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Comparison of Woven Fabrics' Properties from Traditional and Compact Ring-Spun Yarns after Dyeing Processes

Abstract
In this study, plain fabrics were produced via using both 100 % cotton, compact and conventional ring spun yarns in two different yarn counts and two different yarn twists. The purpose of the study was to examine the effect of different pre-treatment processes such as singeing, mercerisation and reactive dyeing on tensile strength, pilling tendency, air permeability, colour efficiency and rubbing fastness properties of plain fabrics, produced with compact and conventional ring spun yarns. In order to determine the effect of singeing process on the properties of the fabrics produced with compact and conventional ring spun yarns, fabrics were divided into two groups and then the properties of the fabrics were measured after bleaching, reactive dyeing and mercerisation + reactive dyeing processes.

Key words: *ring-spun yarn, compact yarn, dyeing process, woven fabrics.*

Introduction

In spite of modernisation and rapid technological development in the field of conventional ring spinning, the mechanism of the ring-traveller spindle has remained almost the same until now. Furthermore, conventional ring spinning remains the dominant spinning technology even today due to yarn structure. In conventional ring spinning, the working principle of the machine is based on the traveller, ring and spindle. Depending on these three elements, spinning on this machine shows some restrictions in efficiency. If the revolution of spindles exceeds 18,000-20,000 rpm, some vibrations in the spindles are caused,, which leads to restrictions in spinning. In order to increase the spinning velocity, the diameter of the ring has to be reduced, which in turn means increasing the time of the doffing period. Besides this, the velocity of the traveller on the ring must be 40 m/sec. Exceeding this velocity causes warming of the traveller; in other words, the velocity of the spindle depends on the traveller speed. Due to these restrictions, the most important drawback of these machines is limited production.

In other ways, though, conventional ring spinning has some important advantages, which are , improved quality parameters due to the yarn structure, the possibility of using various materials, and the yarn counts. In the past few decades, all new spinning processes have been developed to achieve higher production per spinning unit. This is especially true of rotor and air-jet spinning. However, conventional ring-spun yarn still is, and has always been, the undisputed quality benchmark within the spun yarn sector. On the other hand, if conventional ring-spun yarns are examined under the microscope, it will be easy to see protruding fibres, which make no contribution to the yarn strength.

In previous research works, it has been demonstrated that the spinning triangle in the conventional ring spinning system has an enormous effect on yarn hairiness and yarn breakage in the yarn production stage [4]. After this definition, other studies were focused on minimising the spinning triangle. As a result of these studies, a new spinning system called compact spinning minimises the yarn hairiness until an appropriate level has been reached [6, 10].

The compact spinning method forms a different yarn structure. The most evident properties of these yarns are their high breaking strength, high elongation and low hairiness [2, 7, 8, 11]. Other yarn properties such as yarn unevenness, thin/thick places etc. are comparable to the conventional ring-spun yarn. The structure of the yarn offers many advantages in the further yarn processing. It is thought that by using these yarns, the degree of sizing could be minimised and the weaving efficiency could be increased by decreasing the pollution caused by the fibre fly [5]. The present work is focused on the effects of the finishing processes on the properties of plain fabrics produced with compact and conventional ring-spun yarns. The two spinning methods mentioned produce yarns with different structural characteristics and elastic properties. It is therefore expected that the use of different yarn types will introduce divergence in the physical properties of the fabrics produced after several finishing and dyeing processes.

Experimental

In the scope of this study, for the production of plain fabrics, 100% cotton yarns were produced from the roving; they were obtained using the same cotton blend, by using compact and conventional ring spinning principles, in yarn counts of 20 tex and 12 tex with different twists. As stated in the literature, even if the difference of twist between compact and conventional ring-spun yarns is α_{tex} = 6.5 - 8, there will be no difference in the physical properties of the yarns [1]. Low-twisted compact-spun yarns were produced in order to compare the higher-twisted conventional ring- and compact-spun yarns, in order to show the performance of low-twisted compact-spun yarns. The specifications of the yarns are given in the details in Table 1.

Table 1. *Yarn specifications.*

Specification		Compact Spun Yarn	Conventional Ring Yarn
Raw Material	Fibre Length	31 mm	31 mm
	Fibre Fineness	4.5 Micronaire	4.5 Micronaire
	Fibre Strength	32 cN/tex	32 cN/tex
Yarn Counts (linear density)		20 tex, 12 tex	20 tex, 12 tex
Twist Factor α_{tex} for (linear density)		38.6 (20 tex) 37.7 (12 tex) 43.4 (20 tex) 42.5 (12 tex)	43.4 (20 tex) 42.5 (12 tex)
Spinning System		ComforSpin K44, Rieter	Conventional ring spinning system Rieter G33
Winding System		Murata C21	Murata C21

The yarn measurements were carried out with an Uster Tester 3, and for the yarn strength measurement an Uster Tensorapid 4 was used.

