

# Effect of pin spacer apparatus on the properties of knitted fabrics from cotton-tencel yarns

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## REZUMAT – ABSTRACT

### Efectul aparatului de distanțare cu ace asupra proprietăților tricotelurilor din fire de bumbac-tencel

Calitatea firelor este un factor important, deoarece influențează în mod direct proprietățile țesăturilor. Printre numeroasele încercări de îmbunătățire a proprietăților firelor în tehnologiile de filare, dispozitivul de distanțare cu ace este un dispozitiv care poate fi montat separat pe unitatea compactă de filare utilizat pentru îmbunătățirea proprietăților firelor, în special în ceea ce privește uniformitatea și pilozitatea. Firele compacte în amestec bumbac-Tencel sunt preferate pe scară largă de consumatorii de textile, datorită caracteristicilor de confort ridicate ale fibrelor Tencel, combinate cu proprietățile unice ale fibrelor de bumbac. În acest studiu, s-au obținut probe de fire compacte din bumbac (85%) – Tencel (15%) ca grupuri de fire pieptănate și cardate atât prin utilizarea, dar și fără utilizarea unui dispozitiv de distanțare cu ace, la o densitate liniară de Ne 40/1. Pentru a analiza efectul aparatului de distanțare cu ace asupra proprietăților firelor, au fost evaluate măsurătorile privind neuniformitatea, imperfecțiunile, pilozitatea (H) și rezistența la tracțiune. Probele tricotate albe și vopsite din tricot glat produse au fost comparate, de asemenea, în ceea ce privește modificările dimensionale în direcția șirului și a rândului de ochiuri (%), gradului de piling, rezistenței la plesnire (kPa), permeabilității la aer (mm/s), proprietățile culorii de suprafață a țesăturii. Conform rezultatelor testelor, utilizarea dispozitivului de distanțare cu ace, în general, a dus la îmbunătățirea unor proprietăți ale firelor compacte cardate și pieptănate, precum și a unor proprietăți ale tricotelurilor.

Cuvinte-cheie: fir compact, aparat de distanțare cu ace, rezistența la plesnire, permeabilitate la aer, măsurarea culorii

### Effect of pin spacer apparatus on the properties of knitted fabrics from cotton-tencel yarns

Yarn quality is an important factor as it directly plays an important role in fabric properties. Among many attempts for improving yarn properties in spinning technologies, pin spacer is one of the developed apparatus which can be mounted separately on the compact spinning unit used for improving the yarn properties especially in terms of yarn evenness and hairiness. Cotton-Tencel blended compact yarns are widely preferred among the textile consumers owing to high comfort feature of Tencel fibers combined with cotton fibers' unique properties. In this study, cotton (85%) – Tencel (15%) compact yarn samples were produced as yarn groups of combed yarn and carded yarn with utilizing and without utilizing pin-spacer apparatus at a linear density of Ne 40/1. In order to analyze the effect of pin-spacer apparatus on yarn properties, unevenness, imperfections, hairiness (H) and tensile measurements were evaluated. The greige and dyed single jersey plain knitted samples produced from those yarns were also compared in terms of dimensional changes in wale and course direction (%), pilling grades, bursting strength (kPa), air permeability values (mm/s) and the fabric surface color properties. According to test results, using pin-spacer apparatus generally improved carded and combed compact yarns' some properties as well as some knitted fabric properties made of those yarns.

Keywords: compact yarn, pin spacer, pilling, bursting strength, air permeability, color measurement

## INTRODUCTION

Textile industry is expected to meet the wide range of customer demands which result with the obligations requiring the yarn industry to be innovated as well. Although new spinning technologies have been continuing to be introduced to the yarn industry, usage of a modifying apparatus in the existing systems have also been carried out in order to improve yarn quality as well as the fabrics made of those yarns. Yarn imperfections and hairiness have been defined as the undesired yarn parameters leading to machine stops during weaving or the needle clogging in knitting. There is some early literature related to some experimental trials in order to reduce yarn imperfections and hairiness on the existing yarn spinning systems [1–5]. Mirzaei et al. proposed a new developed carding system where the short fibers could remove from the surface with perforated suction rollers and

