EFFECT OF YARN FINENESS AND CORE/SHEATH FIBRE TYPES ON THE PHYSICAL PROPERTIES OF DUAL-CORE YARNS AND FABRICS

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Dual-core yarn, which is a new type of core-spun yarn, has been developed to improve the core-spun yarn properties. The yarn generally comprises elastic/semi-elastic core filaments, and both filaments are covered by sheath fibres. Dual-core yarns have attracted the interest of textile producers and researchers due to the possibility to enhance various functional properties of fabrics. The present study aimed to analyze the effect of various production parameters on dual-core yarn and fabric properties. In the study, X55 and PBT core filaments were used with Spandex filament as a core material of dual-core yarn, while viscose, cotton and cotton/Tencel fibres were chosen as a sheath fibre for covering the core filaments in the yarn centre. Dual-core yarns were produced with three different yarn fineness levels and some properties of the yarn (irregularity, imperfections, hairiness, tenacity and breaking elongation) and of the fabric (tensile properties and bending rigidity) were investigated. The results showed that all production variables have considerable influence on dual-core yarn and fabric properties, and the strength of each parameter changes depending on the yarn and fabric properties.

Keywords: dual-core yarn, core-spun yarn, elastic yarns, X55, PBT, elasticity, sheath fibre, cotton

INTRODUCTION

Core-spun yarn consists of core and sheath parts arranged by the principle of placing a continuous core yarn into the centre and covering the core material with natural and synthetic staple fibres. Thus, the production technology of core-spun yarn makes it possible to benefit from two types of material in the same structure. Due to their multi-functional performance, core-spun yarns are also named composite or hybrid yarns. Different types of materials can be used as core and sheath components, depending on the desired end-uses. In these yarns, the sheath part affects the surface, physical and aesthetic properties, while the core part improves the mechanical properties of the yarn, such as strength and stretch. In addition, the core filament can impart functional properties, such as conductivity, depending on the type of the core material. Today, core-spun yarns attract the interest of textile producers and researchers due to possibility of imparting various functional properties to the fabrics.

Core-spun yarns, consisting of an elastic filament in the yarn centre, find application in the production of elastic fabrics for sportswear, industrial and household threads, medical textile products and industrial fabrics. In many studies, the analysis of elastic core-spun yarn and fabric properties,[1-16] as well as the effect of the various parameters on yarn and fabric properties, such as elastane draft,[1,4,9,14-15,17] twist,[9,14] elastane fineness[4,9,14] and yarn count,[17] have been performed. Recently, a new type of core spun yarn, called dual-core spun, has been developed in order to improve the core-spun yarn properties. Dual-core spun yarns are composed of two core filaments, such as PET+elastane or PA+elastane,[18] and both core filaments are covered with sheath fibres. In particular, elastic and semi-elastic core filaments are used in dual-core yarn production to achieve high elasticity due to the elastic component, and high recovering, stability and low shrinkage due to the semi-elastic component in dual-core yarns.

Core-spun yarns have been used for many years, however, textile producers and researchers have newly focused on dual-core spun yarns. There is still a limited number of studies about dual-core spun yarns. Turksoy et al. (2019),[19] El-Tantawy et al. (2017)[20] and Kılıç (2017)[21] have investigated two types of dual-core yarns and compared their yarn or some fabric properties with that of the core-spun yarns.

In the studies above, dual-core filaments were fed to the yarn centre with and without welding process. Kılıç[21] welded PET and Spandex filaments by the intermingling process and positioned the combined filaments in a front roller nip, in terms of a standard V-grooved guide roller under certain tension (3.5). In the second part of the study, PET and Spandex filaments were fed separately by a similar guide roller under certain tension (for 3.5 for PET, 1.08 for Spandex). Intermingled and separately fed PET and Spandex core filaments were covered by cotton fibres, and multi-component dual-core yarns were obtained. Kılıç[21] determined that the production methods used (core-spun and dual-core) have a statistically significant influence on yarn properties. In addition, production parameters, such as twist, elastane pre-draft, also statistically affect the elasticity and growth values of woven fabrics. El-Tantawy *et al.*[20] studied the effect of dual-core weft yarns with different yarn counts on the pilling properties of jeans fabric (3/1 Z twill), and found that dual core yarn type and yarn fineness influence the fabric pilling property. Ertaş *et al.* (2015)[22] produced Ne 16/1 dual-core yarns for the weft thread, using 77 dtex PES and 78 dtex Spandex core filaments and cotton wrapping fibres. In their study, it was determined that the construction has a much higher impact on the fabric width and thus on the unit weight than on the elasticity ratio. In addition, it was also found that the changes in fabric density cause serious differences in the fabric’s colour values. As reported above, there are a few studies and findings on the dual-core yarns to understand the structure and features of this yarn type.

On the other hand, besides the traditional elastic fibres, such as Spandex, Lycra *etc*., researches have focused on new elastic fibres, such as PBT,[23-26] PTT,[27] T400[25,28-29] *etc*. There is interest in blending these fibres with other fibres in the core-spun yarn production to enhance the physical characteristics of the yarn and hence of the resulting fabric. Despite the growing body of research on this topic, it was not yet investigated how the type of core filament contributes to the dual-core yarn and fabric properties. In this paper, it was therefore aimed to analyze the effect of the core filament type on some properties of dual-core yarns (irregularity, imperfections, hairiness, tenacity and breaking elongation) and those of fabrics manufactured from them (tensile properties and bending rigidity). Two types of core materials were used, and dual-core yarns were produced with three different sheath fibres, having three different yarn fineness levels. Our comparative study was triggered by considerations of the fact that clothing comfort has become one of the most important fabric properties, and cotton and regenerated cellulosic fibres are generally preferred in next-to-skin fabrics, such as underwear and socks, due to their high moisture regain and natural feeling during wear.[30]

EXPERIMENTAL

Material

In this study, dual-core spun yarns were produced, with Ne 12/1, Ne 16/1 and Ne 20/1 yarn fineness, on a Merlin conventional ring spinning machine.[31] Cotton (100%), viscose (100%) and cotton/Tencel fibre blend (50/50%) were used for the sheath part of the dual-core spun yarns. Fibre properties are given in Table 1. As a core material, X55+Spandex and PBT+Spandex filaments were used. The fineness of the core filaments was 50 denier for X55 and PBT filaments, and 70 denier for Spandex. The Spandex fibre, one of the most important thermo-plastic elastomeric fibres commercially produced worldwide, is made of long chain synthetic polymers, comprising mostly segmented polyurethanes.[32] PBT (polybutylene terephthalate) is a textured polyester filament yarn with a chemical structure that enables permanent elastic properties (stretch and recovery), which are achieved by the finishing processes.[23] X55 is the trading name of Spandex fibre commercialized by Xanadu firm, and is used to provide crimp and stretch properties to the material.

