Physical Properties of a Wild-silk/Cotton Blend Yarn, and Shrinkage Properties of its Plain Knitted Product.

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Abstract

The physical properties (count, twist, strength and yarn evenness) of a 30%/70% wild-silk/cotton blend and shrinkage properties of the resultant plain knitted fabric were investigated. The results show that the yarn had an average count of 62.4 tex, high number of thick places (178.5 per km) but low number of thin places (2/km) and neps (13.5/km), and had an unevenness of 10.5U%. It was also observed that the yarn displayed strength of 7.3 Newtons and an elongation of 9-14% which resulted in good knitting performance with no end breakages recorded indicating that the yarn physical properties, strength and elongation, were well suited for knitting.

The shrinkage properties of the developed fabric indicated sensitivity to wet treatment as it shrunk (26.8%) when dried whilst there was no significant change noted after dry relaxation.

It was concluded that the yarn blend could be used to produce knitted products only after it has been pre-treated for shrinkage in order to avoid dimensional changes during use.

Key words: wild-silk/cotton blend yarn, yarn properties, knitting, and shrinkage properties.

1. INTRODUCTION

The cotton fibre is readily available and widely utilised to produce high quality goods. Unlike silk, the cotton fibre is not as expensive as it is grown widely in the Southern region of Africa. [1]. The silkworms of the wild varieties take care of themselves and therefore do not require the constant labour given to the growing of the cotton fibre; the expense of gathering them is nevertheless high. Cocoons must be hunted, trees must be climbed to gather them and much time may be consumed in collecting comparatively a few [1]. These challenges have an impact on the costs attached to the wild silk therefore; blending it with cotton will produce yarns, which possess a competitive price.

Blends of domesticated silk and cotton have been seen to produce fabrics with superior characteristics like comfort when worn close to the skin [2] therefore; it is assumed that blends of wild-silk and cotton will also produce fabrics with similar cost and quality.

This report is on a study carried out to investigate the physical properties (count, twist, uniformity and strength) of a 30%/70% wild silk and cotton blended yarn and to verify its suitability for knitting. A fabric prototype was developed using a plain knitted structure and was subjected to different relaxation conditions to determine its shrinkage properties.

2. EXPERIMENTAL

2.1. Sample preparation

The rotor spun yarn sample composed of stapled wild silk and cotton [30%/70%] was taken from two randomly chosen packages (cones) and the physical properties determined. Prior to testing the packages were left in the testing lab for 24hours to acclimatise with the testing conditions of 28ºC temperature and 64% relative humidity. The temperature and relative humidity were continually measured every 10 minutes. A dry and wet bulb thermometer was used to measure the temperature and a psychometric chart used to determine the relative humidity. The twist tests were conducted under ambient conditions. Physical properties investigated were:

2.2. Yarn Count

A Shirley electronic wrap reel was used to determine the yarn count in accordance to British Standards (BS) Test Method. The machine was set such that the wrap reel wrapped 100 meters of yarn on the swift and 10 hanks were removed and weighed on an electronic balance.

Yarn count has a direct effect on the resultant fabric, for instance the thicker the yarn, the heavier the fabric becomes [3]. In knits, using fine yarns permits a more compact knitted structure if knitting tension is high, which reduces snagging. Hence the measurement of yarn count is necessary for yarns intended for knitted fabric production [4] as this helps in the determination of the knitting machine gauge.

2.3. Yarn Twist

In order to determine the yarn twist, a Shirley electronic twist tester was used (British standards (BS)). For plied yarn (32*2 tex), fifty 25cm long specimens were individually clamped on the machine. A weight of 7g was hung on one end of the plied yarn while the other end was clamped onto the swivelling arm of the machine. This weight was small enough not to cause molecular disorientation that could lead to longitudinal deformation of the yarn, yet at the same time insert just the required tension to cause untwisting of the yarn. The machine was set to untwist the yarn in the Z-direction since it was plied in the S-direction and the number of twists displayed on counter when the yarn was completely untwisted was recorded. Knitting yarns should not posses too high twist as it results in a stiff fabric, but should be enough to allow the yarn to form a U shape with ease when tested for flexibility, and yet strong enough to resist knitting tensions which might lead to breakage.

2.4. Yarn Strength

Strength was tested as a constant rate of elongation (C.R.E.) (BS). A Testometric Micro 500 machine was used. The machine was set to the standard tensile test mode, to read the load in Newtons (N), extension in millimetres (mm) and the test speed in millimetres per minute (mm/m). Testing was done in three variations of testing conditions

1. A sample length of 200 mm, pretension of 1 N, and a test speed of 200 mm/min
2. A sample length of 100mm, pretension of 1 N, and a test speed of 200 mm/min
3. A sample length of 100mm, pretension of 1 N, and a test speed of 100 mm/min

For each variation the machine was calibrated to set the load readout at zero prior to fixing the test specimen on the grips. At the end of the test that was determined by the yarn rupture the peak load and the load-extension graph were displayed on the monitor. Twenty-five tests were conducted per cone.