the yarns produced from this system called as VCC (vacuum clean carded) which resulted with yarn improvements especially in terms of hairiness [6]. Wang et al. reported a hairiness reduction technique by introducing a diagonal yarn path arrangement on conventional ring spinning machine by simply diverting the front roller delivery to the adjacent diagonal spindle on the right side [7]. Khurshid et al. made a study for optimizing drafting parameters for ring spinning by using full factorial experimental design. The parameters were selected as break draft, pin spacer size and rubber cots' hardness. Statistical analyses indicated that pin spacer size has significant effect on yarn unevenness (U%), imperfection index (IPI), hairiness (H) and yarn strength compared to other two chosen factors [8]. Yılmaz and Uysal improved various nozzles having different injector angles, main hole diameters, injector diameters, number of injectors,

nozzle shapes and injector positions in order to reduce hairiness of siro-jet yarns [9]. Thilagavathi et al. studied different diagonal spinning positions and also tried different types of bottom rollers and spinning distances in order to reduce hairiness [10–11]. Apart from those efforts, Pin spacer apparatus which can be mounted on the drafting cylinders in compact spinning mills is made of two components. Basis is the “spacer” which is available in different sizes and the “pin” which is available in different heights (figure 1). When this pin is adjusted with spacer, it is called “pin spacer NT”. Due to using the pin, there is an additional deflection point in the yarn path through the drafting system; as a result, the drafting process tends to be hampered unlike using standard cradle spacer [12].

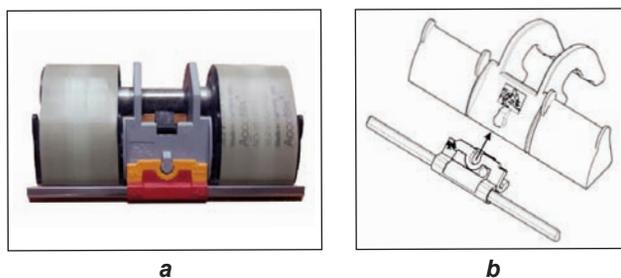


Fig. 1. Pin spacer [12]

As a result of growing demand for the cotton blends with the absorbent fibers which are comfortable and fashionable such as Tencel, modal and viscose, cotton-Tencel blends are generally used for the yarns of next to skin wears such as t-shirts and underwears [13]. In a study related to comparison of structural, physical and mechanical properties of cotton-Tencel and cotton-Promodal blended ring, compact and vortex spun yarns, it was concluded that an increasing ratio of regenerated cellulosic fiber content in the yarn blend resulted with decrement of unevenness, imperfections, diameter and roughness values [14]. As the literature has been investigated, there are not many studies focused on a comparative analyse between combed yarns, pin spacer combed yarns, conventional carded and pin spacer carded yarns made of cotton-Tencel blends by using compact spinning system. Since regenerated cellulosic fibres have a wide range of use from home textiles to apparel clothes, it was considered that it would be useful to investigate the knitted fabric properties made of those cotton-Tencel yarns. The expected target from

the study is to observe the influence of pin spacer utilisation on the cotton-Tencel blended yarn properties as well as on greige and dyed knitted fabrics made of those yarns.

## MATERIALS AND METHODS

Cotton-Tencel carded and combed yarn samples (85% cotton 15% Tencel) at yarn count of Ne 40/1 were produced from the same batch of American Upland type cotton fibres. Fibre properties were measured on High Volume Instrument (HVI) under standard atmospheric conditions of  $21\pm 1^\circ\text{C}$  and  $65\pm 2\%$  relative humidity. Four replications for micronaire value, four replications for colour measurement, and ten replications for length and strength measurements were conducted. Results of the measured fibre properties are given in (table 1). Cotton and Tencel slivers were fed together through the second drawing machine (Rieter RSB-D45) for the combed yarn groups (table 2) whereas cotton and Tencel carding slivers were combined through the first drawing passage for the carded yarn groups (table 3). The roving slivers of Ne 0.92 were spun into Ne 40/1 combed cotton yarns with a twist multiplier of 4.10 ( $\alpha_e$ ) and a twist level of 1020 (tpm) on Rieter K45 compact spinning machine and roving slivers of Ne 1.10 were spun into Ne 40/1 carded cotton yarns with a twist multiplier of 4.22 ( $\alpha_e$ ) and twist level of 1045 (tpm) on the same machine. Carded and combed compact yarn were both produced in conventional way also with the additional apparatus of pin spacer mounted on the drafted system. All yarn samples were produced in a yarn spinning company located in Malatya, Turkey. Ten cops of yarn were spun from each sample at the same identical conditions. Table 4 reveals the description of codes used for the yarn types in the study. The tensile properties of the yarns were evaluated on Uster Tensorapid 4 testing machine. Yarn unevenness and hairiness measurements were performed on Uster Tester 5. All the measurements were conducted under standard test conditions of  $65\pm 2\%$  relative humidity and  $21\pm 1^\circ\text{C}$  temperature according to ISO 139:2005 standard: Textiles – standard atmospheres for conditioning and testing. Single jersey plain knitted fabrics were produced from those four groups of compact yarns (P40, CO40, COP40, WP40) separately by using the TTM-4 model single plated circular knitting machine with a gauge of 28. The technical parameters of the circular knitting machine are revealed in table 5. Fabric codes were