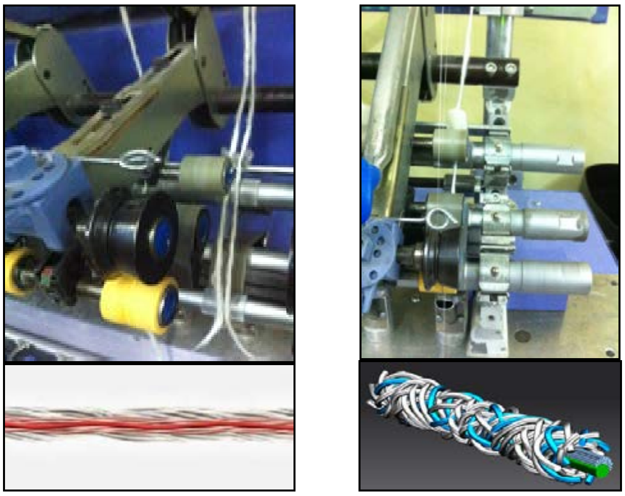
Methods

Yarn production

Similarly to core-spun yarns, during the dual-core spun yarn production, X55 and Spandex (X55+Spandex) or PBT and Spandex (PBT+Spandex) core filaments were supplied separately under the control of a positive feed roller system. The filaments were sent to the V-grooved guide roller (Fig. 1) and both core materials composed of X55+Spandex or PBT+Spandex filaments were wrapped by cotton, viscose and cotton/Tencel sheath fibres. The production parameters of all dual-core yarns are given in Tables 2 and 3.

Table 1
Fibre properties

Properties	Cotton	Viscose	Tencel
UHML	28.62 mm	-	-
Fibre length	-	38 mm	38 mm
Fineness	Mic 4.22	1.3 dtex	1.3 dtex
Maturity	97.2%	-	-
Tenacity	30.58 g/tex	-	-
Colour grade	33-44	-	-


(a) (b)
Figure 1: Single- (a) and dual- (b) core spun yarn production

During the dual-core yarn production, core filaments were given to the drafting system under specific tension, the draft values being of 1.1 for the first type of core filaments (X55 and PBT) and of 3.63 for the second type of core filament (Spandex). Thus, in order to obtain a clearer picture of the effect of the core filament type on yarn properties, the same core draft value for X55 and PBT core filaments was used.

Analysis of yarn and fabric properties

Dual-core spun yarn samples were conditioned under standard atmospheric conditions of 20 ± 1 °C and 65 ± 2% R.H. for 24 h. Seven cops were tested for each yarn property and one test was done on each cop sample. Yarn evenness and imperfections were tested on an Uster Tester 5 at 400 m/min test speed. Mechanical properties of the yarns were measured on an Uster Tensorapid 4. To analyze the fabric properties, the yarn samples were used as weft yarn, and woven fabrics were produced having plain weave, with 30 cm*150 cm dimensions. Fabric density values were 39 warp/cm*18 weft/cm for Ne 12/1, 33 warp/cm*19 weft/cm for Ne 16/1, and 33 warp/cm*21 weft/cm for Ne 20/1 yarn counts. Fabric strength and breaking elongation properties were tested according to EN ISO 13 934-1/1999 on a Lloyd LR5K Plus electronic tensile strength machine. Due to the limited length of fabric samples, the tensile properties of woven fabrics were tested only for the weft direction. In the study, knitted samples were also obtained from the dual-core spun yarns, and fabric density values varied as follows: 110-113 loop/cm^2 for Ne 12/1, 121-125 loop/cm^2 for Ne 16/1 and 124-128 loop/cm^2 for Ne 20/1 yarn counts. Bursting strength of the fabrics was tested according to ISO 13938-2. Three samples of woven and knitted fabrics were tested for tensile and bursting strength properties. Also, bending rigidity of the woven fabric samples was analyzed according to the ASTM D 1388-96 test method by a WIRA bending rigidity tester. Three samples for both the warp and the weft directions were tested for each fabric, and the average values were determined.

All the tests were carried out on the same testers and the test results were analyzed statistically by SPSS 16.0 statistical software to determine any significant differences. Two-way analysis of variance (ANOVA) was used for examining the production parameters, the multiple-range test LSD method – for the comparison of sheath fibre types (Table 4 and Table 6) and t-test – for the comparison of core filament types (Table 5 and Table 7). ANOVA analyses were performed for α = 0.05 significance level.

Table 2
Production parameters for dual-core spun yarns with X55+Spandex dual core filaments
(50/70 denier of core filament fineness)

Yarn count (Ne)	Parameters	Cotton fibre (100%)	Viscose fibre (100%)	Cotton/Tencel blended fibre (50/50%)
12/1	Roving count (Ne)	0.81	0.85	0.85
	αe	4.0	4.0	4.0
	Spindle speed (rpm)	10500	10500	10500
	Total draft	25.6	26.8	26.8
	Core draft 1 (X55)	1.1	1.1	1.1
	Core draft 1 (Spandex)	3.63	3.63	3.63
16/1	Roving count (Ne)	0.81	0.87	0.87
	αe	4.0	4.0	4.0
	Spindle speed (rpm)	10500	10500	10500
	Total draft	36	38	37.4
	Core draft 1 (X55)	1.1	1.1	1.1
	Core draft 1 (Spandex)	3.63	3.63	3.63
20/1	Roving count (Ne)	0.81	0.87	0.87
	αe	4.0	4.0	4.0
	Spindle speed (rpm)	11000	11000	11000
	Total draft	49	50	50
	Core draft 1 (X55)	1.1	1.1	1.1
	Core draft 1 (Spandex)	3.63	3.63	3.63

Table 3
Production parameters for dual-core spun yarns with PBT+Spandex dual core filament
(50/70 denier of core filament fineness)

Yarn count (Ne)	Parameters	Cotton fibre (100%)	Viscose fibre (100%)	Cotton/Tencel blended fibre (50/50%)
12/1	Roving count (Ne)	0.81	0.85	0.85
	αe	4.29	4.0	4.0
	Spindle speed (rpm)	10500	10500	10500
	Total draft	26.9	26.8	26.80
	Core draft 1 (PBT)	1.1	1.1	1.1
	Core draft 1 (Spandex)	3.63	3.63	3.63
16/1	Roving count (Ne)	0.81	0.87	0.87
	αe	4.32	4.0	4.0
	Spindle speed (rpm)	10500	10500	10500
	Total draft	37.5	38.2	37.5
	Core draft 1 (PBT)	1.1	1.1	1.1
	Core draft 1 (Spandex)	3.63	3.63	3.63
20/1	Roving count (Ne)	0.81	0.87	0.87
	αe	4.30	4.0	4.0
	Spindle speed (rpm)	11000	11000	11000
	Total draft	49.8	50.8	50.7
	Core draft 1 (PBT)	1.1	1.1	1.1
	Core draft 1 (Spandex)	3.63	3.63	3.63

