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A Study of the Damage Caused to Dyed Cotton Fibres and its Effects on the Properties of Rotor- and Ring-Spun Melange Yarns

Abstract
A detailed study of the effect of flock dyeing of cotton fibre on the damage and different properties of rotor- and ring-spun (100% dyed, 50% dyed and 50% grey melange) yarns is reported. It was found out that flock dyeing increases fibre damage when compared with grey fibres. The higher degree of damage of the dyed cotton fibres mixed with white ones has a negative effect on the quality of the melange cotton yarn. The quality of the melange yarn depends considerably on the blending stage, as well as the spinning systems. The higher number of drawing stages when blending black and white fibres in the draw frame results in better mechanical properties, but greater hairiness for the yarn. The presence of dyed fibres in the melange leads to a considerable decrease in the mechanical properties of rotor spun yarns, but ring spun yarns do not seem to be considerably affected.

Key words: *fibre damage, cotton, flock dyeing, ring spinning, rotor spinning, melange yarn.*

Introduction

Due to their specific properties of aesthetics and comfort, melange cotton yarns are used in the production of a variety of fabrics for sports and underwear apparel. Melange yarns are spun from a number of fibres with different colours. Mixing black and white fibres to varying degrees is a common method of producing a variety of fancy yarns. Fibres with different colours could be mixed either in the blow room at the start of the spinning preparation or by feeding differently-dyed fibres to the drawing frames. A review of the literature shows that cotton fibres suffer from a rather low decrease in strength after being dyed, especially with reactive and indigo dyes. Dyeing cotton fibres leads to their greater entanglement and cohesion. Moreover, due to the removal of a large portion of the wax present on the surface of cotton fibres during the scouring and dyeing process, the average length of cotton fibres decreases with a higher rate than that of white cotton fibres after going through the blending, carding and drawing processes. This fibre damage not only affects the efficiency of the spinning process, but also the mechanical properties of the final yarn and fabric.

The history of study on fibre damage dates back to as early as 1940, when Clegg [1] reported that the 5% portion of damaged fibres in a cotton bale increased to 54% in the spun yarn. In a paper by Wakeham [2], various methods of measuring fibre length distribution and indications of excessive quantities of short fibres are outlined. Wakeham concluded that despite the small weight fractions, short fibre content matters much more than generally thought. Byatt et al. [3] developed an integro-differential equation governing the changes occurring in the weight distribution of cotton fibre length as a result of random fibre breakage caused by microbial deterioration or by the action of saws, as in ginning. The agreement between theory and experiments is reported to be satisfactory. Grant et al. [4] studied the effect of mechanical processing on the properties of seven varieties of American grown commercial cotton after ginning up to yarn formation. In this research, the changes in length, fineness, tenacity and crystallite orientation were found to be within experimental errors. Grant believed that the inherent fibre properties play an important part in determining the extent of changes occurring as the fibres undergo different processes. Williams et al. [5] reported that changes in a typical portion of fibre length distribution of fibre arrays of 50 samples of raw cotton and 65 of corresponding grey cloth and yarn are not of such a character as to affect the reliability of the estimates of staple length. Rebenfeld [6] studied the effect of several processing stages on the mechanical properties of cotton fibre; he established that all the processing stages affect the mechanical properties of cotton fibres, and their extent is process-dependent, as in bleaching mercerising and resin finishing, which generally alter the fibre properties more than mechanical actions such as carding, spinning and weaving. Rebenfeld also reported that changes in fibre properties are reflected in fabric characteristics. Koo et al. [7] studied the strength, elongation, unevenness and spinnability of component fibres of a specialty yarn as a function of the blending ratio of dyed cotton blended with raw cotton. The result of this research showed that average tenacity, elongation and fibre length decreases after pre-treatment and dyeing. The tenacity of specialty yarns manufactured from dyed and raw cotton decreased as the percentage of dyed cotton increased to 40%. The spinnability of these specialty yarns also decreased as the blending ratio increased. Behara et al. [8] investigated the effect of different blending methods and blending stages on the properties of melange yarns of dyed and grey cotton fibres. The results showed that excessive mechanical action by blowroom and carding causes fibre damage and loss of fibre tenacity. Better yarn evenness and a lower amount of imperfections are achieved by separate processing of grey and dyed fibres at the blowroom and card stages, but better shade uniformity is produced by blowroom mixing. Ishtiaque [9] compared grey and dyed cotton fibres at different stages of the rotor spinning process; he found out that significant changes in length-related parameters were observed in each mechanical processing, the effect being more prominent in the case of dye fibres where the frictional coefficient is high. The initial roller speed had no significant effect on the fibre length of grey cotton, whereas, for natural yellow dyed cotton, the short fibre content increased as the initial roller speed was increased.