Table 1

FIBER PARAMETERS									
SCI	Micronaire	UHML	SFI	Strength (g/tex)	Neps/gr	Rd	(+b)	%RH	Elongation (%)
133	4.07	29.20	8.57	30.24	311	72.82	8.41	2.79	6.91

The abbreviations revealed in table 1 can be described as follows: SCI – spinning consistency index, UHML – Upper half mean length in inches, SFI – Short fiber index, Rd: Reflectance degree, %RH – Relative humidity, (+b) – yellowness of cotton fiber.

Table 2

PRODUCTION LINE STARTING FROM THE BLOW ROOM UP TO SPINNING FOR COMBED YARNS		
1 <sup>st</sup> Draw Machine	Rieter SBD-45 1 <sup>st</sup> passage draw frame machine output (Ne)	0.12
	Doubling (D)	6
	Total Draft	6.94
	Pre-Draft	1.40
Omega Lab	Omegalab E35 Output (m/gr)	80
	Doubling	24
	Omegalab Drafting	1.492
Combing Machine	Rieter E76 Combing Machine Out (Ne )	0.10
	Doubling (D)	8
	Total Draft	15.2
	Pre-Draft	7.2
2 <sup>nd</sup> Draw Machine	Rieter SBD-45 2 <sup>nd</sup> passage draw frame machine output (Ne)	0.11
	Doubling (D)	8
	Total Draft	5.89
	Pre-Draft	1.15
Roving Machine	Rieter FT6-D Roving Machine Output (Ne)	0.92
	Total Draft in Roving Machine	8.25
	Roving twist coefficient ( $\alpha_e$ )	1.11
	Roving twist (rpm)	42
Spinning Machine	Yarn twist ( $\alpha_e$ )	4.10
	Yarn count (Ne)	40
	Ring Spinning Machine (TPM)	1020

Table 3

PRODUCTION LINE STARTING FROM THE BLOW ROOM UP TO SPINNING FOR CARDED YARNS		
1 <sup>st</sup> Draw Machine	Rieter SBD-45 1 <sup>st</sup> passage draw frame machine output (Ne)	0.123
	Doubling (D)	6
	Total Draft	6.94
	Pre-Draft	1.40
2 <sup>nd</sup> Draw Machine	Rieter SBD-45 2 <sup>nd</sup> passage draw frame machine output (Ne)	0.13
	Doubling (D)	6
	Total Draft	5.89
	Pre-Draft	1.15
Roving Machine	Rieter FT6-D Roving Machine Output (Ne)	1.10
	Total Draft in Roving Machine	8.25
	Roving twist coefficient ( $\alpha_e$ )	1.24
	Roving twist (rpm)	51
Spinning Machine	Yarn twist ( $\alpha_e$ )	4.22
	Yarn count (Ne)	40/1
	Ring Spinning Machine (TPM)	1050

Table 4

Yarn Code	Yarn Type
CO40	Ne 40/1 combed yarn without Pin Spacer utilizing
COP40	Ne 40/1 combed yarn with Pin Spacer utilizing
WP40	Ne 40/1 carded yarn without Pin Spacer utilizing
P40	Ne 40/1 carded yarn with Pin Spacer utilizing

Table 5

TECHNICAL DATA OF CIRCULAR KNITTING MACHINE	
Machine Diameter (inch)	32"
Gauge (number of needle/inch)	28 Gauge
Number of needles	2760
Number of feeders	96
Needle type	Groz-Beckert
Sinker type	Kern Liebers

named as the same with the yarns made of them, for example knitted fabric of COP40 is produced from the COP40 coded yarns. Knitted fabric samples were divided into two groups, one group was kept in greige form and second group was send to the wet processing stages. In the wet processing stages, fabrics were pre-treated with H<sub>2</sub>O<sub>2</sub> bleaching at 95°C for 45 minutes by using non-ionic wetting agent, oil remover and sequestering agent. The fabrics were dyed by using reactive dye in a jet dyeing machine at 30°C containing 50 g/l salt and 15 g/l chelating agents. The fabric weights were measured according to the standard test methods for mass per unit area (gr/m<sup>2</sup>) of fabric [15]. The course and wale density of fabric samples were measured by using Leica EZ4 HD stereo microscope with ten measurements for each direction in different places on fabric samples. Fabric thickness was measured with Wira instrument thickness tester according to the standard EN ISO 5084 [16]. Fabric spirality measurement was conducted with the help of Leica EZ4 HD stereo microscope and Autocad Mechanical 2017 programmer. Measured dimensional properties of the fabric samples were revealed in table 6.