RESULTS AND DISCUSSION

Yarn properties

In this part, the properties of dual-core yarns, with Ne 12/1, Ne 16/1 and Ne 20/1, produced with X55+Spandex and PBT+Spandex core filaments and cotton, viscose and cotton/Tencel sheath fibres, are presented. In the figures, cotton, viscose and cotton/Tencel sheath fibres were denoted as C, V and C/T, respectively, while Ne 12/1, Ne 16/1 and Ne 20/1 yarn counts were displayed as 12, 16 and 20. The multiple-range test (LSD) results are summarized in Tables 4 and 5. In the tables, the same abbreviations were used for yarn fineness.

Yarn unevenness (CVm)

Yarn unevenness results are given in Figure 2. As seen in the graph, it was determined that dual-core yarns with cotton sheath fibres give the highest yarn unevenness values, while the yarns with the cotton/Tencel fibre blend provide the lowest ones. In particular, the mass variation (CVm) values of the cotton fibres were significantly different from those of other sheath fibres, while viscose and cotton/Tencel sheath fibres statistically gave similar yarn unevenness. This situation was observed for both core filament types and all yarn fineness levels (Table 4). In the literature, the effect of cotton, viscose rayon fibres and their blends on ring, compact and vortex yarn properties were reported. It was determined that an increased ratio of regenerated cellulosic fibre in the blend decreases the yarn unevenness values, and the lowest CVm value was found for 33/67% cotton-regenerated cellulosic fibre blend. Therefore, the findings regarding the effect of different sheath fibre types on the CVm values of dual-core yarns were in agreement with those reported for other yarn types.[33-34]

Fibre length, length variations and variations in the number of fibres in the yarn cross-section affected yarn evenness. The worse CVm values of cotton dual-core spun yarns might be explained by a higher number of short fibres and fibre length variation values of cotton sheath fibres, in comparison with those of viscose and cotton/Tencel sheath fibres. As the yarn was getting finer, particularly in the dual-core yarns produced from cotton and cotton blended sheath fibres, yarn unevenness values increased. A similar trend was observed for other yarn types, which could be explained by a decreased number of fibres in the yarn cross-section. Furthermore, it has been stated, with regard to core-spun yarns, that the reduction in the number of fibres also increases yarn unevenness, because of lack of uniform coating of the core filament.[9] However, there was a different trend in the yarns with viscose sheath fibres, and the CVm values generally decreased with finer yarns. One possible reason might be the positive effect of viscose sheath fibres on uniform coating, in terms of its better fibre length characteristic. On the other hand, there were different trends regarding the effect of core filament type on yarn unevenness. The CVm results indicated that PBT, a semi-elastic core filament, led to the production of significantly more even yarns for cotton and viscose sheath fibres, while X55, an elastic core filament, gave lower CVm values for cotton/Tencel blended sheath fibres (Table 5).

When the CVm values of the dual-core spun yarns were analyzed statistically, ANOVA results indicated that the effects of sheath fibre ($p = 0.000$), yarn fineness ($p = 0.000$), sheath fibre*core filament type ($p = 0.031$) and sheath fibre*yarn fineness*core filament type ($p = 0.008$) were statistically significant at a level of 5%, while the effect of the core filament type ($p = 0.259$) and the interactive effects of sheath fibre*yarn fineness ($p = 0.193$) and yarn fineness*core filament type ($p = 0.541$) did not have a statistically significant effect on the yarn irregularity values. Therefore, it was concluded that the type of core filament led to different yarn unevenness results, depending on sheath fibre type, while similar CVm values were obtained at different yarn fineness levels.

Yarn imperfections

In the study, no thin places were observed in any of the yarn types. However, thick places and neps were noted and their values are given in Figures 3 and 4. Statistical analysis of the results was performed and the outcome is presented in Tables 4-5. According to the results, cotton sheath fibres gave significantly higher thick area and nep values in both yarn types, with X55+Spandex and PBT+Spandex dual-core filaments (Table 4). This was attributed to the fibre length and the variation in the length, as reported for yarn unevenness. The yarns produced from viscose and cotton/Tencel sheath fibres had statistically similar amounts of yarn imperfections for all yarn fineness levels. Thick places and nep values increased as the yarn became finer. As for the effect of the core material, no clear trend in the values was observed, and the results changed depending on the production parameters. X55 gave lower values in cotton and cotton/Tencel blended sheath fibres at Ne 12 and Ne 20 yarn fineness levels, while PBT was better in viscose sheath fibres. As a conclusion, a lower amount of yarn imperfections was obtained for PBT in viscose fibre, while for X55 in cotton and cotton/Tencel fibres.

When the thick places of the dual-core spun yarns were analyzed statistically, ANOVA results indicated that the effects of sheath fibre ($p = 0.000$), yarn fineness ($p = 0.000$) and sheath fibre*yarn fineness ($p = 0.000$) were statistically significant at 5% level, while the core filament type ($p = 0.212$), sheath fibre*core filament type (p = 0.237), yarn fineness*core filament type (p = 0.638) and sheath fibre*yarn fineness*core filament type (p = 0.840) did not have a considerable effect on the thick places values of the yarns.