After yarn production, sectional warping was carried out in two stages according to the yarn count. As a result, two units of warp beams were prepared, one of which was composed of 20 tex, α_{tex} = 38.6 compact; 20 tex, α_{tex} 43.4 compact; and 20 tex, α_{tex} = 43.4 conventional ring-spun yarns; the other consisted of 12 tex, α_{tex} = 34.7 compact; 12 tex, α_{tex} = 42.5 compact; and 12 tex, α_{tex} = 42.5 conventional ring-spun yarns in order to eliminate the variations in the weaving process. The fabric samples for testing were not taken from the edges of the fabrics, since differences in the warp tension could arise. In the sizing process, these two warp beams were processed subsequently under the same conditions. In the weaving stage, plain weave fabrics were produced under the same conditions using three kinds of yarns at the same time. Using the same yarn count in both the warp and weft yarns, the fabrics were produced. The specifications of each machine in the weaving preparation and weaving departments are given in Table 2.

All the plain fabrics had the same finishing processes applied to them, in order to eliminate any variations during these processes. In order to see the singeing effects on the compact- and conventionally ring-spun yarns, the fabrics were classified into two groups; the first had the singeing + desizing + bleaching processes applied, the second only the desizing + bleaching processes. After bleaching, the two fabric groups were again divided into two groups in order to see the effect of the mercerisation process on the fabrics at issue; one of the fabric groups was mercerised and the other was not. As a result, four groups of plain fabrics were obtained. In Table 3, the specifications and the downstream processes of plain fabrics are given in details.

All the physical and chemical tests after bleaching, reactive dyeing and the mercerisation + reactive dyeing processes were carried out after conditioning of the fabrics for 24 hours under the standard atmospheric conditions (20 ± 2 °C temperature, 65 ± 2% relative humidity). The tensile strength measurements of the plain fabrics in warp direction were carried out on a James Heal marked instrument in accordance with standard TS EN ISO 13934/1; the pilling tests were done on an SDL marked Martindale instrument in accordance with standard ISO 12945/2, and the air permeability tests were performed on a Wira marked instrument in accordance with standard TS 391. For the colour tests of the fabrics, an X-Rite SP 78 model spectrophotometer was used. The rubbing fastnesses of the fabrics were carried out with a crockmeter instrument following standard AATCC 8.

A paired t-test statistical analysis was done in order to see whether there was any significant difference between the dyed fabrics produced with compact and conventional ring-spun yarns. The statistical analysis of the pilling and rubbing fastness properties of the fabrics was not evaluated due to the subjective evaluation of these properties. In the statistical tables, five abbreviations given in Table 4 were used.

***Table 2.** Machine specifications in weaving preparation and weaving departments; weaving mill condition: temperature 27.4 °C, humidity 80.6 %.*

Machine type	Technical data of machines		
Sectional warping machine	Machine mark	Benninger Ben-Supertonic	
	Machine model	1997	
	Creel capacity	640 packages	
Sizing machine	Machine mark	Benninger Zell	
	Machine model	1997	
	Maximum beam width	220 cm	
	Creel capacity	16 beams	
	Number of drying cylinders	10	
Weaving machine	Machine mark/model	Toyota/1996	
	Weft insertion/number of weft colours	Air Jet/6	
	Shedding mechanism	Electronic Dobby	
	Machine data while processing	**20 tex**	**12 tex**
	Warp tension, kN	4.0	3.6
	Main nozzle pressure, kPa	584	420
	Pick density, picks/cm	30	34
	Warp density, ends/cm	45	51
	Machine speed, rpm	670	570
	Reed number	150/3	170/3

***Table 3.** Finishing processes and recipes; process applied - √, not applied - –.*

Finishing processes	Recipes of each process		Group			
			1	2	3	4
Singeing process	–		√	√	–	–
Desizing process	0.5 g/l enzyme, 2.5 g/l wetting agent,	padding at 60 °C Waiting period: 6 hours	√	√	√	√
Bleaching process	35 g/l H_2O_2 (%50), 35 g/l NaOH (48 °Be), 6.5 g/l stabiliser,	3 g/l wetting agent, 2 g/l sequestering agent	√	√	√	√
Mercerisation process	30 °Be NaOH		√	–	√	–
Reactive dyeing	Remazol Violet 5R 0.57 g/l Remazol Blau R spz 0.675 g/l Remazol Schwarz RL 1.375 g/l	Wetting agent 3 g/l Sodium Silicate 67.5 g/l NaOH 23 g/l	√	√	√	√

