Comparison of colour values of plain cotton fabrics woven from ring- and compact-spun yarns

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The colour values of plain woven cotton fabrics made from ring- and compact-spun warp and weft yarns have been compared. Ring and compact cotton yarns were spun from 100% combed cotton at different yarn counts; ring-spun yarns having slightly higher mass irregularities and much higher hairiness than the compact-spun yarns. Fabrics having the same constructional properties were woven under the controlled mill conditions and then dyed with C.I. Reactive Black 5 dye. Reflectance measurements were performed on the undyed and dyed fabrics and colour values (lightness, chroma and K/S) were obtained. It is observed that the colour values change with the change in yarn counts and differ in undyed and dyed fabrics. As the yarn counts increase, the lightness and chroma values increase but the K/S values decrease in dyed fabrics, while the results are opposite in undyed fabrics. The highest numerical differences are obtained between the chroma values of the fabrics. Microscopic photographs of the fabrics show that the hairiness decreases with the increase in yarn count. The yarn hairiness plays a very important role in light reflectances with regard to chroma values and fabrics woven from compact yarns appear lighter in colour because of the more regular structure of the compact-spun yarns.

1 Introduction

Ring spinning is the most important yarn manufacturing process in short staple spinning. Ring spinning holds its importance against other new spinning processes because of its constant development[1]. In the past few decades, several new spinning processes have been developed to achieve higher production per spinning unit. This is especially true for rotor and air-jet spinning which have made a breakthrough until recently. However, ring-spun yarn has always been the undisputed quality benchmark within the spun yarn sector[2].

Compact spinning is a new spinning process. Although the yarn looks very much like ring yarn, compact spinning produces a superior ring yarn[3]. Compact spinning attempts to reduce fly liberation during conventional ring spinning by using pneumatic compression[1]. In compact spinning, the fibres are compacted into a narrow sliver after virtually tension-free drafting in a compacting zone and then twisted after the nipping point as a compact sliver. As in the classic spinning triangle, peripheral fibres are eliminated[3].

Compact spinning produces a novel yarn structure. The particular features of these yarns are greater strength and elongation together with reduced hairiness[1,3]. Hairiness in 3 mm and longer class is significantly reduced. Yarns having less faults and greater uniformity are produced. With the use of compact-spun yarns in weaving, sizing expenses are reduced and lower thread break rates and higher machine efficiency are achieved[4,5]. The present paper focuses on the comparison of colour values of plain cotton fabrics woven from ring- and compact-spun yarns. Colour values of undyed and dyed fabrics were presented and compared with regard to some yarn properties.

2 Materials and Methods

Ring and compact cotton yarns, spun from 100% American Upland type combed cotton fibres were woven to produce plain woven cotton fabrics. The yarn counts were selected as 30, 40 and 50 Ne and the twist factor as $\alpha_e=4.43$. The cotton yarns were produced and woven in the mill under controlled conditions. Properties of the woven fabrics and yarns are given in Tables 1 and 2 respectively.

After weaving, the fabrics were desized in an open-width continuous washing range by using enzymatic

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Table 1—Fabric constructional properties

Fabric code	Warp yarn	Weft yarn	Warp/cm	Weft/cm	Fabric weight g/m^2	Thickness l/mm
R30	Ring (Ne 30)	Ring (Ne 30)	52	24	178	435
C30	Compact (Ne 30)	Compact (Ne 30)	52	24	186	423
R40	Ring (Ne 40)	Ring (Ne 40)	52	24	127	371
C40	Compact (Ne 40)	Compact (Ne 40)	52	24	131	357
R50	Ring (Ne 50)	Ring (Ne 50)	52	24	100	330
C50	Compact (Ne 50)	Compact (Ne 50)	52	24	106	318

Table 2—Mass irregularity and hairiness properties of yarns

Test instrument	Yarn property	Yarn					
		Ring			Compact		
		Ne30	Ne40	Ne50	Ne30	Ne40	Ne50
Uster Tester 3	% CV$_{mass}$	11.63	13.80	14.42	11.18	13.00	14.20
Zweigle G566	Class 1mm	16042	12875	13200	13813	11197	10278
	Class 2mm	3204	2793	2979	3220	2110	1428
	S3-value ($\Sigma \geq$ 3mm)	1874	1723	1696	544	295	215

washing liquor. The pretreatment of the fabrics was performed in an open-width continuous pretreatment range by using anionic surface active agent, NaOH, H_2O_2, and stabilizers in the same amounts as used in the pretreatment of conventional cotton fabrics in the mill. The woven fabrics were desized, scoured, mild bleached and then dyed under mill conditions. Absorbency of the pretreated fabrics was tested according to AATCC test method 79-1995 (ref. 6). The wetting time was lower than the five seconds which indicates good absorbency of the pretreated fabrics.

