter-fibre friction in both alkali-treated and dyed milkweed fibres has led to better self-locking with cotton fibres which improve the twisting and compact packing of fibres, thus leading to increased yarn tenacity. In case of yarn elongation, a trend similar to tenacity is noticed. The elongation values decrease with increase in milkweed percentage of the blend for all spinning systems. The

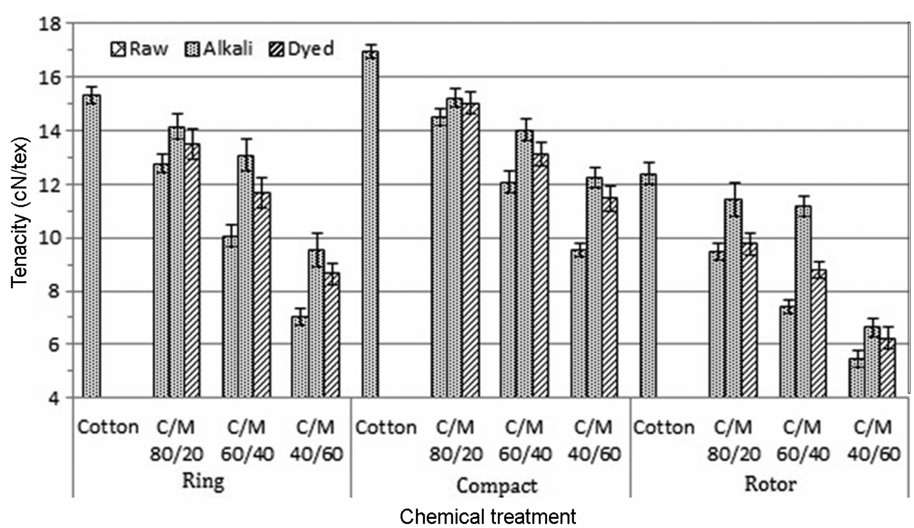


Fig. 2—Effect of milkweed blend proportion, chemical treatments and different spinning systems on yarn tenacity

elongation of rotor-spun yarns is comparable to that of ring- and compact-spun blended yarns. This could be attributed to its differential twist structure.

3.6 Influence of Process Parameters on Yarn Evenness

Figure 3 reveals a slight improvement in yarn evenness of compact-spun blended yarns as compared to ring yarns but the change is not significant. The evenness values deteriorate with the increase in milkweed content, as milkweed fibres could not be controlled effectively in the drafting zone due to its intrinsic nature and lesser fibre-to-fibre friction. In compact spinning machine, the choking of fibres in the suction unit leads to higher yarn unevenness values. The opening of fibre mass by opening roller assembly and deposition of fibres as layers inside the rotor groove (back-doubling) causes lower yarn unevenness in rotor-spun yarns. As the milkweed content increases, the shorter, finer and less dense milkweed fibres move irregularly from the opening roller to transport channel in bunches, thereby leading to uneven deposition in rotor groove. This results in higher frequency of loose fibre wraps which increases with milkweed proportion in the blend.

The results are found slightly better for alkali-treated and dyed C/M blended yarns for all the three spinning systems. The chemical treatment enables the milkweed fibres to move in a controlled manner in the drafting zone due to improved surface and inter-fibre friction.

3.7 Influence of Process Parameters on Yarn Imperfection

The influence of milkweed blend proportion and chemical treatment on total yarn imperfections of C/M blended ring, compact and rotor yarns are shown in Fig. 4. Total yarn imperfections are highest in C/M 40/60 blend. The total imperfections of rotor-spun

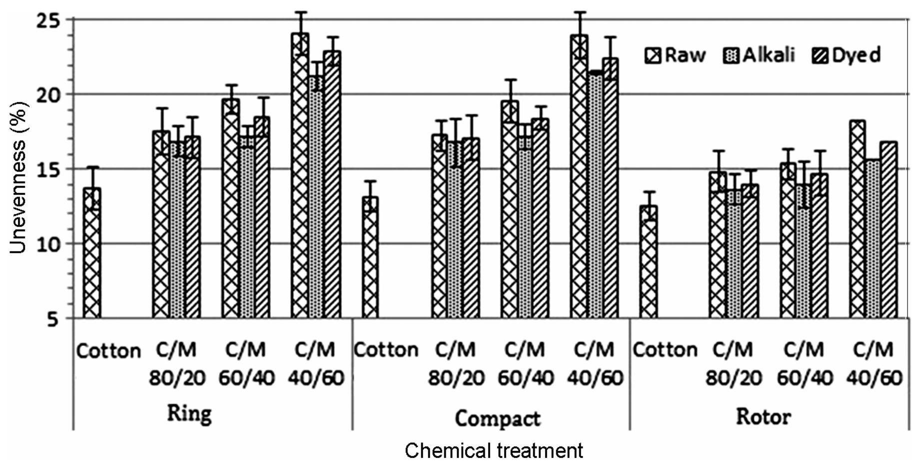


Fig. 3—Effect of milkweed blend proportion, chemical treatments and different spinning systems on yarn unevenness

