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Research on Knitted Fabric Properties of Yak Cashmere and Cotton Blend Yarns

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Abstract

Abstract: *As a natural fibre, yak cashmere has attracted more and more attentions in textile processing due to its excellent properties, environmentally friendly characteristics and inexpensive prices. However, the direct processing of yak cashmere, especially pure yarn spinning, is difficult since the dispersion of the fibre length is large. Therefore, in this paper, yak cashmere and cotton blend yarns were spun. Compact Sirospun yarns with three different kinds of blending ratios; 70/30, 50/50 and 30/70, were spun, and corresponding spun yarn qualities: hairiness, breaking strength and evenness were tested. It is shown that with an increasing content of cotton, for the same yarn count spun, all properties tested were improved. Then the properties of corresponding knitted fabric, including the permeability, thickness, static voltage, warmth retention, whiteness, water permeability, bursting strength, elastic recovery, tensile properties, drape, wear resistance, pilling, anti-ultraviolet resistance and bending stiffness were measured and comparatively analysed. It is shown that with an increasing content of Yak cashmere, the fabric is lighter and thinner, and the air permeability, warmth retention, wear resistance and pilling were all improved, while the strength and elongation properties as well as water permeability were worsened. Meanwhile the average weight distribution of yak cashmere and cotton in the yarn is beneficial for the fabric elastic recovery property and drape.*

Key words: *yak cashmere, blend yarn, knitted fabric, blend ratio*

Introduction

Yak cashmere is one of the natural animal fibres produced from the yak, which mainly grows on the Tibetan plateau of china, and comprises 85% of the world's total production [1]. There are some excellent properties of Yak cashmere, such as comparing to cashmere fibre with same fineness, the density of yak cashmere fibre scales is larger and the thickness smaller, making the warmth retention higher [2]. Meanwhile the tactility of yak cashmere is smoother and the scratchiness less comparing with cashmere fibre. Furthermore the price of yak cashmere is only 1/3 that of cashmere, leading to greater profit margins. These excellent properties make yak cashmere a good substitute for cashmere fibre. Therefore-recently yak cashmere has attracted more and more attention for textile processing due to its excellent properties, environmental friendly characteristics and inexpensive prices [3].

However, there are some difficulties in the direct textile processing of yak cashmere, especially pure yarn spinning, since the dispersion of the fibre length is large [4]. Therefore in practical spinning, some other fibres were employed for yak cashmere spinning which can make up for the deficiency of yak cashmere . In general, some natural fibres, such as cotton and cellulose fibre, were employed, and corresponding blend yarns were spun. In the paper, cotton fibres were used, and blend yarns with three different kinds of blending ratios: 70/30, 50/50 and 30/70 were spun. The properties of corresponding knitted fabric were also studied. The effects of the blending ratios on the yarn and knitted fabric were mainly investigated.

Compact spinning is one of the most widely used of the new kinds of modified ring spinning methods, in which one kind of fibre condensing device is employed on a ring spinning frame in order to decrease the spinning triangles and improve the spun yarn qualities [5-7]. Compact spinning with a lattice apron is the most widely used compact spinning method at present, as well as 3-line roller compact spinning and 4-line roller compact spinning [8]. In this kind of compact spinning, a Lattice apron was used for fibre condensing. Sirospun spinning (Two-strand yarn spinning) is another new modified ring spinning method invented by the Division of Textile Industry laboratories of the CSIRO in Australia and IWS together in the years 1975~1976, which is conducted on a conventional ring frame by feeding two rovings into the apron zone at a predetermined separation simultaneously, thereby improving yarn qualities, especially hairiness reduction [9,10]. Therefore, in this paper, compact Sirospun blend yarns were spun on a ring spinning frame modified with a 4-line roller compact spinning device.