In order to determine the dimensional stability of plain knitted fabrics, greige and dyed fabric groups were exposed to five washing cycles in Electrolux Wascator FOM 71 at wash program 5 A at 40 °C and dried flat after each washing cycle. Fabric samples were conditioned for 24 hours and then tested under standard atmospheric conditions. Dimensional changes of knitted fabrics were calculated using pair of bench marks applied to the fabric before washing process [17–18]. Pilling behavior of all fabrics was tested on the ICI Pilling-Box according to EN ISO 12945-1 test method. The pilling results after 7000

Table 6

Fabric codes	Weight (g/m <sup>2</sup> )		Thickness (mm)		Wale per cm		Course per cm		Loop length (mm)	Spirality degree	
	greige	dyed	greige	dyed	greige	dyed	greige	dyed		greige	dyed
COP40	98.6	115.0	0.49	0.48	13	14	21	20	2.58	20°	20°
CO40	104	118	0.50	0.50	13	14	21	20	2.58	17°	25°
WP40	102	114	0.50	0.49	13	14	21	20	2.53	11°	11°
P40	102	113	0.51	0.46	13	14	21	20	2.53	6°	10°

cycles were evaluated among three different greige and dyed knitted fabrics [19]. The bursting strength of the fabrics was conducted on the SDL ATLAS M229P Pnuburst test device according to test standard of EN ISO 13938-1 [20]. The air permeability values of greige and dyed fabrics were measured in a 20 cm<sup>2</sup> test area at 200 Pa air pressure according to EN ISO 9237 standard with SDL ATLAS MO21A [21]. Whiteness degree was determined using a Data Color 600 spectrophotometer (Data Color International, Lawrenceville, NJ, USA). Color differences and percent reflectance changes (%R) were also analyzed among all fabric samples by using Data Color 600 spectrophotometer under D65/10° illuminant (Data Color International, Lawrenceville, NJ, USA). For the statistical evaluation; randomized one-factor analysis of variance (one direction-ANOVA) was used for the determination of the statistical significance of yarn type on yarn properties in order to make a comparison between the cotton-Tencel yarns of P40, CO40, COP40 and WP40. The means were compared by TUKEY (SNK) tests. The value of significance level ( $\alpha$ ) selected for all statistical tests in the study is 0.05. The treatment levels were marked in accordance with the mean values and levels marked by different number (a, b, c) indicating the significant differences. All statistical procedures were conducted using the SPSS 23.0 statistical software package.

## RESULTS AND DISCUSSION

### Measurements of yarn properties

According to the randomized one-factor analysis of variance (ANOVA) tests conducted for the yarn unevenness, hairiness and tenacity values of four different cotton-Tencel yarns (CO40, COP40, P40, and WP40), there was a significant difference between the mass variation (CV<sub>m</sub>), number of thin places

Table 7

UNIVARIATE ONE DIRECTION ANOVA RESULTS	
Yarn parameter	Sig (p)
CV <sub>m</sub>	0.00*
Thin places (-50%)	0.00*
Thick places (+50%)	0.00*
neps (+200%)	0.00*
elongation (%)	0.02*
Tenacity (cN/tex)	0.00*

\* Statistically significant (5% significance level)

(-50%), thick places (+50%), neps (+200%), hairiness (H), elongation (%) and tenacity values of four different yarn types at the significant difference of 0.05 (table 7).