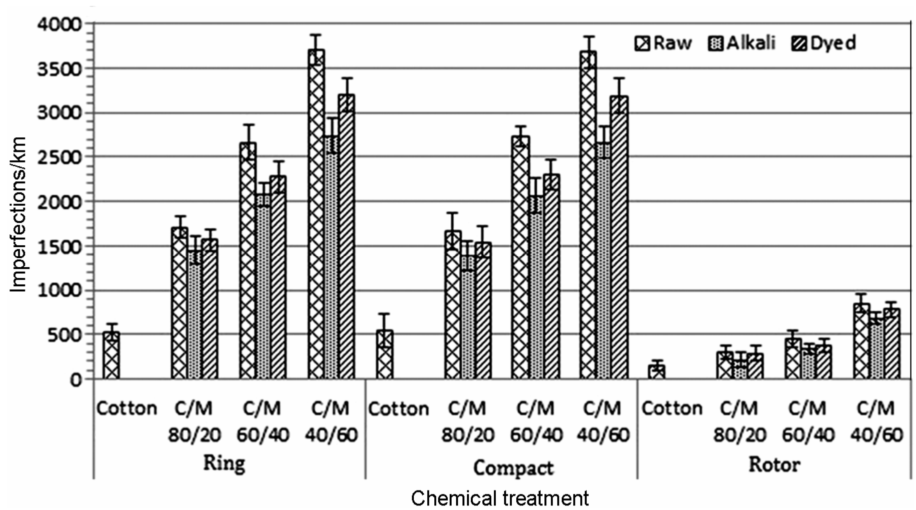


Fig. 4—Effect of milkweed blend proportion, chemical treatments and different spinning systems on yarn imperfection

yarns are significantly lower than those of the ring- and compact-spun yarns due to better fibre individualisation in opening roller assembly in rotor spinning. At higher milkweed blend proportion, the shorter and finer milkweed fibre moves without control as bunches in the drafting zone, leading to thick and thin places formation in ring and compact yarns. The less cohesiveness of milkweed fibres leads to sliver stretch in speed frame and roving stretch in ring frame creel section respectively, leading to more number of thin places in yarn. As the milkweed blend proportion increases, more creel breaks were noticed in ring frame. The high nep count in card sliver is also translated to nep count in yarn.

In case of rotor yarns, the action of opening roller leads to milkweed fibre rupture. These fibres during their travel in the transport channel can also buckle to form neps, resulting in higher nep count with increase in milkweed proportion in blend. Also with increase in milkweed content, the number of loosely bound wrappers increases. The formation of wrapper fibres in rotor-spun yarns is registered as neps in evenness tester[25]. More irregular movement of fibres in the transport tube with increase in milkweed fibre percentage and its uneven deposition in rotor groove can also cause increased thick and thin places in rotor yarn.

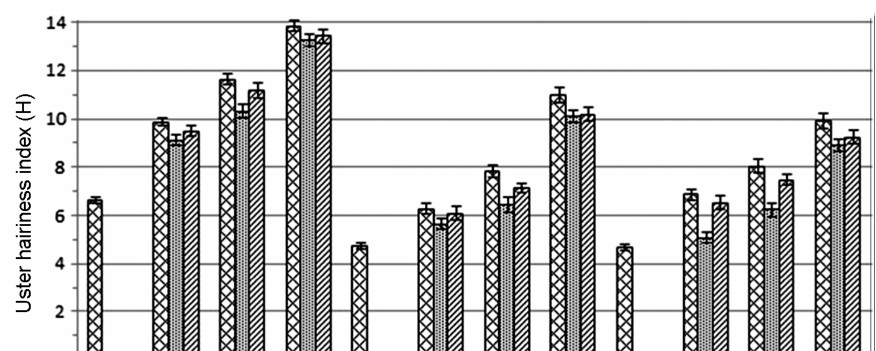
The alkali-treated blended yarn shows lower imperfection values followed by dyed and raw blended samples for all spinning systems. The improvement in inter-fibre friction with alkali treatment results in better drafting and hence lesser thick and thin places in the final yarn.

3.8 Influence of Process Parameters on Yarn Hairiness

The effect of blend ratio, chemical treatment and spinning systems on hairiness index is given in Fig. 5. The spinning tension is higher in ring spinning as compared to that in compact spinning due to the formation of spinning triangle. Due to the formation of spinning triangle, the edge fibres under high tension escape twisting action and are partially inserted in yarn structure, leading to the formation of hairiness in yarn. The increased number of shorter milkweed fibres with high milkweed blend proportion result in uncontrolled movement of shorter fibres in drafting zone, leading to increased hairiness index values.

In compact spinning, after the fibres leave the drafting arrangement, they are condensed by a perforated apron which slides over an inclined suction slot. The fibres are in complete control from the nipping line after drafting zone to the spinning triangle, leading to reduction in yarn hairiness. The increase in hairiness in compact yarns with milkweed proportion could be due to clogging of air slots because of shorter milkweed fibres.