Spinning experiment with compact sirospun blend yarn

Spinning System

Four-line compact spinning (FLCS) is one most widely used pneumatic compact spinning systems, which is primarily produced by the Toyota Company of Japan (see ***Figure 1***). At present, this system can be produced in China with mature technology, and can be used for modification of a traditional ring spinning frame directly [11]. In the FLCS, there is one output roller at the front of the front roller, which is connected with the front roller via the carrier wheel. Correspondingly there is one output top roller above the output roller. An output nip

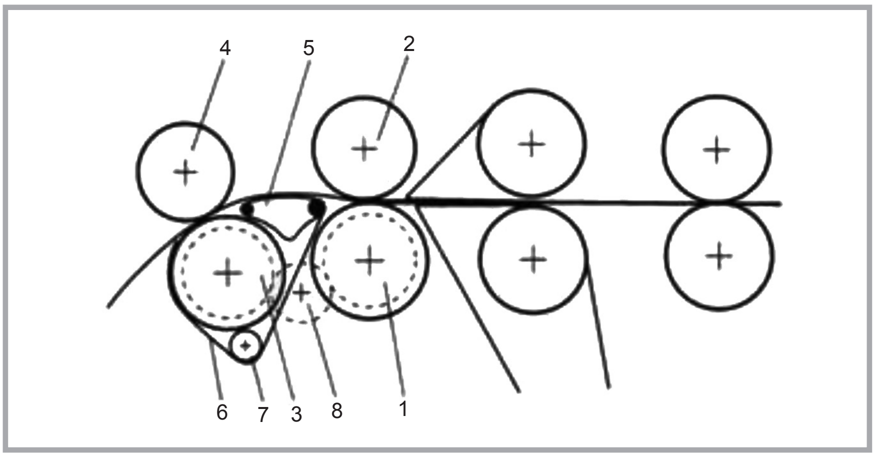

Figure 1. Structure of Four-line compact spinning system [11]: 1) front roller, 2) front top roller, 3) output roller, 4) output top roller, 5) shaped tube, 6) lattice apron, 7) strut, 8) carrier wheel.

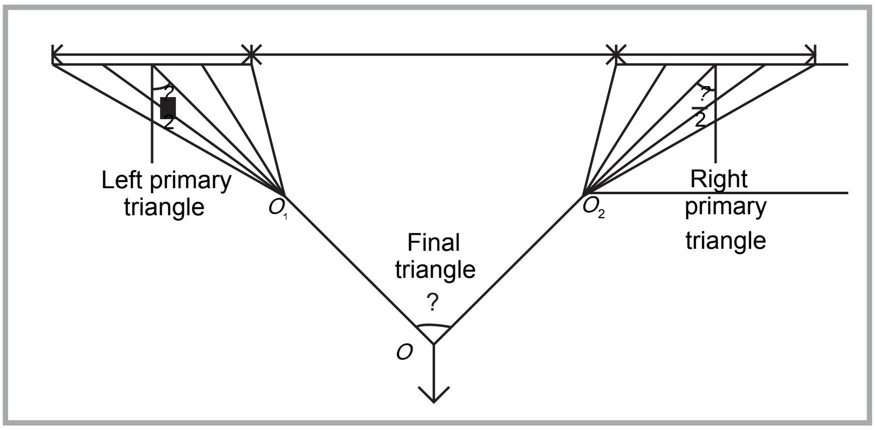

Figure 2. Spinning process of Sirospun spinning system [10].

is produced between the output roller and output top roller, and a front nip is produced between the front roller and front top roller. The area between the front nip and output nip is the condensing zone.

In yarn spinning, the fibre strand coming from the draft zone is condensed in the condensing zone by the negative pressure airflow in the shaped tube. The width of the fibre strand is nearly equal to the diameter of the final yarn, and the spinning triangle is reduced greatly. Afterwards under the twist the fibre strands rotate around the axis, then the fibres on both sides fold gradually and roll into the centre of the spun yarn, and the final yarn is formed.

In the spinning process of Sirospun spinning, two rovings are fed into the apron zone at a predetermined separation simultaneously, and after drafting, two fibre substrands are produced and enter the front nip. Then a primary twist is imposed on those two substrands, where two smaller primary triangles are produced. Finally the two substrands are twisted into a Sirospun yarn by a final twist, and a corresponding final triangle is produced (see ***Figure 2***) [10].

In the paper, to improve yarn qualities, the compact Sirospun spinning method was employed, and yak cashmere and cotton blend yarns with three different kinds of blending ratios: 70/30, 50/50 and 30/70 were spun.

Experimental preparations

Combed roving of 500 tex (5.0 g/10m) with a twist factor of 128 was used as raw material. Then three types of compact Sirospun yarns of 20.8 tex (48 Nm), 18.5 tex (54 Nm), and 16.6 tex (60 Nm) with blending ratios of 70/30, 50/50 and 30/70 were spun. Parameters of the cotton fibre and Yak cashmere chosen are shown in ***Table 1*** and details of the spinning parameters – in ***Table 2***.