The dyeing of cotton woven fabric was done under laboratory conditions in a laboratory type sample dyeing machine (Termal HT). All the samples (3 g each) were dyed separately in independent dyeing liquors using 50:1 liquor-to-material ratio. The samples were dyed (3% owf) with C.I. Reactive Black 5 (Sumifix Black B 150) using the procedure as described by dyestuff manufacturer. The aim of dyeing with a black dye is to obtain minimum light reflectance and to observe the effect of yarn structures on reflectance. The dyebaths contained 40 g/L Glauber's salt and 20 g/L soda ash (sodium carbonate). Both the chemicals were of commercial purity. The dyeings began at 40°C and after 20 min the temperature was raised to 60°C with the rate of 1°C/min. The dyeing continued at this temperature for 60 min and then the temperature was decreased to 40°C with the rate of 2°C/min. The samples were taken out from the dyebath and post treated. The post treatment of the dyed samples was done at 100:1

liquor-to-material ratio. The samples were cold rinsed for 10 min followed by a hot rinse at 60°C for 10 min. The dyed samples were soaped in a soaping solution containing 2 g/L anionic surfactant at 95°C for 25 min. Later, the samples were hot (60°C) and cold rinsed for 10 min each. After the post treatments, the samples were left to dry under laboratory conditions.

Uster Tester 3 was used for testing mass irregularity and Zweigle G566 for hairiness. Fabric thickness was measured with R & B cloth thickness tester. Colour measurements were performed on the pretreated but undyed and on the dyed samples using a reflectance spectrophotometer (Macbeth MS2020+) coupled with a PC between 400nm and 700 nm under D65/10° illuminant at SCI (Specular Component Included mode). Lightness (L^*) and chroma (C^*) values were taken from the measuring software. The per cent reflectance and K/S values at the wavelength of maximum absorption (600 nm) were also recorded. Four reflectance measurements were performed on each sample after rotating it 90° before each measurement so that the samples folded four times. The average of measurements was calculated as the reflectance values by the colour measurement software and used in calculating the colour coordinates according to CIELAB (1976).

3 Results and Discussion

Fabric constructional properties with fabric codes are shown in Table 1. The weights (g/m^2) of compact-spun yarn fabrics (C fabric) are higher than those of ring-spun yarn fabrics (R fabric). The thicknesses

(1/mm) of R fabrics are higher than those of C fabrics. Fabric weights and fabric thicknesses decrease as the yarns get thinner (yarn count increases).

Mass irregularities and hairiness properties of the yarns are presented in Table 2. Ring yarns have slightly higher mass irregularities and much higher hairiness values than those of compact yarns. Mass irregularity values increase and hairiness values decrease as the yarn counts increase.

$L*$ values of both undyed and dyed fabrics are shown in Fig. 1. Fig. 1(a) shows that the $L*$ values of undyed R fabrics (fabrics woven from ring-spun yarns in warp and weft) are higher than those of C fabrics (fabrics woven from compact-spun yarns in warp and weft). $L*$ values decrease as the yarns get thinner. The gradual decrease in $L*$ values for undyed fabrics indicates that the total light reflectances of fabrics decrease as the yarn counts increase. The decrease in $L*$ values which is in relation with the decrease in reflectances is more evident for C fabrics at higher yarn count (C50). Undyed fabrics reflect more light from their surfaces as the yarn counts decrease.

Fig. 1(b) shows that the $L*$ values of dyed R fabrics are lower than those of C fabrics for Ne 30 and Ne 40 counts, while at Ne 50 the $L*$ value of R fabric is higher than that of C fabric. The gradual increase in $L*$ values for dyed fabrics indicates that the total light reflectances of fabrics increase as the yarn counts increase. The increase in $L*$ values which is in relation with the increase in reflectances is more evident for C fabrics at Ne 30 and Ne 40 counts. Dyed fabrics reflect more light from their surfaces as the yarn counts increase.