***Table 4.** The abbreviations of the fabrics used in the statistical tables.*

a	**Singed plain fabric** produced with **low twisted compact** spun yarn
b	**Singed plain fabric** produced with **high twisted compact** spun yarn
c	**Singed plain fabric** produced with **high twisted conventional ring** spun yarn
d	**Non-singed plain fabric** produced with **low twisted compact** yarn
e	**Non-singed plain fabric** produced with **high twisted compact** spun yarn.

Results and discussion

Yarn properties

Table 5 represents the yarn properties and Table 6 shows the statistical results of the compared pairs. Apart from yarn strength, breaking elongation and hairiness, there is no obvious difference between compact and conventional ring-spun yarns. However, examining these three yarn properties, compact-spun yarns have better results compared to conventional ring-spun yarns. The break-

Table 5. Yarn properties.

Yarn Parameters	20 tex			12 tex		
	Compact		Ring	Compact		Ring
	α_{tex}=38.6	α_{tex}=43.4	α_{tex}=43.4	α_{tex}=34.7	α_{tex}=42.5	α_{tex}=42.5
Um, %	9.21	9.25	9.45	9.28	9.29	9.78
CVm, %	11.59	11.65	11.90	11.71	11.74	12.33
Thin places -50%/1000m	0.00	0.00	0.00	0.00	0.20	1.20
Thick places +50%/1000m	4.80	6.80	11.40	8.80	11.00	12.80
Neps +200%/1000m	11.40	10.40	28.40	44.80	43.40	67.60
Hairiness (H)	4.50	4.21	4.83	3.85	3.42	3.97
Breaking force, cN	365.0	372.0	356.0	303.0	313.6	287.6
Elongation at break, %	5.80	5.51	4.52	4.90	5.34	4.48
Breaking strength, Rkm	18.94	19.26	18.44	26.17	27.07	24.82

Table 6. Statistical results of yarn properties; p - significance value (α = 0.05).*

Compared pairs	Yarn property	20 tex	12 tex
		p*	p*
Low twisted compact yarn- High twisted ring spun yarn	Um, %	0.031	0.000
	CVm, %	0.022	0.000
	Thin Place	1.000	0.033
	Thick Place	0.004	0.095
	Neps	0.000	0.000
	Hairiness (H)	0.014	0.129
High twisted compact yarn- High twisted ring spun yarn	Um, %	0.178	0.001
	CVm, %	0.161	0.002
	Thin Place	1.000	0.046
	Thick Place	0.062	0.466
	Neps	0.001	0.000
	Hairiness (H)	0.000	0.000
Low twisted compact yarn- High twisted compact spun yarn	Um, %	0.707	0.889
	CVm, %	0.643	0.806
	Thin Place	1.000	0.374
	Thick Place	0.405	0.300
	Neps	0.554	0.710
	Hairiness (H)	0.032	0.000

ing force of the compact spun yarn in yarn counts of 20 tex and 12 tex is higher than the conventional ring-spun yarn due to the minimisation of the spinning triangle. The elongation at break of compact-spun yarns is higher compared to that of conventional yarns. The Uster hairiness (H) of compact-spun yarns is significantly lower when compared to the hairiness of conventional yarns. No significant changes regarding the Uster properties (Uster CV%, number of thick/thin places and neps) in the conventional and compact-spun yarns were determined. The statistical results of yarn properties are shown in Table 6, where the significant values highlighted (marked gray) demonstrate that compact-spun yarns are better than conventional ring-spun yarns with regard to that specific yarn property. (The same is valid for Tables 7, 8, and 9)