Table 1. *Fibre parameters.*

Fibre	Tenacity, $cN \cdot dtex^{-1}$	Elongation, %	Linear density, dtex	Fibre length, mm
Yak cashmere	4.63	5.6	3.71	30.5
Cotton	2.33	49.13	1.34	37

Table 2. *Spinning parameters.*

Yarn kind, tex	Draft multiple	Blending ratios	Negative pressure, Pa	Spindle speed, r/min
20.8	48.01	70/30	3000	9300
		50/50	3000	11000
		30/70	3000	12500
18.5	54.05	70/30	2800	8800
		50/50	2800	10000
		30/70	2800	11300
16.6	59.88	70/30	2600	7300
		50/50	2600	8500
		30/70	2600	10500

Results

Taking ten bobbin yarns as measuring samples, all were placed under standard conditions of 20 ± 3 °C and 65 ± 3% RH for at least 24 hours before testing. Yarn hairiness, strength, evenness and the number of snarlings were measured. The test instruments were as follows: an uster tester – 5-S800 evenness tester and single yarn tester – YG068C. The yarn evenness and hairiness were evaluated once by the Uster tester – 5-S800 evenness tester at a speed of 400 m/min, with a test time of 1 minute, and the value obtained was accepted as the evenness and hairiness of this one bobbin yarn. The breaking force of yarns was also tested ten times on a YG068C fully automatic single yarn strength tester at a speed of 500 mm/min, and the average value of ten tested results was taken as the breaking force of this one bobbin yarn. Finally the average values of ten bobbin yarns

Table 3. *Yarn properties of modified yarn 20.8tex*

Blending ratios	H	Strength, cN	Strength CV, %	Evenness CV, %	-50% Thin, km	+50% Thick, km	+200% Nep, km	Elongation, %	Twist, $T \cdot m^{-1}$
70/30	4.52	219.4	10.7	13.1	11.8	48.6	52.1	4.96	745.2
50/50	4.19	310.6	5.8	11.6	0.6	22.3	33.8	5.13	717.6
30/70	3.68	391.7	3.6	10.3	0.1	3	8.7	5.99	692.1

Table 4. *Yarn properties of modified yarn 18.5 tex.*

Blending ratios	H	Strength, cN	Strength CV, %	Evenness CV, %	-50% Thin, km	+50% Thick, km	+200% Nep, km	Elongation, %	Twist, $T \cdot m^{-1}$
70/30	3.97	184.8	12.9	14.5	19.2	68.5	82.3	5.12	801.3
50/50	3.67	274.6	6.1	12.9	1.5	43.5	63.5	5.75	782.6
30/70	3.24	356.4	4.5	11.6	0.3	20	35.3	6.14	724.4

Table 5. *Yarn properties of modified yarn 16.6 tex.*

Blending ratios	H	Strength, cN	Strength CV, %	Evenness CV, %	-50% Thin, km	+50% Thick, km)	+200% Nep, km	Elongation, %	Twist, $T \cdot m^{-1}$
70/30	3.43	162.3	15.1	15.9	33.1	97.3	103.4	5.23	896.0
50/50	3.16	250.7	9.3	14.3	2.9	71.6	81.9	5.86	864.2
30/70	2.77	321.1	6.8	12.9	0.7	51	56.1	6.21	803.6

were taken as the corresponding qualities of the spun yarn. Properties of the spun yarns measured are shown in ***Tables 3-5***.

From ***Table 2***, it is easy to see that with an increasing content of cotton, for the same yarn count spun, the negative pressure is the same, where the spindle speed can be increased, and the spinning efficiency is increased correspondingly. According to the results measured, shown in ***Tables 3-5***, it is obvious that with an increase in the content of cotton, for the same yarn count spun, all properties tested were improved. That is, the addition of Yak cashmere is not beneficial for spun yarn conventional qualities. The possible reason is that compared with cotton, the value of the length of Yak cashmere is less and its dispersion larger, making the addition of Yak cashmere non-beneficial for blend yarn qualities. However, there are some excellent functional properties of Yak cashmere, such as warmth retention, which would be reflected in the fabric. Therefore, in the following section, the properties of knitted fabric made of yak cashmere and cotton blend spun yarns were studied.