Table 4
LSD test results for dual-core yarn properties produced with different sheath fibres and yarn fineness

Property	Sheath fibre		X55	PBT
CVm12	Viscose	Cotton	0.000*	0.119
		Cotton/Tencel	0.419	0.866
	Cotton	Cotton/Tencel	0.000*	0.235
CVm16	Viscose	Cotton	0.000*	0.007*
		Cotton/Tencel	0.933	0.816
	Cotton	Cotton/Tencel	0.000*	0.029*
CVm20	Viscose	Cotton	0.000*	0.710
		Cotton/Tencel	0.001*	0.871
	Cotton	Cotton/Tencel	0.000*	0.633
Thick12	Viscose	Cotton	0.000*	0.027*
		Cotton/Tencel	0.840	0.941
	Cotton	Cotton/Tencel	0.000*	0.062
Thick16	Viscose	Cotton	0.000*	0.026*
		Cotton/Tencel	0.904	0.677
	Cotton	Cotton/Tencel	0.000*	0.023*
Thick20	Viscose	Cotton	0.000*	0.032*
		Cotton/Tencel	0.658	0.647
	Cotton	Cotton/Tencel	0.000*	0.025*
Neps12	Viscose	Cotton	0.000*	0.011*
		Cotton/Tencel	0.868	0.768
	Cotton	Cotton/Tencel	0.000*	0.014*
Neps16	Viscose	Cotton	0.000*	0.009*
		Cotton/Tencel	0.729	0.643
	Cotton	Cotton/Tencel	0.000*	0.008*
Neps20	Viscose	Cotton	0.000*	0.013*
		Cotton/Tencel	0.667	0.705
	Cotton	Cotton/Tencel	0.000*	0.013*
H12	Viscose	Cotton	0.000*	0.102
		Cotton/Tencel	0.487	0.385
	Cotton	Cotton/Tencel	0.001*	0.564
H16	Viscose	Cotton	0.001*	0.023*
		Cotton/Tencel	0.520	0.632
	Cotton	Cotton/Tencel	0.003*	0.018*
H20	Viscose	Cotton	0.000*	0.005*
		Cotton/Tencel	0.073	0.651
	Cotton	Cotton/Tencel	0.015*	0.035*
Tenacity12	Viscose	Cotton	0.773	0.002*
		Cotton/Tencel	0.006*	0.313
	Cotton	Cotton/Tencel	0.013*	0.035*
Tenacity16	Viscose	Cotton	0.049*	0.091
		Cotton/Tencel	0.001*	0.289
	Cotton	Cotton/Tencel	0.000*	0.021*
Tenacity20	Viscose	Cotton	0.000*	0.000*
		Cotton/Tencel	0.842	0.489
	Cotton	Cotton/Tencel	0.000*	0.000*
Elogantion12	Viscose	Cotton	0.000*	0.000*
		Cotton/Tencel	0.787	0.352
	Cotton	Cotton/Tencel	0.000*	0.000*
Elogantion16	Viscose	Cotton	0.000*	0.000*
		Cotton/Tencel	0.717	0.000*
	Cotton	Cotton/Tencel	0.000*	0.000*
Elogantion20	Viscose	Cotton	0.000*	0.000*
		Cotton/Tencel	0.000*	0.000*
	Cotton	Cotton/Tencel	0.000*	0.000*

*The mean difference is significant at the 0.05 level

Table 5
t-Test results for X55 and PBT core filaments for yarn properties

Production parameters		CVm	Thick areas	Neps	H	Tenacity	Elongation
Viscose	Ne 12	0.000*	0.111	0.006*	0.000*	0.000*	0.000*
	Ne 16	0.000*	0.001*	0.001*	0.000*	0.000*	0.000*
	Ne 20	0.000*	0.082	0.000*	0.000*	0.000*	0.000*
Cotton	Ne 12	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
	Ne 16	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
	Ne 20	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Cotton/Tencel	Ne 12	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
	Ne 16	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
	Ne 20	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

*The mean difference is significant at the 0.05 level

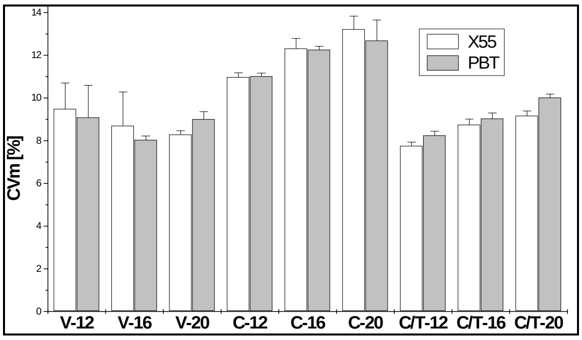


Figure 2: Yarn unevenness for X55 and PBT dual-core yarns

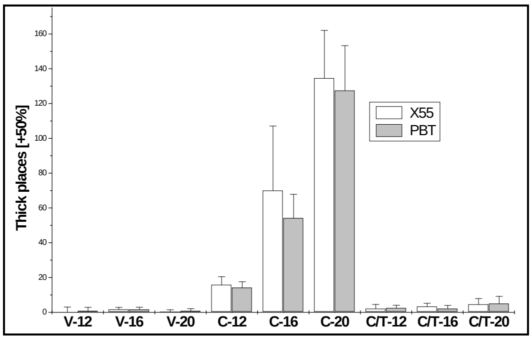


Figure 3: Thick places for X55 and PBT dual-core yarns

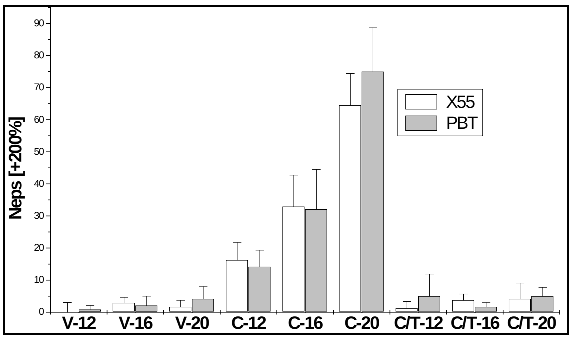


Figure 4: Neps for X55 and PBT dual-core yarns

As to the neps, sheath fibre ($p = 0.000$), yarn fineness ($p = 0.000$), core filament type ($p = 0.003$), sheath fibre*yarn fineness ($p = 0.000$) and yarn fineness*core filament type ($p = 0.013$) had a statistically important influence, while the effects of sheath fibre*core filament type ($p = 0.085$), and sheath fibre*yarn fineness*core filament type ($p = 0.238$) were not statistically significant with regard to the nep values. The results revealed that the sheath fibre type and yarn fineness were more significant factors leading to lower thick places and nep values, and both core filaments led to similar yarn imperfections at the same sheath fibre types and yarn fineness levels. The effect of different core materials on yarn imperfections became more significant as a function of sheath fibre type and yarn fineness.

Yarn hairiness

The Uster H hairiness values of the dual-core yarns are shown in Figure 5, and the statistical test results are given in Tables 4-5. Similarly to yarn unevenness, the cotton sheath fibres gave higher Uster H hairiness values, while the viscose and cotton/Tencel fibres led to lower ones in X55+Spandex and PBT+Spandex dual-core yarns.