Tensile strength after finishing processes

The tensile test results are shown in Figure 1, and the statistical results of the tensile strength property is given in Table 7. The results indicate that the tensile strength behaviour of all the fabrics is similar, and the results are very close to each other. However, finishing processes are affected in different ways according to the yarn production method and yarn count. In the yarn count of 20 tex, there is no statistically significant difference between the fabric groups produced with low- or high-twisted compact and conventional ring-spun yarns, irrespective of whether singeing or mercerisation process is applied. However, in the yarn count of 12 tex, the finishing processes of singeing and mercerisation react in a different way. Although singeing has no statistical importance on the tensile strength of the fabrics, mercerisation has an obvious and statistically important effect. The non-singed fabrics produced with compact-spun yarns have better tensile strength results compared to the singed fabrics produced with conventional ring-spun yarns. Furthermore, singed, mercerised reactive-dyed fabrics produced with conventional ring-spun yarns have almost the same results compared to the non-singed and non-mercerised reactive-dyed fabrics produced with compact-spun yarns. Thus, if finer yarns must be used, compact-spun yarns have advantages over conventional ring-spun yarns, such as eliminating the need for the mercerisation or the singeing processes. Furthermore, the results of non-singed and non-mercerised fabrics produced with low-twisted compact spun yarns are very similar, with the results of singed and mercerised fabrics produced with high-twisted conventional ring-spun yarns which results in increasing the yarn productivity. However in coarser yarns, compact-spun yarns show a slight increase in tensile results compared to conventional ring-spun yarns, although this difference is statistically insignificant. Thus, by using finer compact-spun yarns, the singeing and mercerisation processes can be eliminated according to the end use of fabric. More recently, Cheng & Yu have reported that Rieter's compact spinning system is only suitable for producing finer yarns, due to the limitation of the condensing system in controlling individual fibres when their number increases in coarser yarns. This causes the quality of coarser compact spun yarns to be similar to that of the conventional ring-spun yarns [2, 3]. Our results support this finding (Table 7).

Air permeability after the finishing processes

Air permeability is mainly affected by two parameters, porosity and fabric thickness. The fabric thickness and density of warp and weft yarns are the same for all the compared samples. The only parameter which could affect the air permeability is yarn production type, and twist factor could affect the porosity. In recent studies, it has been proved that the twist factor has an obvious effect on air permeability when the other parameters such as density and fabric thickness are constant [9]. As shown in Figure 2, the twist factor of the yarns affects the air permeability

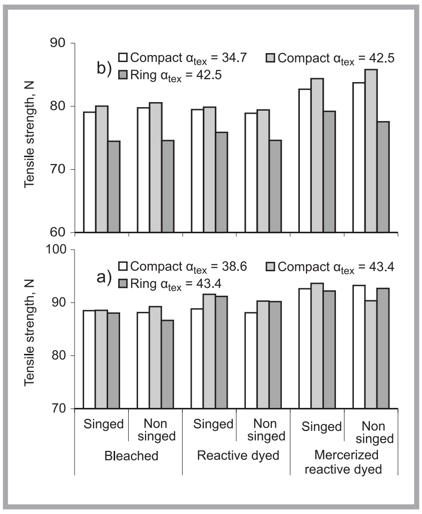

Figure 1. Tensile strength of the fabrics consisting of a) 20 tex and b) 12 tex yarns.

Table 7. *Statistical results of fabric tensile strength properties manufactured of 20 tex and 12 tex yarns.*

Processes	20 tex					12 tex				
	a-b	a-c	b-c	d-c	e-c	a-b	a-c	b-c	d-c	e-c
Bleaching	0.918	0.665	0.557	0.926	0.100	0.774	0.012	0.014	0.013	0.011
Reactive Dyeing	0.223	0.177	0.827	0.308	0.611	0.154	0.043	0.031	0.002	0.044
Mercerised Reactive Dyeing	0.697	0.850	0.448	0.479	0.122	0.292	0.046	0.037	0.027	0.025

Table 8. *Statistical results of fabric air permeability properties manufactured of 20 tex and 12 tex yarns; * means there is a significant difference in terms of fabrics produced with conventional ring spun yarns.*

Processes	20 tex					12 tex				
	a-b	a-c	b-c	d-c	e-c	a-b	a-c	b-c	d-c	e-c
Bleaching	0.002	0.000	0.000	0.000	0.000	0.000	0.090	0.000*	0.041*	0.000*
Reactive dyeing	0.004	0.000	0.001	0.000	0.000	0.002	0.142	0.013*	0.229	0.004*
Mercerised reactive dyeing	0.178	0.005	0.000	0.001	0.001	0.048	0.047	0.006*	0.048*	0.045*

results as the twist factor increases the air permeability of the fabrics. In the yarn count of 12 tex, the twist factor difference is greater than that of 20 tex; thus, in the results of 12 tex the effect of twist factor is more evident. In the yarn count of 20 tex, conventional ring-spun yarns with high hairiness, which can block the air flow, showed lower air permeability (Figure 2a). In the yarn count of 12 tex, the hairs of conventional ring-spun yarns in the examined fabric construction cannot block the pores, which are bigger than in 20 tex. So, the difference between compact and ring-spun yarns is not too great (Figure 2.b).