Properties of knitted fabric

In this section, the properties of corresponding knitted fabric, including the permeability, thickness, static voltage, warmth retention, whiteness, water permeability, bursting strength, elastic recovery, tensile properties, drape, wear resistance, pilling, anti-ultraviolet resistant and bending stiffness were measured and comparatively analysed. Firstly 48 Nm yarns with blending ratios 70/30, 50/50 and 30/70 were used for fabric knitting, with details of the weaving parameters shown in ***Table 6***. Then the properties of corresponding knitted fabric were measured and studied comparatively.

Physical properties

Physical properties are the basic characteristics of fabric, and have a great direct influence on fabric wearability. Therefore, in the paper, the physical properties of the fabric, including thickness, weight per square meter, air permeability, antistaticness, warmth retention, whiteness,

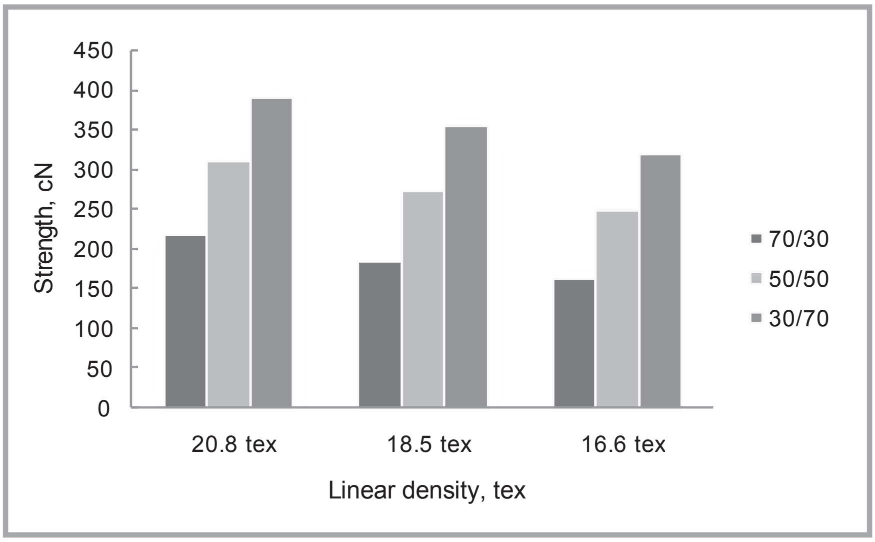

Figure 3. *Strength of yarns with different blending ratios under different linear densities.*

Table 6. *Braiding parameters.*

Blend ratio	Fabric structure	Loom	Loom type	Knitting gauge, G	Speed, $m.s^{-1}$
70/30	Plain weave	Computerized flat knitting machine	SES122S	14	1.0
50/50			SES122S	14	0.8
30/70			CMS420TS	16	0.8

Table 7. *Physical properties of fabrics*

Properties		70/30, CV/%	50/50, CV/%	30/70, CV/%
Thickness, mm		0.63 [5.65]	0.69 [4.97]	0.70 [5.72]
Weight per square meter, g/m^2		173.6	180.2	180.8
Air permeability, mm/s		2066.46 [7.49]	1036.83 [4.27]	1027.98 [4.39]
Antistaticness	Static voltage, V	1684	1320	1233
	Static voltage half-life, s	1.24	1.24	1.09
Warmth retention	Heat Transfer Coefficient, W/m^2·°C	53.09 [14.8]	59.91 [12.1]	54.45 [12.8]
	Warmth retention rate, %	24.98 [15.2]	22.68 [13.2]	24.40 [13.0]
	Clo value, 0.155 °C·m^2/W	0.12 [15.3]	0.11 [12.9]	0.12 [13.6]
Whiteness		76.57 [0.54]	77.45 [0.43]	78.44 [0.37]
Water permeability		212 [1.76]	221 [1.95]	232.25 [7.48]
Wear resistance, %		2.71	2.22	1.99
Pilling		0.5	1.75	2.5
Anti-ultraviolet resistant	UVA, %	7.58	3.16	0.59
	UVB, %	0.54	0.46	0.41
	UPF	83.97	120.46	194.03
Bending stiffness, mN·m	Radial	0.024	0.019	0.011
	Zonal	0.0072	0.0034	0.0035