2.5. Yarn Evenness

Yarn evenness was measured using an Uster Tester I (BS). The machine was set to run at a testing speed of 400 m/min and the evaluation time was set at 2.5 minutes. The machine was then set to the standard sensitive levels, for open-end yarn:

a) Thin places- -50%
b) Thick places- +50%
c) Neps- +280%

The appropriate capacitor plates specified for the count range under which the yarn fell were selected as specified on the Uster Tester I. After the evaluation time the results of thin places, thick places, neps and U% (Unevenness %) were recorded. Twenty-five tests were conducted per cone.

3. RESULTS AND DISCUSSION

3.1. Yarn count

Average count was 62.42 tex instead of the stated 32*2 tex [64 tex] by the yarn supplier and the variance was 0.628. Count variation in a yarn has an effect on the weight of the resultant fabric however the variation is considerably low. The yarn count value is used to determine the suitable gauge of machine. The course gauge machines produce fabrics whose shrinkage properties can be easily determined. However, determination of number of wales and courses per given area becomes more accurate if courser yarns are used therefore, the yarn was doubled so to be accommodated on the coarse gauge (2 needles per cm).

3.2. Yarn twist

The average S-twist value for the plied yarn was 434.6 turns per meter, with a twist factor of 34.36. The deviation of the test values from the mean is considerably low with a standard deviation of 8.76. The plied yarn does not exhibit twist liveliness, which is an important characteristic of the yarn desired for knitting. The average Z-twist value for the single yarn obtained from plied yarns is 170.7 turns per meter, with a twist factor of 40.86. The standard deviation of the test results between the single yarn samples tested is higher (14.9) than that of the plied yarns (8.76). This variation in twist in single yarns is probably due to the variation in the uniformity of the yarn, with thin places exhibiting regions of high twist and thick places low twist. Due to plying, the yarn diameter is altered and twisting two or more yarns together reduce the non-uniformity. It is important that the yarn twist is as uniform as possible along its length as this has an effect on the dimensional properties and drapeability of the resultant knitted fabric. Highly twisted yarn will produce a fabric that is likely to slowly change in its dimension when the yarn slowly untwists due to repeated laundering and usage. Yarns with low twist will not perform as a cohesive structure and will result in a fabric that is likely to deform quickly in terms of dimension and drape.

Tests of the looping characteristics of the yarn show that when 50cm of the yarn sample is held on both ends in a stretched out manner, the ends slowly move towards each other and the yarn forms a smooth U-shape on bending as the middle section drops due to gravity. This is an indication that the yarn has the required flexibility that is desirable in loop formation during machine knitting.

3.3. Yarn Strength

In Tables 1-3 load at peak is the highest force resisted by the yarn before molecular slippage occurs and the elongation at that peak is referred as the elongation at peak. The force at rupture is denoted as load at break and at that load is the force at rupture. The yarn strength was tested at a constant pretension load. The length of yarn and testing speed were varied, as it is known that length determines the surface area forces distributed due to stress during straining. The testing speed determines the rate at which the forces will be distributed within the strained sample. Therefore, these two have a direct effect on the physical behaviour of the specimen under examination. Tables 1-3 show the average result for 50 tests, 25 tests per cone. The results in Table 1 show that, in general the standard deviation from the mean are very small (0.01-1.47) which is an indication that the average strength of the yarn parameters do not show obvious variations since the standard deviation in most cases is less than one. From the results (Table 2) the average strength of the yarn is 7.49N, and the average elongation at break is 14.34mm. The values in this table also do not show large variations from the mean as displayed by their low standard deviation (below 1), and coefficient of variation for all the variables that are way below 50%. (1.48-11.64%) A coefficient of 50% or more would mean that more than half of the obtained data vary, and therefore results cannot be relied on.

Table 1: Average tensile strength properties of the yarn blend – testing condition 1

	Load at peak N	**Elongation at peak mm**	**Strain at peak %**	**Energy at peak Nm**	**Load at break N**	**Elongation at break mm**	**Strain at break %**	**Energy at peak Nm**
Minimum value	6.68	15.37	7.58	0.06	5.61	16.36	7.64	0.06
Mean Value	**6.94**	**17.54**	**8.62**	**0.07**	**6.03**	**17.74**	**8.72**	**0.07**
Maximum value	7.37	19.12	9.37	0.08	6.43	18.46	9.47	0.08
Standard deviation	0.35	1.45	0.69	0.01	0.33	1.47	0.71	0.01
Coefficient of variation%	5.04	8.29	8.06	11.38	5.51	8.35	8.13	11.34

Test length = 200mm
Testing speed = 200mm/min
Pretension = 1N

Like in the two testing conditions presented in Tables 1 and 2 the values in Table 3 do not show large variation from the mean values as displayed by their low standard deviations (0.06-14.36) and coefficient of variations (8.18-27.75).