The $C*$ values of undyed and dyed fabrics are presented in Fig. 2. Fig. 2(a) shows that the undyed fabrics have almost the same $C*$ values at increasing yarn counts. $C*$ values decrease as the yarn counts increase and the value for C50 fabric is slightly higher than the R50 fabric. The gradual decrease in $C*$ values observed for undyed fabrics indicates that the chroma of the fabrics gets closer to the grey point at $a* - b*$ color plane of CIELAB colour space as the yarn counts increase.

Fig. 2(b) shows that the $C*$ values of R fabrics are higher than those of C fabrics at all yarn counts. This indicates that the R fabrics appear more saturated in colour than the C fabrics. The gradual increase in $C*$ values further indicates that the chroma of dyed fabrics increases as the yarn counts increase and the fabrics become more saturated in colour. The K/S
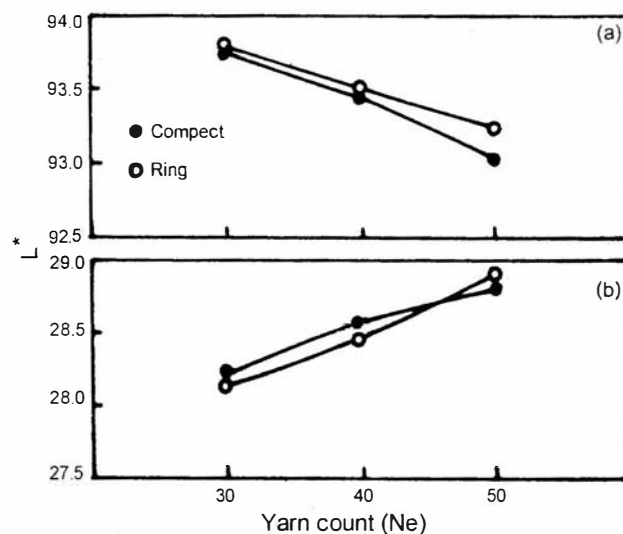

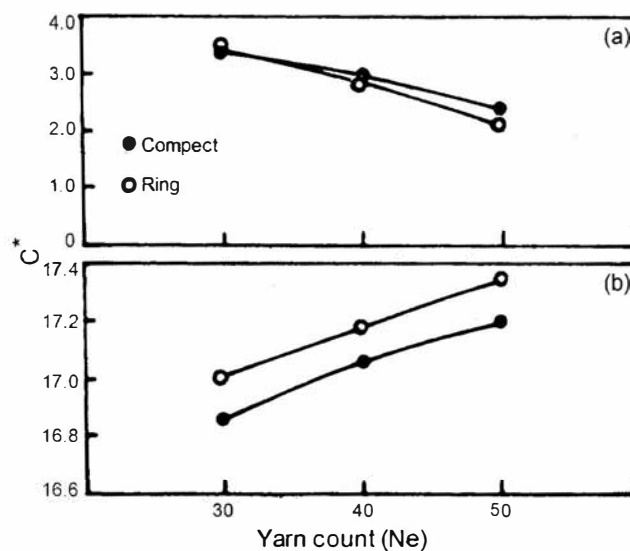Fig. 1—Effect of yarn count on lightness values of (a) undyed, and (b) dyed fabrics

Fig. 2—Effect of yarn count on chroma values of (a) undyed, and (b) dyed fabrics

values of undyed and dyed fabrics are presented in Fig. 3. In Fig. 3(a), the K/S values are the average of values obtained between 400 nm and 700 nm at 20 nm intervals (total 16 values) of the undyed fabrics. In Fig. 3(b), K/S values are obtained at the wavelength of maximum light absorption (λ_{max}, 600 nm) of the dyed fabrics.