Table 8. *Mechanical properties of fabrics.*

Properties			70/30, CV/%	50/50, CV/%	30/70, CV/%
Bursting strength, N			453.2 [9.95]	625.5 [3.27]	751.2 [7.72]
Elastic recovery	Elastic recovery percentage, %	Radial	51.55 [4.75]	59.12 [0.87]	57.88 [8.71]
		Zonal	62.28 [7.16]	61.38 [4.23]	52.77 [4.62]
	Plastic deformation rate, %	Radial	24.21 [5.03]	20.41 [1.26]	21.05 [6.38]
		Zonal	18.85 [7.83]	19.37 [5.43]	23.61 [6.33]
Tensile property	Breaking strength, N	Radial	86.53 [11.72]	143.83 [7.37]	158.47 [8.86]
		Zonal	62.73 [3.65]	88.77 [3.81]	99.6 [6.81]
	Breaking elongation, %	Radial	25.85 [4.10]	35.84 [5.42]	33.49 [5.12]
		Zonal	40.67 [4.16]	49.76 [10.96]	46.67 [11.82]
	Breaking work, J	Radial	0.15 [9.63]	0.33 [8.21]	0.31 [5.54]
		Zonal	0.19 [11.37]	0.28 [6.66]	0.32 [12.76]
Drape	Static drape coefficient, %		36.17 [9.35]	30.54 [4.32]	32.36 [5.25]
	Ratio of dynamic and static drape coefficient		0.995 [9.24]	0.91 [8.44]	1.18 [10.5]

water permeability, wear resistance, pilling, anti-ultraviolet resistance and bending stiffness were tested, and the results measured are shown in ***Table 7***, where CV is the coefficient of variation of the test.

The thickness of the fabrics made of three different blend yarns was measured. The test instrument was the fabric thickness tester YG141D, and for each fabric the thickness was tested ten times and the average value taken as test results of the fabric. The weight per square meter of the fabrics was measured using an electronic balance – JA2003. From ***Table 7***, it is shown that with an increasing content of yak cashmere, the thickness of fabrics decreases, and the corresponding weight per square meter also decreases. That is, the addition of yak cashmere is beneficial for producing light and thin fabric, which can increase the economic value of the fabric directly.

Air permeability is another important parameter of fabric wearability, which is mainly determined by the number and size of voids between the warp and weft. The air permeability of the knitted fabrics made of three different blend yarns were measured ten times for each fabric using the test instrument YB461E Fabric Air Permeability Tester, and the average value was taken as the test results. As shown in ***Table 7***, we can see that with an increasing content of Yak cashmere, the air permeability of the fabrics is increased. In ***Table 3***, it is evident that with an increase in the content of yak cashmere, the hairiness of blend yarns increases, which makes the fabric bulk and potentially leads to larger fabric air permeability.

The antistaticness of the fabric, including the static voltage and static voltage half-life, was tested using a YG(B)340D induction type electrostatic determinator, with an electrifying time of 15s and discharging time of 30s. From ***Table 7***, we can see that with an increase in the content of yak cashmere, the static voltage and static voltage half-life of the fabrics both increase. That is, the addition of yak cashmere makes it easy for the fabric to produce static electricity.

The warmth retention of the fabric, including the heat transfer coefficient, warmth retention rate and clo value, was tested using a YG606D flat fabric heat retention tester, with a preheating time of 30s and heating cycle of 5. From ***Table 7***, it is easy to see that compared with the fabric made of 70/30 and 30/70 blend yarns, the heat transfer coefficient of the fabric made of 50/50 blend yarn is larger and the warmth retention rate smaller, i.e. the warmth retention is decreased. Meanwhile, compared with the fabric made of 30/70 blend yarn, the warmth retention of the fabric made of 70/30 yarn increases slightly. That is, the average weight distribution of yak cashmere and cotton is not beneficial for fabric warmth retention. Compared with cotton, more yak cashmere is more beneficial to improve fabric warmth retention.

The Anti-ultraviolet resistance of the fabric, including the UVA, UVB and UPF, was tested using a YB912E tester. From ***Table 7***, it is obvious that with an increasing content of Yak cashmere, the UVA of the fabric increases, while the UPF decreases. That is, with an increasing content of Yak cashmere, the anti-ultraviolet resistance of the fabric decreases.