According to Tukey test (table 8), the highest CV<sub>m</sub> result was found in WP40 coded compact yarns whereas the minimum CV<sub>m</sub> results was obtained from COP40 coded compact yarns. Considering thin places (-50%), the maximum value was obtained from WP40 coded yarns whereas the P40, COP40 and CO40 coded yarns were lower and estimated in the same subset with at significance level of 0.05. The highest number of thick places (+50%) was obtained from the WP40 coded yarn groups whereas the lowest values were obtained from yarn groups of COP40. The same trends were encountered with the neps values of (+200%) where the highest neps value was obtained from WP40 coded yarn groups as 80.51 while the lowest values was found among the yarn groups of COP40 coded as the 14.50. Another prominent result was the lower hairiness of pin-spacer mounted carded and combed yarn groups when compared to their counterparts produced without pin

Table 8

SNK TEST RESULTS FOR USTER EVENNESS, IMPERFECTION AND TENSILE RESULTS							
Yarn type	CV <sub>m</sub>	Thin places (-50%)	Thick places (+50%)	Neps (+200%)	H	Tenacity (cN/tex)	Elongation (%)
WP40	16.65c	25.18	427.08c	80.51c	4.19c	16.91a	4.31a
P40	13.94b	3.65a	98.350b	40.80b	4.01b	16.91a	4.23a
COP40	11.36a	3.15a	61.00a	14.50a	3.00a	18.35b	5.20b
CO40	11.38a	3.38b	61.75a	15.09a	3.51a	18.27b	4.49b

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5%.

spacer utilization. As it is observed, hairiness of P40 was lower than WP40 and hairiness of COP40 was lower than CO40 yarn groups' hairiness. Considering the yarn tensile results; Tenacity (cN/tex) of P40 and WP40 yarn groups were in the same subset at significance level of 0.05 and lower than CO40 and COP40 coded yarn groups' tenacity values. Elongation (%) of P40 and WP40 yarn groups were in the same subset and lower than CO40 and COP40 yarn groups' elongation which were statistically under the same subset at significance level of 0.05.

### Measurement of fabric properties

On an ideal knitted fabric, it is necessary that the wales on knitted fabric should be perpendicular to the course. However, the wales are not always perpendicular to the course and skew to the right or left forming a spirality angle ( $^{\circ}$ ) as seen in our knitted fabrics (figure 2). The unbalanced structure of plain knitted fabrics resulted in high percentages of loop distortion in all samples. According to figure 2, the highest spirality degree ( $^{\circ}$ ) was obtained from COP40 coded among the greige samples whereas the lowest value was found in P40 coded greige fabrics. CO40 coded fabrics revealed the highest spirality degree whereas P40 coded indicated the lowest spirality degree among the dyed samples. It should be also emphasized that spirality degree ( $^{\circ}$ ) of P40 and CO40 coded fabrics increased with dyeing process whereas spirality

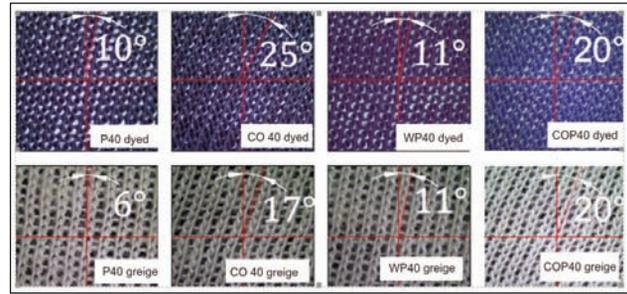


Fig. 2. Measurement of fabric spirality for greige and dyed fabric groups (All drawings were made by using Autocad Mechanical 2017)

groups revealed a dimensional change (%) in positive direction which means there was a growth. It was very interesting that dyed fabric groups of P40 and WP40 revealed lower positive dimensional change (%) compared to fabric groups of CO40 and COP40. When it is considered in course direction; greige and the dyed knitted fabric groups both revealed the dimensional change (%) in negative direction, however the greige knitted fabrics revealed by far higher dimensional change results (%) in negative direction comparing to dyed fabric groups. This can be attributed to the inherited dimensional change that already occurred during the series of pre-treatments in dyeing process. Greige fabric groups of WP40 had higher dimensional changes (%) than the P40 and CO40 in negative direction.