Results in Tables 1-3 show that the strength and elongation of yarn for the three testing conditions have very little variation. This displays uniformity in terms of strength and elongation of the yarn, which is greatly desired in knitting because when one package runs out another, is threaded on the machine. Since the yarn strength is not variable no changes in the knitting tensions is necessary from one package to another.

The test sample length has an effect on the properties as reflected in Tables 1 and 2. It can be observed that breaking force is less when the test length is higher.

From the results the yarn displays a fair degree of elongation of 9-14% of the initial length, which is one of the primary requirements of knitting yarn. These results show that the yarn is both strong and uniform enough for use in fabric development. This therefore indicates that the yarn can thus be used in knitting as it can endure forces during that process.

Table 2: Average tensile strength properties of the yarn blend – testing condition 2

Test number	Load at peak N	Elongation at peak mm	Strain at peak %	Energy at peak Nm	Load at break N	Elongation at break mm	Strain at break %	Energy at break Nm
Minimum value	7.25	13.98	13.77	0.06	5.14	14.20	13.83	0.06
Mean Value	**7.49**	**14.34**	**13.92**	**0.06**	**6.12**	**14.59**	**14.16**	**0.06**
Maximum value	7.62	14.58	14.12	0.06	6.74	14.85	14.36	0.07
Standard deviation	0.15	0.24	0.21	0.00	0.71	0.25	0.22	0.00
Coefficient of variation%	2.02	1.64	1.48	2.28	11.64	1.69	1.52	2.46

Test length = 100mm
Testing speed = 200mm/min
Pretension = 1N

Table 3: Average tensile strength properties of the yarn blend – testing condition 3

Test number	Load at peak N	Elongation at peak mm	Strain at peak %	Energy at peak Nm	Load at break N	Elongation at break mm	Strain at break %	Energy at break Nm
Minimum value	6.16	12.08	11.87	0.05	3.11	12.31	12.10	0.05
Mean Value	**7.30**	**14.27**	**13.91**	**0.06**	**6.38**	**14.39**	**14.02**	**0.06**
Maximum value	7.99	15.80	15.31	0.07	7.99	15.92	15.43	0.07
Standard deviation	0.62	1.24	1.17	0.01	1.77	1.18	1.15	0.01
Coefficient of variation%	8.51	8.67	8.42	14.83	27.75	8.43	8.18	14.56

Sample length = 100mm
Test speed = 100mm/min
Pretension = 1N

Table 4: Yarn Evenness of the 30% -70% wild silk-cotton blend yarn respectively

Measured variable	
U %	10.5
Thin place per km (-50%)	2
Thick places per km (+50%)	178.5
Neps per km (+280%)	13.5

3.4. Yarn Evenness

Yarn evenness deals with the variations in yarn fineness. This property, commonly measured, as the variation in mass per unit length along the yarn is a basic and important one since it can adversely influence so many other properties of the yarn and of fabrics made from it. Yarn evenness variations are inevitable because they arise from the fundamental nature of textile fibres and from their resulting arrangement. The wild-silk/cotton blend yarn displays few thin places and neps compared to thick places. (Table 4).

Neps can influence the knitting process and appearance of the knitted fabric quite considerably. Furthermore neps of a certain size can lead to processing difficulties particularly in the knitting machines and therefore, the avoidance of neps in the production of spun yarns is fundamental.

The irregularity, U%, is the percentage mass deviation of unit length of material and is caused by uneven fibre distribution along the length of the yarn strand. It is proportional to the intensity of the mass variations around the mean value.

The yarn (Table 4) clearly shows a large number of thick places, which is not desirable for knitting yarn. During production of yarn for knitting, thick places should be avoided as much as possible as they present problems during the knitting process that result in the formation of holes on the knitted fabric. These thick knobs can cause needle damage in the knitting machine and even show on the finished fabric.

The variation of thick and thin places also results in variation of twist in yarn. Thin places present points of high twist and thick places present points of less twist. These variations have an effect on the strength of the yarn. As a thin place has fewer fibres in the cross-section, it normally represents a point of high twist (less resistance to torsion). Thus, in many cases, can indicate a different breaking force value than would be expected based on the number of fibres in the cross-section and the mean yarn twist. With thick places, the conditions are vice-versa [5]. As shown by the mean strength values as indicated by load at break, (6.03 Newtons, 6.12 Newtons and 6.38 Newtons), the high number of thick places have no considerable effect on the strength. However they may cause needle breaks during knitting especially on machines with fine needle gauges.