Fig. 3(a) also shows that the K/S values of C fabrics are higher than those of the R fabrics. The K/S values increase as the yarn counts increase; the increase in K/S values is however more evident in C fabrics at higher yarn count (C50). The gradual increase in K/S
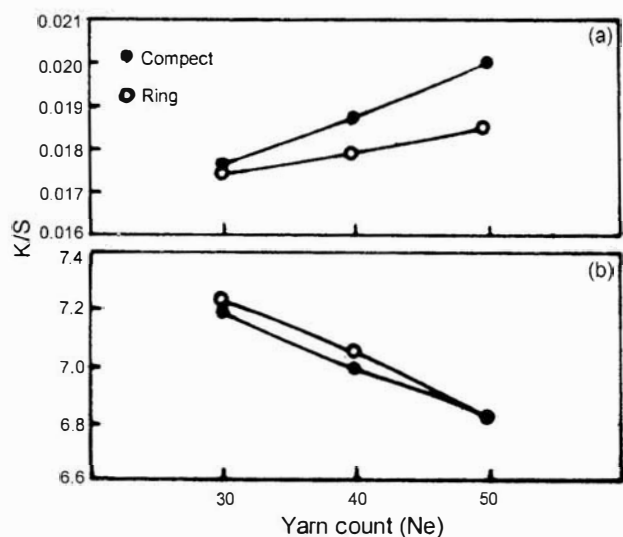
Fig. 3—Effect of yarn count on K/S values of (a) undyed, and (b) dyed fabrics

values for undyed fabrics indicates that the total light reflectances of fabrics decrease as the yarn counts increase and the decrease in reflectance is more evident at C fabrics. The behaviour of K/S values observed with the increase in yarn counts is closely related with $L*$ values [Fig.1 (a)].

Fig. 3(b) shows that the K/S values of R fabrics are slightly higher than those of the C fabrics at Ne 30 and Ne 40 yarn counts. The K/S values of both the fabrics are almost the same at Ne 50. The gradual decrease in K/S values for dyed fabrics indicates that the light reflectances of fabrics increase as the yarn counts increase and the increase in reflectance is almost the same for R and C fabrics at the wavelength of maximum light absorption.

Light absorption and calculated K/S value at λ_{max} are the measure of the dyeing properties of the dyes and amount of dye retained in fibres after dyeing. As
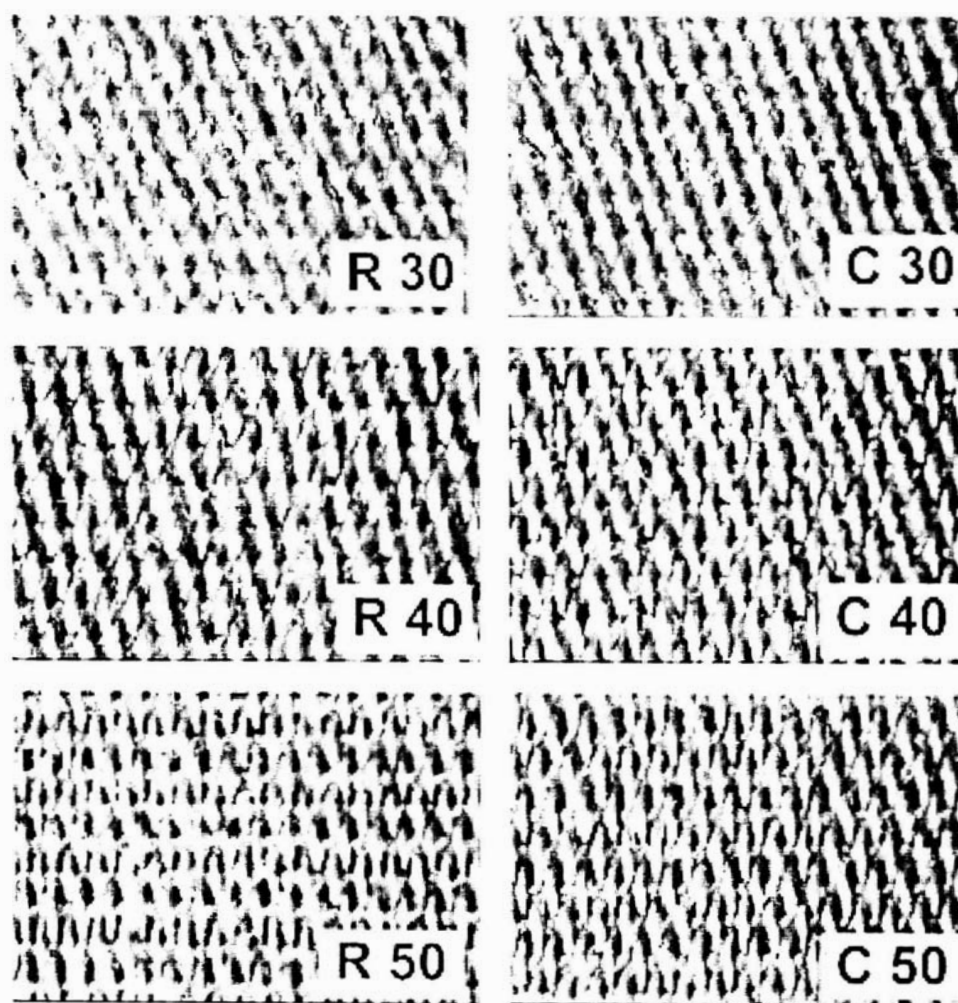