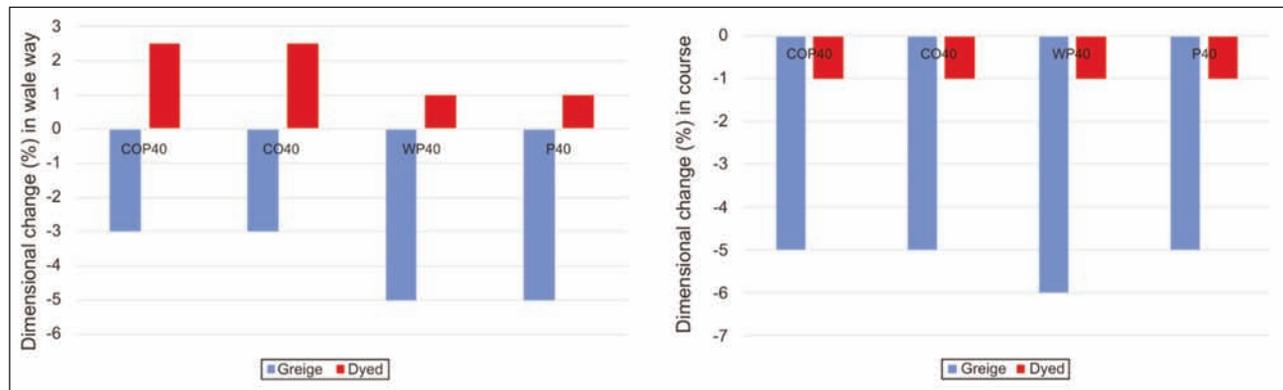


Fig. 3. Dimensional change (%) in wale and in course direction

degree of WP40 and COP40 coded fabrics remained the same before and after dyeing process. Our results were consistent with the early findings of Yener and Korkmaz's study where spirality degree of knitted supreme fabrics of combed yarns were slightly higher than the spirality degree ( $^{\circ}$ ) of knitted single jersey plain knitted fabrics made of carded yarns after dry, wet and washing relaxations [22].

The dimensional changes of knitted fabrics (%) after washing process were determined in wale and course direction according to dimensional test standard of ISO 5077 (figure 3). Considering the wale direction; all greige knitted fabrics revealed a dimensional change (%) in negative direction which means there was a shrinkage, whereas the dyed knitted fabric