The lowest hairiness values were mostly obtained in the yarns produced from viscose fibres, followed by cotton/Tencel blended fibres. However, the viscose and cotton/Tencel sheath fibres yielded significantly less hairy yarns than cotton fibres. As determined previously for different yarn types, such as ring, rotor, vortex *etc*., the longer length of viscose rayon fibre, when compared with that of cotton fibre, might lead to fewer protruding fibres and better H values.[33] As expected, the dual-core yarns turned less hairy when finer yarns were produced, as a consequence of the lower number of fibres in the yarn cross-section. On the other hand, the PBT core filament was found to produce less hairiness for coarser yarns, such as Ne 12, while the X55 core material tended to yield better hairiness values for finer yarn counts, like Ne 16 and Ne 20 yarn counts. Therefore, PBT mostly tended to increase the hairiness index (H) of the dual-core yarns, and thus, such core filament might require more wrapping fibres for achieving lower yarn hairiness.

ANOVA results also indicated that sheath fibre (p = 0.000), yarn fineness (p = 0.000), core filament type (p = 0.000) and yarn fineness*core filament type (p = 0.003) had a statistically significant effect on the H hairiness values of the dual-core yarns. However, the interactive effects of sheath fibre*yarn fineness (p = 0.103), sheath fibre*core filament type (p = 0.878) and sheath fibre*yarn fineness*core filament type (p = 0.358) were found statistically insignificant at a 5% level. Therefore, as in ring spun and other yarn types, the hairiness of the dual-core yarns was influenced by the length characteristics of the fibres and the number of fibres in the yarn cross-section. In particular, the number of fibres might have a higher effect on yarn hairiness because of the coating performance of sheath fibres, also, uniform covering of the core filament had a positive effect in reducing hairiness. On the other hand, the core material type could be important, depending on yarn fineness, but X55 and PBT core filaments were prone to producing similar hairiness at the same sheath fibres.

Yarn tenacity

When the tenacity results of the dual-core yarns were analyzed, it was determined that the dual-core yarns produced with cotton sheath fibres have the lowest, while the yarns containing cotton/Tencel blended sheath fibres have the highest tenacity values. This situation was observed for both (PBT and X55) core filaments (Fig. 6). On the other hand, the differences in the tenacity values of the dual-core yarns were found statistically significant (Table 4). In a core-spun yarn, sheath fibres contribute more to the tensile properties of the yarn, since the sheath part of the yarn carries more of the load, compared to the core component. Therefore, the tensile properties of the core-spun yarns changed depending on the sheath fibre types.[14-15,35]

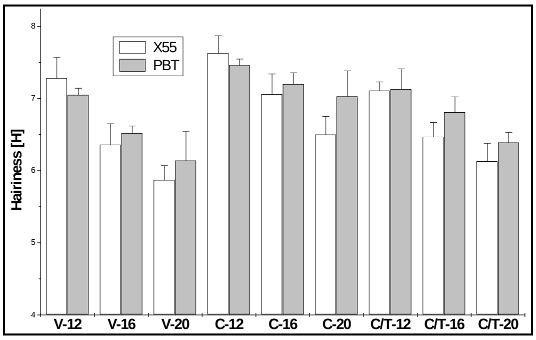


Figure 5: Yarn hairiness for X55 and PBT dual-core yarns

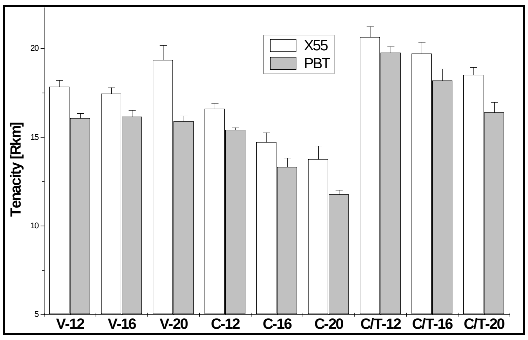


Figure 6: Yarn tenacity for X55 and PBT dual-core yarns

A similar pattern was also observed for the dual-core yarns. Although viscose fibres have smaller tenacities than cotton fibres, their fibre length, more fibre length uniformity and lower number of short fibres might actually lead to higher tenacity values in dual-core yarns covered by viscose than in those covered by cotton fibres. This conclusion is consistent with previous findings reported for ring, rotor, compact and vortex yarns.[33-34]

On the other hand, as known for yarn types, such as ring spun, the yarn tenacity values of dual-core yarns mostly reduced with increasing yarn fineness. This might have resulted from the reduction in the number of sheath fibres in yarn cross-section, thereby leading to less contribution of the sheath fibres to the yarn strength. When the effect of the core filament type was analyzed, it was found that the strength of the dual-core yarns comprising an X55 core filament was significantly greater than that of the PBT core filament containing yarns (Table 5). Therefore, it could be said that the X55 core filament affects the yarn strength positively for all sheath fibres, compared with the PBT core filament. The less hairy structure and lower level of yarn imperfections of the X55 core filament might be considered as a reason for the stronger yarns, compared to PBT. A uniformly covered core filament might have a positive effect on the tenacity of dual-core yarns.

ANOVA results indicated that the effect of sheath fibre ($p = 0.000$), core filament type ($p = 0.000$) and yarn fineness ($p = 0.000$) and the interactive effects of these parameters ($p = 0.000$) had a statistically significant effect on yarn tenacity values. Therefore, all the production parameters of dual-core yarns had a relatively high influence on the tenacity of the yarns.

Yarn breaking elongation

The breaking elongation values of the dual-core yarns produced with three different sheath fibres and two different core filament types are presented in Figure 7, and the statistical analysis results are given in Tables 4-5. According to the results, the breaking elongation values were considerably higher for the viscose dual-core yarns than for the cotton ones for X55 and PBT core filaments (Table 4). This can be explained by the breaking elongation and fibre length characteristics of viscose and cotton fibres. Kılıç and Okur[34] and Erdumlu *et al*.[33] also recorded the highest elongation values in viscose rayon yarns for different yarn types, such as ring, compact, rotor and vortex. Additionally, it was suggested that fibre type has a relatively higher significant influence on yarn breaking elongation results than the yarn spinning system.[33] As the yarn became finer, no noticeable change in the elongation values was observed. Nevertheless, the breaking elongation values mostly showed a decreasing trend in finer yarns. As to the effect of the core filament type, a similar pattern was remarked as that determined in yarn hairiness and tenacity results, and the X55 core filament type gave significantly higher elongation values than the PBT core filament. A possible reason for this could be the fibre breaking elongation feature of the core filaments. As stated, X55 is a polyurethane fibre and this led to higher elongation values than in the case of the elastic PBT textured polyester filament. According to ANOVA results, the effects of all the parameters and their interactions on breaking elongation were generally statistically significant at 5% level. Therefore, not only the sheath fibre and yarn fineness, but also the core filament type, are parameters that have a considerable effect on the breaking elongation of dual-core yarns.