The singeing process has no statistically significant effect on the air permeability Table 8. However, the mercerisation process is statistically significant for the air permeability ($p = 0.000$). Mercerisation increases the results of all groups of fabrics where the most changes occur in conventional ring-spun yarns. This is thought to be due to the fibre arrangement in the cross-section of the yarn. Before mercerisation, the fibres in compact-spun yarns are better arranged than the fibres in conventional ring-spun yarns, but after the mercerisation, which is done by stretching, the fibres are better arranged in the cross-section than before mercerisation. Thus, this process affects the fibre arrangement in conventional ring-spun yarns more than in compact-spun yarns, since the fibre arrangement of compact yarns are well-arranged before mercerisation.

Pilling behaviour after finishing processes

The pilling test results are shown in Figures 3.a and 3.b. The results indicate that the pilling behaviour of the fabrics produced with compact spun yarns shows better results than those produced with conventional ring-spun yarns, independent of yarn count. The results also show that all the fabrics show better pilling degrees as the fabrics are mercerised as expected. Also, the singeing process affects the pilling behaviour of all the fabrics in a positive way. In general, according to the pilling results, the singed and reactive-dyed fabrics produced with high-twisted compact-spun yarns have the best results among the group of singed & mercerised reactive-dyed fabrics. Thus, by using high-twisted compact-spun yarns, the mercerisation process can be eliminated. Also, low-twisted compact-spun yarn shows similar behaviour to the high-twisted compact-spun yarn, compared to the conventional ring-spun yarn. According to the end use of the fabric, the mercerisation process can be eliminated when using compact-spun yarns, and the same results can be obtained with conventional ring-spun yarns when applying the singeing and mercerising processes. Furthermore, low-twisted compact-spun yarns can be used instead of high-twisted conventional ring-spun yarns, since the pilling results of low-twisted compact spun yarns are similar to those of high-twisted compact- and ring-spun yarns.

During the mercerisation process, the outer fibres can be removed from the yarns by the effect of the high alkaline concentration, and so the pilling values increase. For both compact and conventional ring-spun yarns, after the mercerisation of singed fabrics, the pilling degrees are similar, at the level of 5 degrees. Thus, if the fabrics are mercerised, there will be no need to use compact-spun yarns, which are more expensive than conventional ring-spun yarns, since there is no significant difference in the colour efficiency or tensile strength.

Colour efficiency

The colour efficiency of the fabrics woven with compact and conventional ring-spun yarns has been tested via a spectrophotometer under daylight conditions (D65). As expected, the mercerisation process increases the dye take-up for both conventional ring- and compact-spun yarns, and so the colour efficiency of all the mercerised fabrics is higher than that of non-mercerised fabrics. The effects of the singeing process on colour efficiency are negligible for all fabrics. The results show that the singeing process is statistically insignificant, while the mercerisation process is statistically significant for the colour efficiency (Table 9).

When the results are examined according to the yarn type, it is found that there is

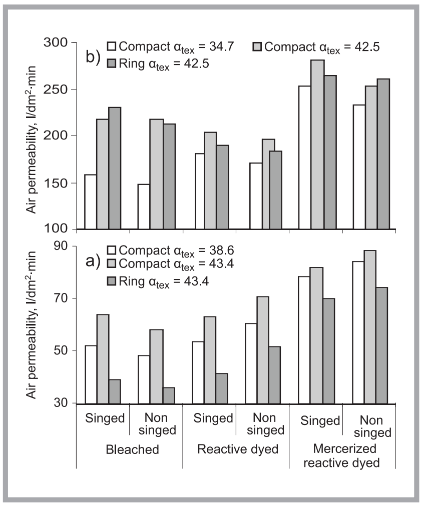

Figure 2. *Air permeability of the fabrics consisting of a) 20 tex and b) 12 tex yarns.*

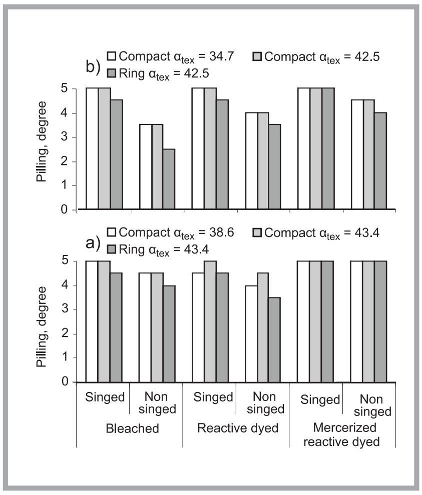

Figure 3. *Pilling behaviour of the fabrics consisting of a) 20 tex b) 12 tex yarns.*

Table 9. Statistical results of colour efficiency of the fabrics; α = 0.05.