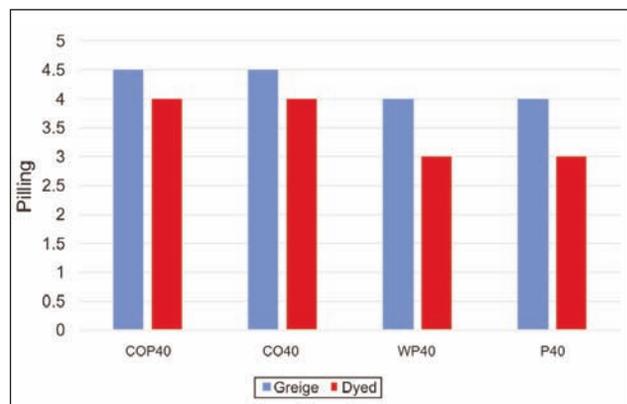


Fig. 4. Pilling values of knitted fabrics

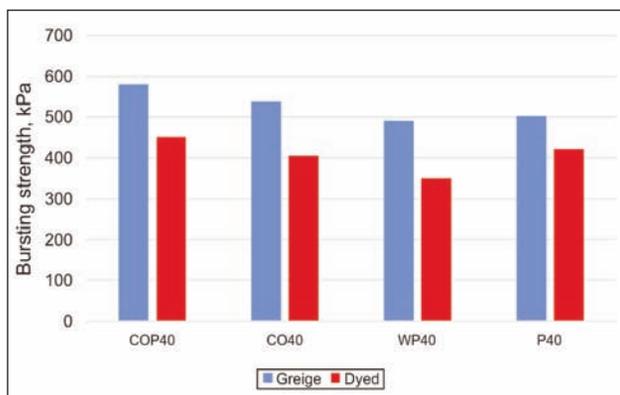


Fig. 5. Bursting strength values of the knitted fabrics

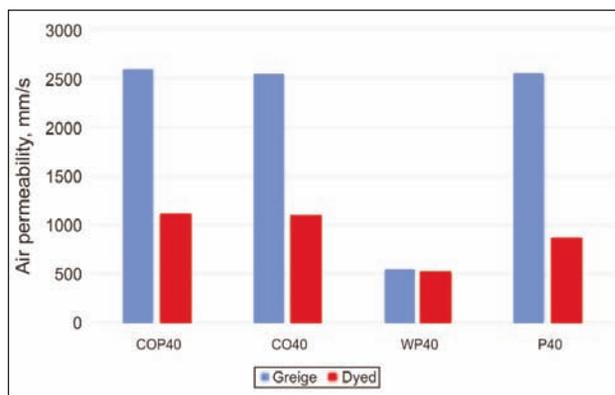


Fig. 6. Air permeability values of the knitted fabrics

Pilling is caused by protruding fibres which entangle when a fabric is rubbed. The magnitude of the pilling depends upon the number and lengths of protruding fibres and the ease with which they can bend round one another [23]. The well-aligned and compact structure of compact yarns generally do not allow easy fibre pull-out, which led to higher pilling resistances. According to figure 4, all knitted fabrics made of compact yarns have well pilling resistance of over “3”. The greige and dyed knitted fabrics which are made of CO40 and COP40 yarns have lower pilling tendency comparing with the other fabric groups whereas the fabric groups made of WP40 and P40 yarns have the same pilling tendency level. The results may be associated with the yarn evenness and yarn hairiness results revealed in table 8. When it comes to bursting strength values (kPa), all bursting strengths of the knitted fabrics revealed the minimum performance requirement of 275 kPa among the greige & dyed fabrics [20]. There was not a clear trend for the greige knitted fabrics’ bursting strength according to their yarn type (figure 5). The highest bursting strength was obtained in greige knitted fabrics made of COP 40 yarns whereas the the lowest bursting strength (kPa) was found among greige knitted fabrics made of WP40 coded yarns. It can be clearly observed that the bursting strength of dyed fabrics decreased when compared with the greige knitted groups. The highest bursting strength (kPa) was obtained in fabric groups of COP40 whereas the lowest bursting strength (kPa) was obtained in fabric groups of P40 among the dyed fabric groups. Figure 6 reveals the air permeability of knitted fabrics before and after dying process. The highest air permeability was found in fabric groups made of COP40 yarns whereas lowest air permeability values were obtained from WP40 coded knitted fabrics among greige samples. The same trend was observed among the dyed fabrics as well. It is useful to emphasize that dying process led the decrement of air permeability for all knitted fabric groups. It is also understood that air permeability results have the same trend with the hairiness results of the yarn groups revealed before in table 8 which indicates that more hairy surface results with lower air permeability on the knitted fabrics.

Whiteness results also should be considered when the end product color is different from white color. The higher value of  $W_{CIE}$  reveals the higher whiteness of samples. Whiteness index of 100 displays the perfect reflecting diffuser [24]. CIE WI values (yellowness, stensby) of the undyed knitted fabric samples are revealed in figure 7 and figure 8 respectively.

Considering the stensby results; the highest stensby values were obtained from knitted fabrics of COP40 whereas the lowest stensby values were obtained from the fabrics of WP40. The highest yellowness index was found WP40 coded knitted fabrics whereas the lowest yellowness index of the knitted fabrics was obtained from COP40 coded fabrics.

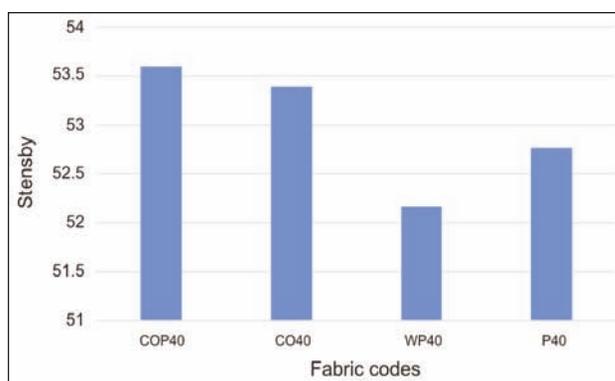


Fig. 7.  $W_{CIE}$  values of greige fabric samples (Stensby)

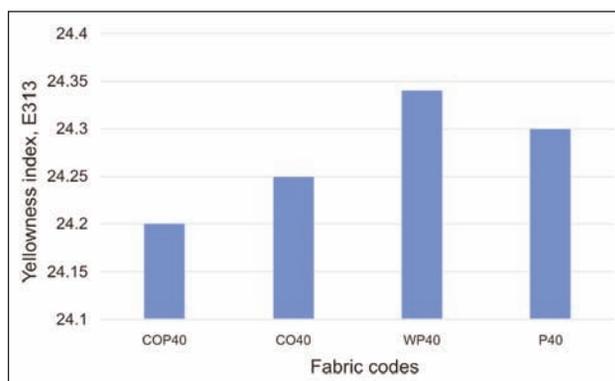


Fig. 8.  $W_{CIE}$  values of greige fabric samples (Yellowness index)

Table 9

	K/S	L*	a*	b*	h	C*
WP40	13.85	28.21	-5.98	-11.96	243.42	13.37
P40	13.65	28.13	-6.10	-12.01	243.07	13.48
CO40	12.60	29.66	-6.52	-12.56	242.55	14.15
COP40	12.61	30.12	-6.20	-12.32	241.56	14.02

air permeability results of the knitted fabrics which were thought to be improved with the usage of pin spacer utilized yarns.