Fig. 4—Photographs (× 20) of different fabrics [R30 – Ne30 ring, R40 – Ne40 ring , R50 – Ne50 ring , C30 – Ne30 compact, C40 – Ne40 compact, and C50 – Ne50 compact]

shown in Fig. 3(b), the amounts of dye absorbed by both the fabrics are almost the same. This is an accepted result because the yarns were spun from the same raw material. But the difference of C^* values [Fig. 2(b)] indicates that the R fabrics are dyed more saturated. This may be due to the differences in hairiness of the yarns. Increasing hairiness together with increasing yarn counts affect the light reflection properties of surfaces and the observed colour saturation. Lower hairiness and lower mass irregularity of the compact yarns cause the fabrics to look more regular. This results in a decrease in colour appearance and colour saturation, making the fabric surfaces look lighter, i.e. higher L^* values and lower K/S values of dyed fabrics as the yarn counts increase.

The increasing difference between the K/S values as the yarn counts increase in undyed fabrics [Fig. 3(a)] indicates that the effect of compact yarn structure is more evident as the yarns get thinner (C50). However, it can be estimated that the lower hairiness of compact yarns causes slightly higher reflectances and slightly lower K/S values in dyed fabrics.

The distinct difference between the slopes of L^* and K/S values for undyed and dyed fabrics (Figs 1 and 3) indicates that the fabrics woven from ring- and compact-spun yarns have different light reflecting behaviour before and after dyeing. The aim of choosing a black dye in dyeing process was to observe the intrinsic reflectance of the surface under practical dyeing concentration. As pointed out earlier[1-5] and shown in Table 2, the yarn hairiness is lower for compact-spun yarns. The hairiness difference gets higher between ring- and compact-spun yarns as the yarn count increases. The results indicate that the hairiness of yarns and the regularity of surface are to be considered independently in dyed and undyed plain woven fabrics. Yarn hairiness plays a more important role in reflectance than the regularity of surface in colour depths, especially in C^* values. The higher light reflectance of R fabrics, especially at lower yarn count before dyeing and at higher yarn count after dyeing, is a result of yarn hairiness which is lower in compact-spun yarn at higher yarn counts.

Dyeing minimizes the surface reflectance differences occurring from either yarn hairiness or surface regularity, but visible colour depths are higher in R fabrics [Fig. 2(b)]. The increase in chroma values of the dyed fabrics as the yarn counts increase indicates that the colour of dyed surfaces becomes more saturated. The lower chroma values of the C fabrics are the result of compact effect in yarn structures.

The photographs (20 times magnified) of fabrics are shown in Fig. 4. It is observed that the hairiness at the fabric surface decreases as the yarn count increases.

4 Conclusions

In compact spinning, the fibres are packed closer to each other in yarn structure than in ring spinning; the number of fibres in yarn cross-section being the same. Compact spinning brings the advantages of lower hairiness, better alignment of fibres in yarn structure and slightly lower mass irregularity. The fabric thickness is lower and fabric weight is higher in the fabrics woven from compact yarns. Because of the technological aspects outlined above, fabrics woven from compact yarns are estimated to have a more regular surface than the fabrics woven from ring-spun yarns. Therefore, the fabrics woven from compact yarns appear lighter in colour (less saturated) and higher in lightness when compared with the fabrics woven from ring – spun yarns having the same yarn counts as the compact-spun yarns. A back-scattering effect similar to fabrics woven from microfibre yarns is observed in fabrics woven from compact-spun yarns. The efficiency of the dyes is reduced in the dyed fabrics because of the more regular structures of the compact yarns. L^* values increase and K/S values decrease in the dyed fabrics as the yarn counts increase and yarn hairiness decreases, making the woven surface look lighter in colour. However, the fabric constructional patterns may become more visible due to the lower hairiness and more regular fabric surfaces.

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