Fabric properties

In this part, some properties of the woven and knitted fabrics produced with the dual-core spun yarns, comprising X55+Spandex and PBT+Spandex core filaments and cotton, viscose and cotton/Tencel sheath fibres, for Ne 12/1, Ne 16/1 and Ne 20/1 yarn counts, are discussed. The multiple range test (LSD) results are summarized in Tables 6 and 7.

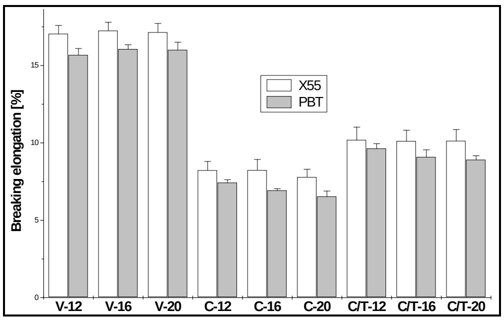


Figure 7: Breaking elongation for X55 and PBT dual-core yarns

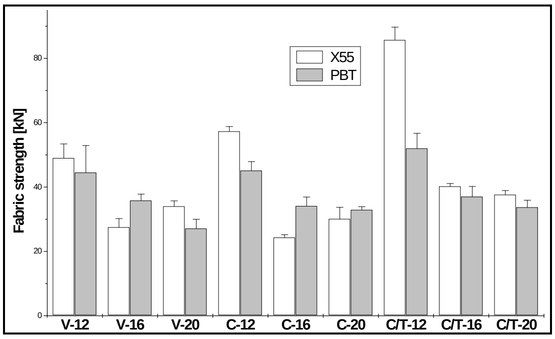


Figure 8: Strength of woven fabrics for weft direction

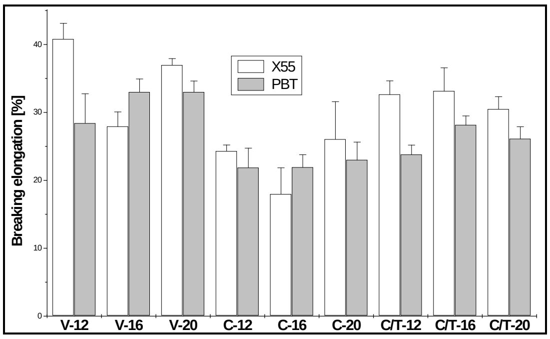


Figure 9: Breaking elongation of woven fabrics for weft direction

Tensile properties of woven fabrics

As mentioned above, the dual-core yarns were used as a weft yarn during the production of woven fabrics, and fabric strength and breaking elongation properties were tested for only the weft direction because of an inadequate length of fabric samples. Statistical analysis results are given in Tables 6-7. When the tensile properties of the fabrics were analyzed, a similar situation was observed as in the case of yarn tenacity and breaking elongation (Figs. 8-9). Fabric strength was the lowest for the fabrics woven from cotton sheath dual-core yarns, while the highest for the yarns comprising cotton/Tencel blended sheath fibres. The differences in the strength values were found statistically significant for the X55 core filament, depending on the sheath fibre types and yarn fineness, while the strength values mostly differed insignificantly for PBT (Table 6).

As to the breaking elongation results, the fabrics woven from dual-core yarns with viscose rayon sheath fibres recorded the highest breaking elongation values, while the fabrics with cotton sheath fibres had the lowest ones. Regarding the effect of the core filament type on the tensile properties of the fabrics, it was found that the fabrics that included X55 core filament have generally exhibited significantly higher fabric strength and elongation than those with PBT filament (Table 7). The better tensile properties of the fabrics with X55 core filament might be the result of its higher strength and breaking elongation, compared to those of the PBT core filament. According to the statistical analysis, as determined above for yarn tensile properties, the effect of sheath fibre ($p = 0.000$, $p = 0.000$), yarn fineness ($p = 0.000$, $p = 0.019$) and core filament type ($p = 0.000$, $p = 0.000$), as well as the interactive effects of sheath fibre*core filament type ($p = 0.000$, $p = 0.000$), yarn fineness*core filament type ($p = 0.000$, $p = 0.004$) and sheath fibre*yarn fineness*core filament type ($p = 0.001$, $p = 0.035$) were found to have a statistically significant effect on fabric strength and breaking elongation values. Therefore, yarn fineness, type of sheath fibre and core filament influenced the tensile properties of the woven fabrics significantly.

Bursting strength of knitted fabrics

Bursting strength is the ability of fabric to resist rupture under pressure, and it depends on the tensile strength and extensibility of the material. In this study, the bursting strength of the fabrics knitted from the dual-core yarns produced from different sheath fibres and core filaments was measured for three different yarn fineness levels, and comparisons were made. According to the results illustrated in Figure 10, the bursting strength of the plain knitted fabrics varied as a function of the sheath fibre and core filament types. Considerably higher bursting strength values were obtained in 100% cotton fabrics than for other sheath fibres (Table 6), and this was consistent with previous findings recorded for different yarn types.[33] As to the effect of the core filament type, better bursting strength values were obtained for the X55 core filament with viscose and cotton sheath fibres, as well as for the PBT core filament with cotton/Tencel fibres. One of the reasons explaining this bursting strength of the fabrics might lie in the yarn strength results – hence, the higher bursting strength of cotton sheath fibre and X55 core filament resulted from the better tensile properties of these materials. According to statistical analysis, the effects of all the parameters and their interactions on bursting strength were found to reach a statistically significant level.

Bending rigidity

Bending rigidity is the resistance of a textile sample of a certain size to bending under its own weight and one of the parameters representing fabric comfort. In this study, the bending rigidity of the fabrics was tested for warp and weft directions and calculated for the entire fabric. As seen in Figure 11, the fabrics woven from X55+Spandex dual-core yarns had mostly higher rigidity values, compared with those of the PBT+Spandex dual-core yarns. Therefore, the fabrics with X55+Elastane dual-core yarns were stiffer than those with PBT+Spandex dual-core yarns.

