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Milkweed blended fabrics and their thermal insulation and UV protection properties

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Two sets of milkweed blended weft knitted fabrics have been produced and then tested for their constructional properties like courses/wales per inch, thickness, weight and tightness factor. These fabrics are also evaluated for thermal insulation (TI), water vapour permeability, air permeability and ultraviolet protection factor (UPF) properties and then compared with the only cotton and polyester knitted fabrics. The UPF and TI data of various blends of milkweed fibre with cotton or polyester have beed evaluated using one-way analysis of variance (ANOVA). Results reveal that the thermal insulation and ultraviolet protection factor of the milkweed blended fabric are higher than the corresponding properties of cotton and polyester fabrics, while the air permeability and water permeability properties are lower than the corresponding properties of cotton and polyester knitted fabrics.

Keywords: Cotton, Loop length, Milkweed, Polyster, Tightness factor, Thermal insulation, Ultraviolet protection factor, Water vapour permeability

1 Introduction

Though nature has produced large varieties of natural fibres, except for few of them such as cotton, jute, flex, silk and wool, rest have not been fully explored for clothing purposes. One of the least explored natural fibres is milkweed. Milkweed floss is a non-allergic natural cellulose seed hair fibre[1]. The plant produces silky needle-like hollow fibre with a relatively smooth surface[2]. Hollow structure of milkweed fibre could help in imparting warmth to the fabric, as air entrapped in the hollow structure acts as an insulator[3]. It can adapt to almost any kind of soil conditions from swampy and moist to sandy and arid. It is a perennial plant and, so once planted does not require replanting in each season. This contributes to its appeal as an alternate crop because theoretically it is easy and economical to cultivate [3].

Table 1 shows the physical properties of milkweed, cotton and polyester fibres. It can be seen that milkweed is quite comparable with cotton in terms of fibre length, fibre strength and fibre diameter. Unlike cotton and polyester, the fibre is hollow and has low density. Therefore, the fabrics produced from this fibre are expected to have better comfort in terms of thermal insulation, smoothness, softness and good surface appearance. However, the smooth and straight contour (without fibre crimp) of milkweed makes the fibres difficult to spin 100% milkweed yarns. During spinning, condensation of fibre web at the carding machine would be difficult due to absence of fibre cohesion (smooth fibre and no crimp). Further, as shown in Table 1, the fibre has low elongation which results in fibre rupture during opening and carding operations. Therefore, to produce a yarn, this fibre must be blended with other fibres to improve fibre cohesion.

In this study, blended yarns of milkweed with cotton and polyester have been produced and converted in to single jersey knitted fabrics. These fabric samples were then studied for their thermal insulation, ultraviolet protection factor and other properties.

2 Materials and Methods

2.1 Yarn Spinning

Seven different types of yarns were produced from milkweed (Mw), cotton (C) and polyester (P), namely 100% cotton, 10/90 Mw/C, 33/67 Mw/C, 50/50 Mw/C, 75/25 Mw/C, 100% polyester, 33/67 Mw/P, 50/50 Mw/P, 75/25 Mw/P.

The properties of fibres used in manufacture of yarn are shown in the Table 1. The single fibre denier was determined using Vibro Skop-400, Lenzing, Austria and HVI, while the fibre breaking strength, elongation and tenacity properties were determined by

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Vebrodyne, Lenzing, Austria and HVI. Comb sorter and Fibrograph instruments were used to determine length of the fibres.

The blend components were first hand mixed and then fed into the blow room to have an intimate and homogeneous blend[4]. Thereafter, the materials were processed through card, draw frame and simplex machines. Yarns were spun on a ring frame. These yarns were tested for physical properties (Table 2), such as twist per inch (TPI), yarn Count, single yarn strength, lea strength, elongation, unevenness, hairiness and yarn friction.

2.2 Weft Knitted Fabrics

Two sets of single jersey weft knitted fabric samples as indicated below were produced using knitability tester (TK 83 Harry Lucas) of Delha, Germany. The details of Set-1 and Set-2 are given below:

Table 1—Fibre properties

Property	Milkweed (Mw)	Cotton (C)	Polyester (P)
Fibre denier (ASTM D 1577)	0.8	1.64	1.03
Fibre length, mm (ASTM D 5867)	28.9	29.5	38.7
Breaking strength, g (ASTM D 3822)	3.80	4.00	6.46
Tenacity, g/den (ASTM D 3822)	2.7	2.55	6.29
Elongation-at-break, % (ASTM D 3822)	1.5	7.84	17.04
Moisture regain, % (ASTM D 2495)	10.8	7.5	0.4
Density, g cm^{-3} (ISO 1183)	0.89	1.5	1.3

Set-1(Mw: C) — 10% Mw : 90%C (MwC1090); 33% Mw : 67%C (MwC3367); 50% Mw : 50%C (MwC5050); and 100% C (C100).