As it is observed that the fabric groups made of pin spacer combed yarns and the fabric groups made of pin spacer carded yarns had more satisfying test results when compared with their counterparts made of those yarns without pin spacer utilizing.

Table 10

Fabric property	COP40		CO40		P40		WP40	
	greige	dyed	greige	dyed	greige	dyed	greige	dyed
Bursting strength (kPa)	580	452	537.4	404.2	501.2	420.9	490.8	350.8
Air permeability (mm/s)	2594.2	1106	2530.4	1083	2524.2	862	526.2	499

Color measurements among dyed knitted samples by using DataColor 600 spectrophotometer were displayed in table 9. The highest L\* value was obtained from dyed fabrics of COP40 which may be attributed to the low hairiness of combed yarn (table 8). The result was consistent with study of Örtlek which emphasized that there is a strong relation with the knitted fabrics' L\* values and their yarn hairiness [25]. The researchers declared that lower hairiness values result with the smoother surface of yarns and smooth surfaces reflect light more than the rough surfaces. The color strength (K/S value) (color efficiency) of dyed fabrics was calculated by measuring the K/S values of the dyed fabrics with a spectrophotometer under a reflectance model. In the study, K/S values were recorded at wavelength of maximum absorption (for blue: 620 nm). According to table 9; knitted fabrics of WP40 had the highest color strength whereas the knitted fabrics of CO40 had lowest color strength values. Figure 9 indicates a\*, b\* values where a\* (red/green) component values of P40, COP40 and CO40 fabrics shifted towards green when compared with WP40 fabrics. A same trend was witnessed for b\* values meaning P40, CO40 and COP40 were found as more blue compared with WP40 (figure 9). For a general evaluation which gives an idea for the effect of pin spacer utilizing on fabric properties, table 10 indicates the test results of bursting strength and

## CONCLUSION

Yarn is a main parameter that influences the fabric properties. The efforts for reducing yarn hairiness and yarn imperfections generally result with the improved fabric properties. The aim of the study is to compare some performance properties of cotton-Tencel knitted fabrics made from conventional combed, conventional carded and pin spacer combed and pin spacer carded yarns.

- According to results of tests conducted for the yarns, it was observed that mounting of pin spacer apparatus improved combed and carded yarn characteristics especially in the manner of yarn evenness and imperfection values. This result may be attributed to decrement of cohesive forces among the fibres during drafting. The pin positioned between the cradle and the top front roller oriented the individual fibres from the drafted fibre assembly to the spinning triangle without any stretch or accumulation.
- As a general result, pin spacer compact yarns indicated better hairiness and imperfection results at yarn count of Ne 40/1. But it may be also suggested to investigate the compact yarn production with pin spacer utilizing in a wide yarn count.
- The improvement of yarn hairiness resulted with better air permeability properties of knitted fabrics. Further studies related to investigation of thermal comfort properties of fabrics made of pin spacer yarns may be suggested.
- Bursting strength and air permeability values of the fabrics made of yarns with pin spacer were slightly improved when compared with their counterparts made of yarns without pin spacer utilizing. This result may support the idea of convenient usage of pin spacer apparatus for the improved yarn characteristics along with some effects to final product.
- Colour measurements obtained from the knitted samples indicated that there is no clear difference between the whiteness and colorimetric values of knitted fabrics made of both conventional compact yarn and pin spacer compact yarns.

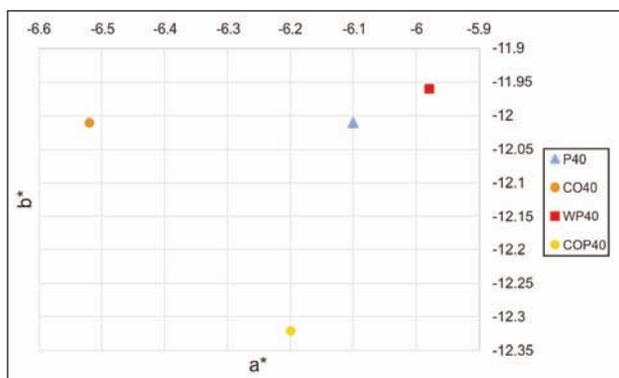


Fig. 9. a\*-b\* plot

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