Finishing processes	Reactive dyeing		Mercerised reactive dyeing	
Variables	P value (20 tex)	P value(12 tex)	P value (20 tex)	P value(12 tex)
Yarn production type	0.272	0.069	0.052	0.809
Singeing process	0.154	0.051	0.154	0.864
Mercerisation process	-	-	0.000	0.000

no statistically significant difference between the fabrics produced with compact and conventional ring-spun yarns. The results are very close to each other (Figure 4.a and b).

Rubbing fastness

It has been demonstrated that the dry and wet rubbing fastness values of the reactive dyed and mercerised + reactive dyed fabrics produced with compact and conventional ring-spun yarns are all the same, and have the maximum value of 5. It has also been demonstrated that yarn production type has no effect on the rubbing fastness of the fabrics.

Conclusions

The aim of the study presented herein was to analyse the effects of finishing processes on the properties of fabrics produced with conventional ring- and compact-spun yarns. The yarns were produced using the same cotton blend under the same conditions. All the plain fabrics mentioned in the research were produced simultaneously in the same machine, as different settings of the machine may cause differences in the results. After production of the fabrics, all of them were treated with the same finishing processes under the same conditions. An analysis of the yarn tests and properties of the fabrics led to the following conclusions:

- Compact-spun yarns can be regarded as new ring-spun yarns with respect to their structural, physical and mechanical properties. These yarns have better breaking force, elongation and hairiness values, while the other yarn quality parameters are comparable to conventional ones.
- Whereas compact-spun yarns have the advantages of less hairiness, a smooth surface and improved mechanical properties, such as breaking force & elongation, in the yarn form, there is no obvious difference between the colour efficiency, rubbing fastness and air permeability of the fabrics produced with compact and conventional ring-spun yarns. However, the pilling properties of the fabrics produced with compact-spun yarns and the tensile strength of the fabrics produced with finer compact-spun yarns are better.
- The singeing process improves the pilling properties of the fabrics produced with both compact and conventional ring-spun yarns. In terms of tensile strength, non-singed fabrics with compact-spun yarns have the similar results to singed fabrics with ring-spun yarns, and so the singeing process can be eliminated when using compact-spun yarns. Considering the adequate quality in terms of pilling, the singeing process can be eliminated if fabrics with compact spun yarns are used.
- The mercerisation process positively affects all of the fabric properties produced with compact and conventional ring-spun yarns. According to the tensile strength, when using finer compact yarns, the mercerisation process can be eliminated, since non-mercerised reactive-dyed fabrics with finer compact yarns show similar results to those of mercerised reactive-dyed fabrics with conventional ring-spun yarns. The pilling degrees of all mercerised fabrics are higher, and in the majority of tests of the level of 5 degrees. When using compact yarns, it is possible to eliminate mercerisation due to the pilling results being similar to those of mercerised fabrics produced with conventional ring-spun yarns. However, if the mercerisation is carried out in order to obtain higher colour efficiency, there is no need to use compact-spun yarns, which are more expensive.
- Finally, low-twisted compact-spun yarn shows almost identical behaviour to high-twisted compact and conventional ring-spun yarn. As stated in other literature, low-twisted compact-spun yarns can be used instead of high-twisted conventional ring-spun yarns, provided that the same finishing treatments are applied. In this way, yarn production can be increased.

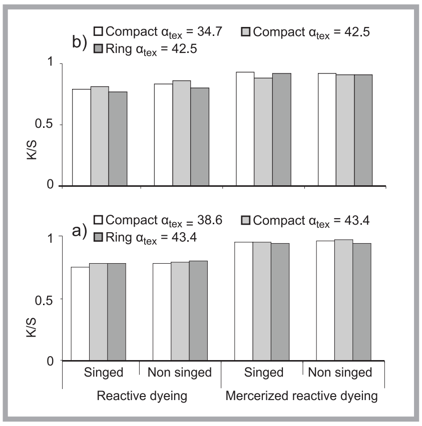

Figure 4. Colour efficiency (K/S) of the dyed fabrics consisting of a) 20 tex and b) 12 tex yarns.

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