Set-2(Mw: P) — 33%Mw:67%P (MwP3367); 50% Mw:50%P (MwP5050); and 100%P (P100).

2.3 Scouring and Bleaching

The laboratory grade chemicals were used for scouring and bleaching. The quantity of chemicals to be taken was based on the weight of material. The combined scouring and bleaching was carried out using 2% sodium hydroxide, 1.5% sodium carbonate, 1.5% hydrogen peroxide (50%) and 0.05% wetting agent for 30 min at 90°C. They were then washed and neutralized using acetic acid followed by tumble dry. All samples (Set-1 and Set-2) were treated under identical conditions to compare the effect of treatment.

2.4 Fabric Testing

The fabric samples were tested for thickness as per ASTM D-1777. The fabric weight in g/m^2, course/wales per inch and bursting strength were tested as per ASTM D-3776, ASTM D-3775 and ASTM D 3787 test methods respectively. All measurements were repeated three times. The loop length, and tightness factor[5] of the samples were also determined as given below:

Loop length = length of thread (say 100 loops)/ number of loops (say 100 loops)

Tightness factor = $\sqrt{T}/l$

where T is the tex of yarn; and l, the loop length.

The ultraviolet protection factor (UPF) of the fabric samples was determined on UV 1000 F, UV Transmittance Analyzer, Labsphere using

Table 2—Physical properties of yarns

Physical property	100% C	10/90 Mw/C	33/67 Mw/C	50/50 Mw/C	100% P	33/67 Mw/P	50/50 Mw /P
TPI	19	18	18	19	16	17	16
Count, Ne	20	20	24	20	21	23	21
Single yarn strength, gf/tex	12.85	12.54	11.06	8.12	27.7	23.63	18.4
Count strength product	257	250.8	265.44	162.4	581.7	543.49	380.94
Lea strength, lbs	127.2	102	81.7	73.3	203.7	168.5	146.6
Elongation, %	6.15	6.16	5.37	5.66	13.61	12.80	12.2
Unevenness, U%	17.05	18.26	17.74	16.76	13.25	15.88	18.11
Hairiness (h)	8.5	10.9	11.6	13.0	6.4	10.5	12
Coefficient of yarn friction	0.23	0.23	0.23	0.23	0.21	0.22	0.22

C—Cotton, Mw—Milkweed, P—Polyester.

AS/NZ-4339 test method. The UPF is transmission of UVA and UVB through fabrics measured by spectro-photometer. The UPF is a numerical rating given to clothing to indicate how effectively the fabric blocks ultraviolet (UV) radiation. A UPF rating of 25 means that only 1/25th (or 4%) of the UV radiation can penetrate the fabric. Unlike SPF, which only expresses a sunscreens protective value in terms of limited wavelengths of light, UPF applies to a range of broad spectrum UVA and UVB radiation. The highest UPF rating a garment can be assigned is 50+; a piece in this range is determined as providing "excellent" protection from UV radiation. Each fabric sample was evaluated at five different locations and measurements were taken five times at each location by rotating the sample in clockwise direction by 90^0 after each measurement. The average UPF value was calculated using mean percentage transmission in UVA region (320-400 nm) and mean percentage transmission in UVB region (280-320 nm) according to the following equation[6]:

$$\mathrm{UPF_t} = \frac{\sum_{\lambda=280}^{400} E_\lambda \times S_\lambda \times \Delta\lambda}{\sum_{\lambda=280}^{400} E_\lambda \times S_\lambda \times T_\lambda \times \Delta\lambda}$$

where E_λ is the relative erythemal spectral effectiveness; S_λ, the solar spectral irradiance; T_λ, the average spectral transmission of the specimen; and $\Delta\lambda$, the measured wavelength interval (nm).

The air permeability of the fabric samples was tested as per BS 5636. Water vapour transmission (WVT) of knitted fabric samples was measured in accordance with ASTM E96-2010. The thermal resistance/insulation property (TI) of the samples was evaluated at 6.9 Pa pressure as per ISO-5085-1 test method. Each fabric sample was evaluated at five times at different locations.

2.5 Statistical Analysis

Experimental data were analyzed using SPSS (Version 20). One-way ANOVA was used to compare means. The null hypothesis (Ho) is that there is no relationship between milkweed content in the blend and ultraviolet protection factor (UPF) and thermal insulation (TI) properties of the fabric. The alternative hypothesis is that there is a relationship between milkweed content in the blend and UPF and TI of the fabric. The Ho will be rejected when the p-value turns out to be less than a predetermined significance level, i.e 0.05.