As a result of the identified yarn parameters, the following conditions were found suitable for knitting this wild-silk/cotton blend yarn:

i) Knitting gauge: 12 needles per inch (5 needles per cm). From results, it can also be concluded that several yarn ends can also be plied together and be knitted on coarser gauge machines.

ii) The knitting tension of the yarn can be set at any value up to 30% of the yarn strength. (6). From the strength results, the resulting fabric will have uniform properties due to consistent knitting tension that the yarn can withstand owing to very small variations in strength as indicated by the standard deviation.

iii) The degree of extensibility of the yarn allows it to be processed on the knitting machine without snapping/breaking or straining as the needles pull the yarn during loop formation.

iv) Due to twist unliveliness of the yarn, the resulting fabric will not have the problem of spirality.

Uniformity of the yarn is of paramount importance in knitting. Non-uniform yarn may lead to constant needle breakages during knitting.

4. KNITTING AND SHRINKAGE PROPERTIES OF THE RESULTANT FABRIC

4.1. Knitting the fabric

A length of one metre plain fabric was produced on A PASSAP® DUOMATIC hand flat machine with a gauge of 2 needles per cm. Knitting was done on 138 needles on the back needle bed (knitting width of 69 cm) at a knitting tension of 6 Newtons. During takedown, the fabric displayed width-wise (wale wise) shrinkage. After removal of the fabric from the machine, the wales and courses per cm were determined and the stitch density calculated.

After removal from the machine, the fabric showed that it had an average of 3.44 wales per cm and 5.49 courses per cm and displayed shrinkage of about 33%. The results are based on 20 different places randomly marked on the fabric piece. The stitch density of this fabric before it was subjected to the wet and dry treatments was 18.89 stitches/cm^2.

4.2. Shrinkage Properties of the Fabric

The plain fabric was subjected to different relaxation treatments. Sample 1 was wet relaxed and sample 2 was dry relaxed. According to the standard procedure stated in the textile research journal [7], when wet conditioning, give the sample a static soak for 24 hours at room temperature and then dry flat overnight in a standard atmosphere of 25ºC and 65% relative humidity. However, because standard conditions could not be achieved, the plain knitted fabric was given a static soak in water for 24 hours under room conditions. After 24 hours it was removed and allowed to dry flat under the same conditions and after drying, the courses and wales per centimetre were determined. The length, width and area shrinkage percentage was also calculated.

After subjecting the fabric to wet treatment, the average stitch density increased to 4.27 wales/cm and 5.76 courses/cm resulting in 24.60 stitches/cm^2 as compared 18.89 stitches/cm^2, giving an area shrinkage of 26.80%.

The second sample was dry relaxed, according to standard methods [ASTM D-13). The knitted samples were kept on a flat surface under standard conditions for 24 hours without tension. Mark three lines in each direction with indelible ink. Measure the distance between the lines prior to relaxation and after relaxation.

4.3. Wet relaxation

On wet relaxation the fabric displayed considerable area shrinkage (26.8%). The effect of water on individual fibres varies greatly with their chemical constitution. Hydrogen bonding is perhaps the most important kind of bond between and within the fibres that influences stabilization. Cellulose (in cotton) and protein (in silk) have strong hydrogen bonding networks. Hydrogen bonds that contribute to the transverse structure of the fibres are more or less readily broken and reformed with water molecules [8]. The action of water on the loop structure of the knitted fabric from hydrophilic yarns is a chemical one that affects the fibre molecules, thus having a significant effect on the dimensions of these yarns [9]. On absorbing water, the yarn can easily slip as the bonds between the fibres are broken, and be relieved from the stresses applied during knitting.

This high width wise shrinkage is probably due to higher tension experienced between adjacent loops as the yarn was being formed into stitches. The low lengthwise shrinkage is probably due to the low takedown force experienced by the fabric section since no weight was hung on it. These results show that plain fabrics knitted from the wild-silk/cotton blend yarn would display high shrinkage after relaxation upon wet processing.

4.4. Dry relaxation

On dry relaxation the plain fabric does not display any considerably changes. It displays 2.63% area shrinkage, which is quite small. It can be said that dry relaxation does not have much effect on the fabric after it has been removed from the machine. The spiral edges of the fabric remain.

5. CONCLUSION

The 30%/70% wild-silk/cotton blend yarn was suitable for knitting resulting in good knitting performance with no end breakages recorded This is attributed to the strength and elongation displayed by the yarn which proved to be suitable for the knitting machine gauge used. The non-uniformity observed during yarn testing did not have visible effect on the appearance of the plain knitted fabric, neither were there any needle breaks due to the high number of thick places on the yarn. The fabric on relaxation showed sensitivity to wet treatment, this is attributed to the hydrophilic fibres constituting the blend yarn.

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