The hairiness index values of rotor-spun yarns are much lesser compared to ring-and compact-spun blended yarns. Since the fibres are deposited in the rotor groove before twisting, the spinning tension is lower in rotor spinning, which results in lower yarn hairiness values. As the milkweed proportion increases, the clumps of fibres at the exit of transport tube leads to improper deposition of fibres in the rotor groove. During twisting, the fibres which are not



	Ring				Compact				Rotor			
	Cotton	C/M 80/20	C/M 60/40	C/M 40/60	Cotton	C/M 80/20	C/M 60/40	C/M 40/60	Cotton	C/M 80/20	C/M 60/40	C/M 40/60
Raw	6.63	9.88	11.64	13.85	4.75	6.27	7.84	10.97	4.69	6.88	8.04	9.93
NaOH		9.12	10.32	13.25		5.65	6.44	10.11		5.08	6.24	8.89
Dyed		9.49	11.17	13.43		6.09	7.14	10.19		6.52	7.49	9.25

Fig. 5—Effect of milkweed blend proportion, chemical treatments and spinning systems on yarn hairiness index

deposited well inside the rotor groove could not be able to fully integrate into the yarn structure, leading to higher yarn hairiness values. The more number of loosely wrapped fibres with increase in milkweed fibre proportion could be counted as yarn hairiness during testing, which is also responsible for higher rotor yarn hairiness values. Better inter-fibre friction due to chemical treatments could have resulted in lower hairiness.

4 Conclusion

4.1 The coefficient of variation for various properties of C/M blended yarns is found to be slightly higher than expected. This is due to typical milkweed fibre properties and lab model machinery used for yarn production.

4.2 During the spinning trials, blends with various milkweed percentages like 20, 40 and 60% represent new data, compared to the results reported in literature. Because of milkweed's specific properties, such as smooth appearance, brittleness and lack of cohesiveness, it is difficult to spin a pure milkweed yarn. Similar processing difficulties, such as web falling in card, roller lapping, creel breaks, and end breaks in draw frame, speed frame and ring frame, are also noticed even for 60% milkweed fibres in the blend.

4.3 Though the physical properties of yarns made from C/M blends are found to be inferior than those of pure cotton yarn, chemically modified milkweed fibres show an improvement in physical properties than in regular milkweed fibres.

References

1 Eichhorn S J, Baillie C A, Zafeiropoulos N E, Mwaikambo L Y, Ansell, M P & Dufresne A, *J Mater Sci*, 36 (2001) 2107.
2 Rout J, Misra M, Tripathy S S, Nayak S K & Mohanty A K, *Polym Compos*, 22 (2001) 770.
3 Bhaskar V H & Balakrishnan N, *Int J Pharmtech Res*, 1 (2009) 1305.
4 Gaur R D & Nautiyal S, *Indian Forestry*, 2 (1991) 193.
5 VarshneyA C & Bhoi K L, *Biol Waste*, 22 (1987) 157.
6 Pushpanjali Prasad, *J Text Assoc*, 67 (2006) 63.
7 Jones D & Von Bargen K L, *Trans ASAE*, 35 (1992) 243.
8 Andrews B A, Linda B Kimmel, Noelie R Bertoniere & Hebert J J, *Text Res J*, 59 (1989) 675.
9 Louis G L & Kottes B A, *Text Res J*, 57 (1987) 339.
10 Jean-Yves F Drean, Jacinthe J Patry, Gérard F Lombard & Marek Weltrowski, *Text Res J*, 63 (1993) 443.
11 Patricia Cox Crews & Wendelin Rich, *Cloth Text Res J*, 13 (1995) 213.
12 Sakthivel J C, Mukhopadhyay S & Palanisamy N K, *J Ind Text*, 35 (2005) 63.
13 Varshney A C & Bhoi K L, *Biol Waste*, 26 (1988) 229.
14 Shakyawar D B, Dagur R S & Gupta N P, *Indian J Fibre Text Res*, 24 (1999) 264
15 Prabakaran C, Rengasamy R & Dipyan Das, *Indian J Fibre Text Res*, 36 (2011) 190.
16 Amir Nourbakhsh & Alireza Ashori, *J Rein Plas Comp*, 28 (2009) 2143
17 Dauda B M D & Kolawole EG, *Indian J Fibre Text Res*, 28 (2003) 150.
18 Jie Liu & Fumei Wang, *J Eng Fibre Fabric*, 6 (2011) 63.
19 Karthik T & Murugan R, *Fiber Polym*, 14 (2013) 465.
20 KarbalaieKarim S, Gharehaghaji A A & Tavanaie H, *Fibres Text East Eur.*, 15 (2007) 63.
21 Mahendra Gowda, R V & Mohanraj, S, *Res J Text Apparel*, 12 (2008) 30.
22 Karthik T & Murugan R, *J Nat Fiber*, 11 (2014) 54.
23 Karthik T & Murugan R, *J Text Inst*, 104 (2013) 938.
24 Pinar N Duru & Osman Babaarslan, *Text Res J*, 73 (2003) 907.
25 Lawrence C A & Chen K Z, *J Text Inst*, 79 (1988) 367.