The bending stiffness of the fabric in the radial and zonal direction was tested using aYG207, which was calculated according to the equation $G = 9.8 \times \rho (0.5L)^3$, where ρ is the weight per Square Meter of the fabrics and L is the exsertion length. Form ***Table 7***, it is obvious that with an increasing content of yak cashmere, the bending stiffness of the fabric increases.

The whiteness, water permeability, wear resistance and illing of the fabrics were also tested with a WSD-III whiteness meter, YG(B)812-120, Y522N, YG502N. From ***Table 7***, it is shown that the whiteness of all three kinds of fabrics can reach grade 5. With an increasing content of yak cashmere, the water permeability of the fabric decreases, the wear resistance of the fabric increases, and the pilling of the fabric decreases.

Mechanical properties

In the practice, the mechanical property of fabrics is also important and closely related to the wearability. Therefore, in the paper, the mechanical properties of the fabric, including the bursting strength, elastic recovery, tensile property and drape were tested, and the results measured are shown in ***Table 8***, where CV is the coefficient of variation of the test.

Bursting strength is one of the most important evaluation parameters of fabric mechanical properties. The bursting strength of the fabrics made of three different blend yarns was measured with a fabric strength tester – HD036N, and the drawing speed was 100 mm/min. Meanwhile the tensile properties, including the breaking strength, breaking elongation and breaking work in the radial and zonal directions, were tested with a HD026NS fabric strength tester, where the drawing speed was 100 mm/min and pre-tension 2N. From ***Table 8***, it is shown that with an increasing content of yak cashmere, the bursting strength of the fabrics decreases greatly, and the breaking strength and breaking work also decrease. That is, the addition of yak cashmere is not beneficial for fabric strength and elongation properties. Furthermore the average weight distribution of yak cashmere and cotton is beneficial for improving the breaking elongation of the fabric.

The Elastic recovery of the fabric, including the elastic recovery percentage and plastic deformation rate in the radial and zonal directions, was tested using YG026C, where the pre-tension was 1 N, clamp length 100 mm, the drawing speed 100 mm/min, the relaxation time 60 s, the tension relaxation time 30 s, and the backing velocity 50 mm/min. From ***Table 8***, it is shown that with an increasing of content of yak cashmere, in the Radial direction, the Elastic recovery percentage increases, and the plastic deformation rate decreases, while in the zonal direction, the elastic recovery percentage decreases, and the plastic deformation rate increases. In general, the fabric made of 50/50 blend yarn has the bestelastic recovery property.

The drape of the fabric, including the static drape coefficient and ratio of the dynamic and static drape coefficient, was tested using an XDP-1 Drape Tester. From Table 8, it is shown that compared with the fabric made of 70/30 and 30/70 blend yarns, the static drape coefficient and ratio of the dynamic and static drape coefficient of the fabric made of 50/50 blend yarn are both smaller, indicating that the fabric is softer.

Conslusions

In this paper, for overcoming the difficulty of direct yarn spinning of yak cashmere, cotton fibres were used, and Yak cashmere and Cotton blend yarns with three different kinds of blending ratios were spun. Three types of compact Sirospun yarns: 48 Nm, 54 Nm, and 60 Nm, with blending ratios 70/30, 50/50 and 30/70, were spun, and corresponding spun yarn qualities, hairiness, breaking strength and evenness were tested. It is shown that with an increasing content of cotton, for the same yarn count spun, all properties tested were improved. That is, the addition of Yak cashmere is not beneficial for spun yarn conventional qualities.

Then, taking 48 Nm yarns with blending ratios 70/30, 50/50 and 30/70 as an example, the physical properties and mechanical properties of corresponding knitted fabrics were tested and comparatively analysed. It is shown that with an increasing content of yak cashmere, the thickness and weight per square meter of the fabrics are both decreased, making the fabric lighter and thinner. Meanwhile, with an increasing content of Yak cashmere, the air permeability, warmth retention, wear resistance and pilling of the fabric were all improved, while the strength and elongation properties and water permeability worsened. Furthere-more the average weight distribution of yak cashmere and cotton in the yarn is beneficial for the fabric elastic recovery property and drape. That is, although the addition of yak cashmere is not beneficial for spun yarn conventional qualities, functional properties of the corresponding fabric would be improved.

Acknowledgements

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