Table 6
LSD test results for dual-core fabric properties produced with different sheath fibres and yarn fineness

Property	Sheath fibres		X55	PBT
Woven-Strength12	Viscose	Cotton	0.028*	0.939
		Cotton/Tencel	0.000*	0.358
	Cotton	Cotton/Tencel	0.000*	0.395
Woven-Strength 16	Viscose	Cotton	0.057	0.487
		Cotton/Tencel	0.000*	0.596
	Cotton	Cotton/Tencel	0.000*	0.241
Woven-Strength20	Viscose	Cotton	0.095	0.093
		Cotton/Tencel	0.115	0.018*
	Cotton	Cotton/Tencel	0.009*	0.002*
Woven-Elongation12	Viscose	Cotton	0.000*	0.042*
		Cotton/Tencel	0.002*	0.119
	Cotton	Cotton/Tencel	0.001*	0.475
Woven-Elongation16	Viscose	Cotton	0.009*	0.000*
		Cotton/Tencel	0.095	0.014*
	Cotton	Cotton/Tencel	0.001*	0.004*
Woven-Elongation20	Viscose	Cotton	0.008*	0.001*
		Cotton/Tencel	0.059	0.001*
	Cotton	Cotton/Tencel	0.163	0.553
Knitted-Bursting12	Viscose	Cotton	0.009*	0.302
		Cotton/Tencel	0.002*	0.000*
	Cotton	Cotton/Tencel	0.160	0.000*
Knitted-Bursting16	Viscose	Cotton	0.000*	0.011*
		Cotton/Tencel	0.000*	0.000*
	Cotton	Cotton/Tencel	0.000*	0.000*
Knitted-Bursting20	Viscose	Cotton	0.175	0.775
		Cotton/Tencel	0.006*	0.000*
	Cotton	Cotton/Tencel	0.001*	0.000*

*The mean difference is significant at the 0.05 level

Table 7
t-Test results for X55 and PBT core filaments for fabric properties

Production parameters		Strength	Elongation	Bursting strength
Viscose	Ne 12	0.000*	0.000*	0.000*
	Ne 16	0.000*	0.000*	0.000*
	Ne 20	0.000*	0.000*	0.000*
Cotton	Ne 12	0.000*	0.000*	0.000*
	Ne 16	0.000*	0.000*	0.000*
	Ne 20	0.000*	0.000*	0.000*
Cotton/Tencel	Ne 12	0.000*	0.000*	0.000*
	Ne 16	0.000*	0.000*	0.000*
	Ne 20	0.000*	0.000*	0.000*

*The mean difference is significant at the 0.05 level

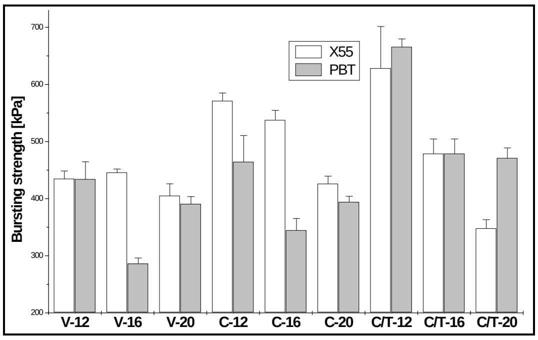


Figure 10: Bursting strength of fabrics knitted from different dual-core yarns

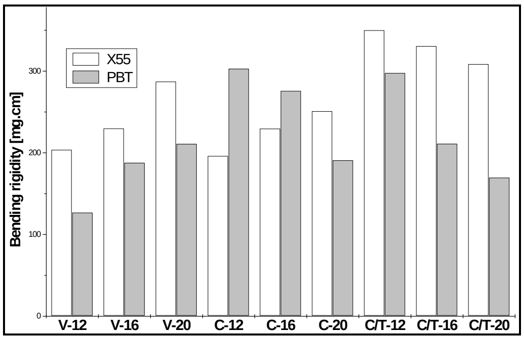


Figure 11: Bending rigidity of fabrics woven from different dual-core yarns

Regarding the fibre type, the results varied as a function of the core filament type. Viscose and cotton/Tencel sheath fibres with PBT core filament exhibited lower bending rigidity, while cotton fibres showed lower values when a X55 core filament was used, due to the higher fibre density of cotton fibre.

CONCLUSION

This research investigated the effect of dual-core yarn production parameters on some yarn and fabric properties. The results are summarized below.

- As indicated in previous studies regarding other yarn types, such as ring, rotor, compact, vortex *etc*., the sheath fibre characteristics, such as fibre length, length variations, number of fibres in the yarn cross-section and tensile properties, affected the unevenness, imperfections, hairiness, tenacity and breaking elongation properties of dual-core yarns.
- Dual-core yarns with cotton sheath fibres exhibited higher yarn unevenness, thick places, neps, hairiness, and lower tenacity and breaking elongation values, while the yarns with the cotton/Tencel fibre blend provided better values for these yarn properties. Viscose sheath fibres mostly presented statistically similar values to those of the cotton/Tencel sheath fibres.
- Contrary to our expectations, the tenacity values of the dual-core yarns were better for the yarns produced with viscose and Tencel sheath fibres. Despite the higher strength values of cotton sheath fibres, their fibre length characteristics might a negative effect and lead to lower tenacity values in dual-core yarns covered with cotton fibres.
- An evaluation of the tensile properties of fabrics revealed a similar pattern as those remarked for yarn tenacity and breaking elongation of the dual core-yarns.
- As to the effect of the core filament type on yarn properties, PBT, which is a semi-elastic core filament, provided more even yarns in combination with cotton and viscose sheath fibres, and fewer yarn imperfections in combination with viscose fibres, while X55, which is an elastic core filament, provided better results when combined with cotton/Tencel blended fibres. Both core filaments were prone to producing similar hairiness for the same sheath fibres. Regarding the tensile properties of the yarns, as well as those of woven fabrics, X55 contributed to significantly higher strength and breaking elongation values for all the analyzed sheath fibres and yarn fineness levels. However, the sheath fibre type had a more important effect on the bursting strength values of knitted fabrics. Higher bursting strength values are obtained for combinations of the X55 core filament with viscose and cotton sheath fibres, and of the PBT core filament with cotton/Tencel fibres.
- Due to the higher bending rigidity values of the fabrics, X55+Spandex yielded stiffer fabrics than PBT+Spandex.
- The effect of yarn fineness on the dual-core yarn quality parameters showed a similar trend as that observed for other yarn types. However, as regards the CVm results, compared with other fibre types, the dual-core yarns comprising viscose sheath fibres had generally better values for finer yarns due to the positive effect of the length characteristic of viscose sheath fibres on uniform coating.

As mentioned above, previous studies reported in the literature mainly focused on core-spun yarn production and the effects of process parameters on the structure and properties of cotton/Spandex core-spun yarns, with limited research available on the way dual-core yarns are affected by the same parameters. Therefore, the present investigation has revealed that the examined process variables, such as sheath fibre and core filament type, as well as yarn fineness, affect significantly the properties of dual-core yarns and those of the fabrics woven or knitted from such yarns.