3 Results and Discussion

3.1 Fabric Construction Parameters

The fabric construction details are shown in Table 3. It is observed that all fabric samples are having nearly same weight (170 - 176 g/m^2) and tightness factor (14.09 - 16.51). The weight of knitted fabric depends on loop length and yarn count. For a given yarn count, as the loop length increases, the weight of fabric decreases. Similarly, for a given yarn count, as the loop length of the fabric increases the tightness factor of the fabric decreases. Since all fabrics have nearly same loop length and yarn count, their weight is also similar[6]. The slight variation is found in the thickness of fabric samples. The variation in fabric thickness may be attributed to the little variation in the yarn count and fibre composition (Table 2).

3.2 Bursting Strength

Bursting strength of knitted fabrics depends on the ability of the fabrics to withstand the multidirectional stresses exerted on the fabrics, by the movement of the liquid and the diaphragm associated in the testing process. The mean values of bursting strength are given in the Table 3. The bursting strength of

Table 3—Fabric construction details and other parameters

Parameter	Cotton	Mw:C			Polyester	Mw:P	
		10:90	33:67	50:50		33:67	50:50
Weight per unit area, g/m^2	170	174	172	175	176	170	172
Fabric thickness, mm	0.64	0.67	0.69	0.71	0.66	0.70	0.72
Courses/wales per inch	30/36	31/41	31/41	29/43	32/45	33/42	33/41
Loop length, cm	0.35	0.37	0.35	0.36	0.32	0.32	0.32
Tightness factor	15.53	14.69	14.17	15.09	16.56	15.84	16.20
Bursting strength, kg/cm^2	3.37	2.90	1.47	1.08	7.40	5.25	3.80
Air permeability, cc/s/cm^2	34.44	26.56	26.24	23.78	114.82	78.72	59.05
Water vapour permeability, g/m^2/day	76.58	74.63	75.46	75.50	76.50	76.50	75.88

milkweed blended fabrics decreases with the increase in percentage of the milkweed fibre in the blended fabric. This may be due to increase in the yarn unevenness with increase in milkweed content in the blended yarns. The increase in the yarn unevenness may be due to milkweed fibre breakage during yarn manufacturing process, resulting in shorter fibre length in the yarn.

3.3 Air Permeability

The resistance of a fabric to the flow of air is the measure of the initial warm/cool feeling when garment is worn. The higher the air flow value, the greater is the intensity of the warm/cool feeling. The effect of air permeability on comfort properties is much greater when the speed of air is high, as in the case of stormy weather conditions. The results of air permeability, in terms of the amount of air passing through a unit fabric area per unit time, are given in the Table 3. The results indicate that milkweed blended fabrics permit less air to pass through as compared to 100% cotton and 100% polyester fabrics. The reason for a lower air permeability of milkweed blended fabric can be attributed to a higher hairiness of these yarns[8].

The air permeability results reveal that the fabrics made from milkweed fibres are more suitable for winter dress material as compared to summer wear, provided the other comfort parameters of milkweed fabrics are made suitable to meet the requirements.

3.4 Water Vapor Permeability

An ideal fabric should allow water vapour on skin (perspiration) to pass through its pores, irrespective of the fibre material's natural absorbency. If the water vapour cannot escape at a faster rate than it is released by the skin, the wearer feels uncomfortable. In order to assess the fabric's ability to permit moisture through it in a steady state, vapour transfer is measured with a MVTR cell[8]. The results (Table 3) are observed in terms of the amount of vapour passed in grams per 24 h per square meter of fabric surface area. The results show that there is marginal decrease in water vapour permeability of milkweed blended fabric with cotton and polyester than the fabrics made out of corresponding 100% cotton and polyester fabric. The lower water permeability of milkweed blended fabric may be due to the fact that the porosity of milkweed blended fabric is lower than that of 100% cotton and polyester fabrics, as indicated by their air permeability results (Table 3).

3.5 Ultraviolet Protection Factor (UPF)

The UPF increases with fabric density, weight and thickness for similar construction and is dependent on porosity[9]. A high correlation exists between the UPF and the fabric porosity, and it is also influenced by the type of fibres[10]. The relative order of importance for the UV protection is given by % cover > fibre type > fabric thickness[11].

It is evident from the Fig. 1 that milkweed blended fabrics have a higher UPF (50+) than corresponding 100% cotton and 100% polyester fabrics even though they are produced with nearly same fabric construction particulars (thickness 0.64 - 0.72 mm and tightness factor 14.17 - 16.56) and also have nearly same weight (170 - 175 g/m^2) . It is also clear that with the increase in milkweed content, UPF value of fabric increases. It is clearly evident that this increase in UPF is due to the presence of milkweed floss fibre. The higher UPF of milkweed fibre may be attributed to higher lignin content (~ 18%) of this fibre. The earlier studies have also indicated[12,13] that the fibre having higher lignin content may have higher UPF value. It is also explicit from Tables 4 and 5 that p value is < 0.05, so we reject the null hypothesis. This indicates that there is a relationship between milkweed content in the blend and UPF value.

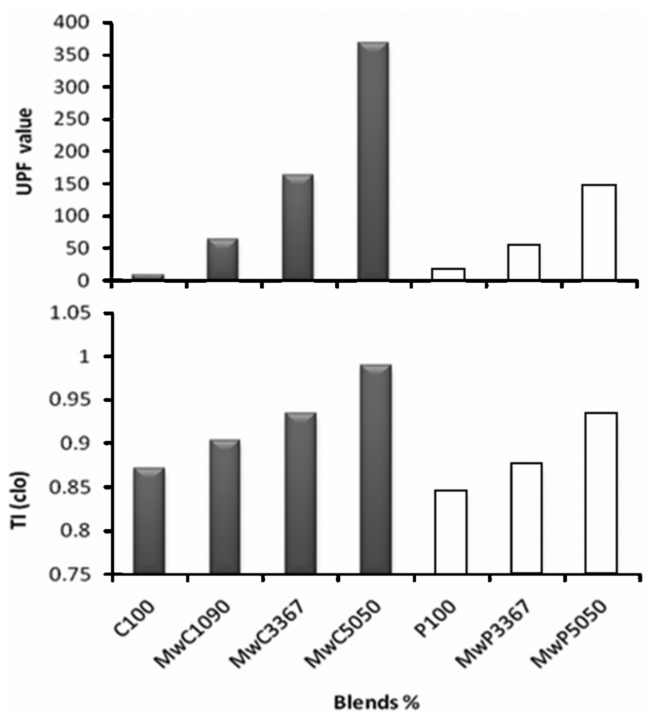

Fig.1—Effect of blend % on UPF and TI values

Table 4—ANOVA tests – UPF and TI of cotton-milkweed blends

Property	Sources of variation	Sum of squares	Df	Mean square	F	Sig. (p)
	Between Groups	376465.558	3	125488.519	7893.477	
UPF	Within Groups	254.364	16	15.898		0.000
	Total	376719.922	19			
	Between Groups	0.038	3	0.013	118.208	
TI	Within Groups	0.002	16	0.000		0.000
	Total	0.040	19			

Table 5—ANOVA tests – UPF and TI of polyester-milkweed blends

Property	Sources of variation	Sum of squares	Df	Mean square	F	Sig. (p)
	Between Groups	43163.536	2	21581.768	8953.852	0.000
UPF	Within Groups	28.924	12	2.410		
	Total	43192.460	14			
	Between Groups	0.020	2	0.010	214.587	0.000
TI	Within Groups	0.001	12	0.000		
	Total	0.021	14			

3.6 Thermal Resistance/Insulation

Thermal resistance is a measure of a material's ability to prevent heat from flowing through it. Under certain climatic conditions, if the thermal resistance of clothing is low, heat energy will tend to gradually decrease, giving rise to a cool feeling. Thermal resistance is a very important parameter and is greatly influenced by fabric structure. Increase in fabric thickness will result in increase in thermal insulation, as there will be a decrease in heat loss for the space insulated by the textile. Thermal resistance is a function of the thickness and thermal conductivity of a fabric[14]. From the Table 3, it is clear that the fabric thickness of all fabrics is nearly the same. Therefore the influence of thickness on thermal insulation will be minimal. Figure 1 indicates that with the increase in milkweed content, thermal insulation (Clo) of the fabric increases. This could be because of the fact that milkweed floss fibre is hollow and has a low density[12, 15]. Hence it is expected to have good thermal insulation property[3]. It is also explicit from Tables 4 and 5, p value is < 0.05, so we reject the null hypothesis. This indicates that there is a relationship between milkweed content in the blend and TI value.

4 Conclusion

This study highlights the following conclusion:

Milkweed blended fabrics are having higher ultraviolet protection factor (UPF) compared to fabric made out of only cotton and only polyester. The high UPF may be due to presence of lignin in the milkweed floss fibre.

The thermal insulation values of milkweed blended fabrics are found to be higher than those of only cotton and polyester fabrics which may be due to the hollow structure of milkweed floss fibre. The air is entrapped in the hollow structure and act as an insulator.

The water vapour permeability of milkweed blended fabric (with cotton and polyester) is lower than fabrics made out of corresponding 100% cotton and polyester fabrics. The low water permeability of milkweed blended fabrics may be due to the fact that the air permeability's of these fabrics are lower than those of only cotton and polyester fabrics.

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