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REFERENCES

[1] C. I. Su and H. Y. Yang, *Text. Res. J.*, **74**, 1041 (2004), https://doi.org/10.1177/004051750407401202

[2] C. I. Su, M. C. Maa and H. Y. Yang, *Text. Res. J.*, **74**, 607 (2004), https://doi.org/10.1177/004051750407400709

[3] S. Demirbas, Master's Thesis, University of Suleyman Demirel, Institute of Naturel and Applied Science, Isparta, 2005

[4] B. Dhouib, S. El-Ghezal and M. Cheikhrouhou, *J. Textile Inst.*, **97**, 167 (2006), https://doi.org/10.1533/joti.2005.0121

[5] S. Kakvan, S. Najar, R. G. Saidi and M. Nami, *J. Textile Inst.*, **9**8, 57 (2007), https://doi.org/10.1533/joti.2005.0194

[6] N. Özdil, *Fibres Text. East. Eur.*, **16**, 63 (2008), http://www.fibtex.lodz.pl/66_17_63.pdf

[7] C. N. Herath and B. C. Kang, *Text. Res. J.*, **78**, 209 (2008), https://doi.org/10.1177/0040517507082958

[8] H. W. Yang, H. J. Kim, C. Y. Zhu and Y. Huh, *Text. Res. J.*, **79**, 453 (2009), https://doi.org/10.1177/0040517508099912

[9] D. Vuruskan, Ph.D. Thesis, University of Cukurova, Institute of Natural and Applied Science, Adana, 2010

[10] B. Baghaei, M. Shanbeh and A. A. Ghareaghaji, *Indian J. Fibre Text. Res.*, **35**, 298 (2010), http://hdl.handle.net/123456789/10744

[11] B. Adeli, A. G. Akbar and M. Shanbeh, *Text. Res. J.*, **81**, 137 (2011), https://doi.org/10.1177/0040517510380104

[12] H. Helali, A. Babay Dhouib, S. Msahli and M. Cheikhrouhou, *J. Textile Inst.*, **103**, 378 (2012), https://doi.org/10.1080/00405000.2011.580542

[13] H. Helali, A. Babay Dhouib, S. Msahli and M. Cheikhrouhou, *J. Text. Sci. Eng.*, **3**, 127 (2012), https://doi.org/10.4172/2165-8064.1000127

[14] A. Das and R. Chakraborty, *Indian J. Fibre Text. Res.*, **38**, 237 (2013), http://hdl.handle.net/123456789/21427

[15] M. B. Qadir, T. Hussain, M. Malik, F. Ahmad and S. H. Jeong, *J. Textile Inst.*, **105**, 753 (2014), https://doi.org/10.1080/00405000.2013.848045

[16] N. Varghese and G. Thilagavathi, *J. Textile Inst.*, **106**, 242 (2015), https://doi.org/10.1080/00405000.2014.914652

[17] H. Helali, A. Babay Dhouib and S. Msahli, *J. Textile Inst.*, **103**, 451 (2013), https://doi.org/10.1080/00405000.2011.584383

[18] H. Zhang, Y. Xue and S. Wang, *Text. Res. J.*, **76**, 922 (2006), https://doi.org/10.1177/0040517506074236

[19] H. G. Türksoy, G. Kılıç, S. Üstüntağ and D. Yılmaz, *J. Textile Inst.*, **110**, 980 (2019), https://doi.org/10.1080/00405000.2018.1534541

[20] S. El-Tantawy, M. Sabry and M. Bakry, *Int. Design J.*, **7**, 161 (2017), https://doi.org/10.12816/0044133

[21] G. Kılıc, Ph.D. Thesis, Erciyes University, Graduate School of Natural and Applied Sciences, Kayseri, 2017

[22] O. G. Ertaş, B. Z. Ünal and N. Çelik, *J. Textile Inst.*, **107**(1), 116 (2016), https://doi.org/10.1080/00405000.2015.1016319.

[23] M. Bizjak, H. Kadoglu, K. Kostajnsek, P. Celik, G. Bayraktar Basal *et al.*, in *Procs. IOP Conference Series: Materials Science and Engineering*, 2017, p. 092001, https://doi.org/10.1088/1757-899X/254/9/092001

[24] H. I. Çelik and H. K. Kaynak, in *Procs. IOP Conference Series: Materials Science and Engineering*, 2017, p. 082007, https://doi.org/10.1088/1757-899X/254/8/082007

[25] C. Broega, A. M. Rocha, A. P. Souto, F. Ferreira and L. Oliveira, in *Procs. 16th Autex World Textile Conference 2016*, Ljubljana, Slovenia, 2016, p. 1, http://hdl.handle.net/1822/43393

[26] H. Kadoğlu, K. Dimitrovski, A. Marmaralı, P. Çelik, G. B. Bayraktar *et al.*, *Autex Res. J.*, **16**, 109 (2016), https://doi.org/10.1515/aut-2015-0025

[27] T. Hua, N. S. Wong and W. M. Tang, *Text. Res. J.*, **88**, 1065 (2018), https://doi.org/10.1177/0040517517693982

[28] N. T. Akankwasa, W. Jun, Z. Yuze and M. Mushtaq, *Materialwissenschaft und Werkstofftechnik*, **45**, 1039 (2014), https://doi.org/10.1002/mawe.201400246

[29] N. T. Akankwasa, J. Wang and Y. Zhang, *J. Textile Inst.*, **107**, 504 (2015), https://doi.org/10.1080/00405000.2015.1045254

[30] O. Demiryürek, İ. Güleyüpoğlu and E. Turhan, *Cellulose Chem. Technol.*, **53**, 795 (2019), https://doi.org/10.35812/CelluloseChemTechnol.2019.53.78

[31] Çelikkan Aydoğdu, S.H., Production Of Single And Double-Strand Core-Spun Yarns And Analysis Of Their Properties, Master Thesis, University of

Suleyman Demirel, Institute of Naturel and Applied Science, Isparta, 2018.
[32] J. Hu, J. Lu and Y. Zhu, *Polym. Rev.*, **48**, 275 (2008), https://doi.org/10.1080/15583720802020186
[33] N. Erdumlu, B. Ozipek, A. S. Oztuna and S. Cetinkaya, *Text. Res. J.*, **79**, 585 (2009), https://doi.org/10.1177/0040517508093590
[34] M. Kilic and A. Okur, *Text. Res. J.*, **81**, 156 (2011), https://doi.org/10.1177/0040517510377828
[35] O. Babaarslan, *Text. Res. J.*, **71**, 367 (2001), https://doi.org/10.1177/004051750107100415