In this research, we have studied the damage inflicted on the dyed cotton fibres during yarn manufacturing by blending and carding process, and the effect of this damage on the properties of ring and rotor spun melange yarns (50% black and 50% white) as well as on 100% black yarn.

Experimental

Scouring and dyeing

The cotton fibre employed in this research was of grade-one type (Gorgan) with an average length of 28 mm, a linear density of 0.15 tex and an average tenacity of 21 g/tex. The scouring of fibres was carried out in a boiling bath containing 3 g/l of sodium carbonate and 1 g/l of detergent for 45 minutes with a liquor ratio of 30:1. This was followed by 10 minutes of rinsing at about 50 °C. The scoured fibres were dyed in a dyeing machine manufactured by Platt with 6% (owf) Benzonerol Black 600% VSF (C.I. Direct B class) and 6.5 g/l of sodium sulphate. The liquor ratio was 30:1. The dyeing was started at 50 °C and the temperature was raised to boiling point over 30 minutes. 15 minutes later, sodium sulphate was added to the boiling bath, and the dyeing was continued for another 45 minutes at boiling point. At the end, the dyed fibres were rinsed (40 °C) for 10 minutes, hydroextracted by centrifuge and finally dried in hot air.

Yarn production

Three kinds of ring and rotor spun cotton yarns (29,5 tex), namely 100% white, 50% white and 50% dyed (melange) as well as 100% dyed were produced. The two 100% white and 100% black yarns were produced by passing the related fibres through blending, carding, drawframe, roving (for ring) and ring- or rotor-spinning machines. However, two kinds of each ring- or rotor-spun melange yarn were produced. For one type, flocks of black and white fibres were mixed in the blowroom, and for the other, black and white slivers were mixed in the drawframe.

Measuring fibre and yarn properties

In order to investigate the fibre damage, micrographs from a Philips scanning electron microscope (X230-series B) were used. The spun length of 2.5% of the fibre samples and their strength and elongation at break were measured by Star Fibre Lab (FL-900) and a Zwick tensometer (Model 1446) based on the CRE method, respectivaly. For strength and elongation at break, 30 specimens were tested for each sample on the basis of standard ASTM D2256-97. The parameters related to the evenness of the yarns were measured by an Uster 4 on the basis of standard ASTM D1425-96. Yarn hairiness was measured by an SDL yarn hairiness/friction Tester Y089/6 according to ASTM D3108. Hairiness was measured for 10 test specimens of 100 metres each, which were chosen randomly from each yarn sample.

Results and discussion

SEM Micrographs

Figures 1 to 10 show a variety of damages inflicted upon the white and coloured fi-

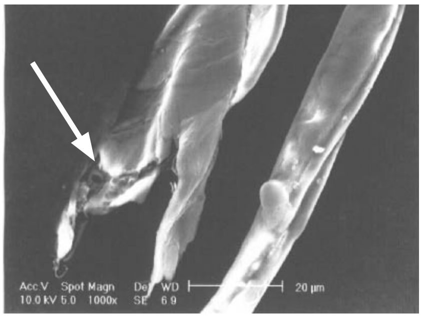

Figure1. *End rupture (grey fibre).*

Figure2. *End rupture (grey fibre).*

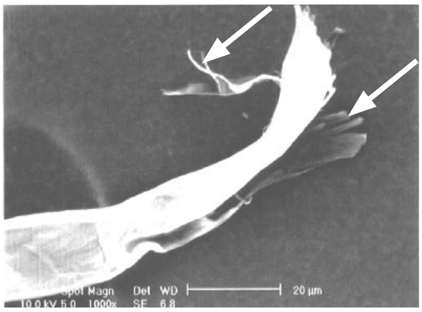

Figure 3. *End rupture (grey fibre).*

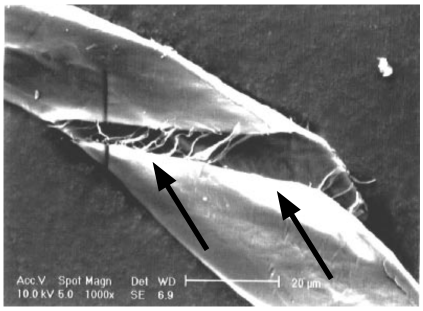

Figure 4. *Deep cracks (dyed fibre).*

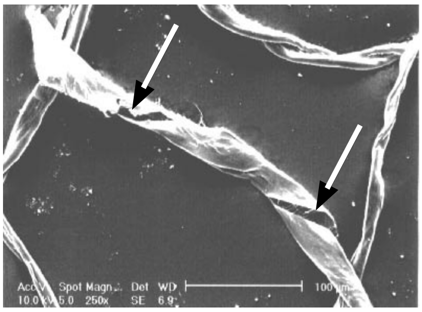

Figure 5. *Deep cracks (dyed fibre).*

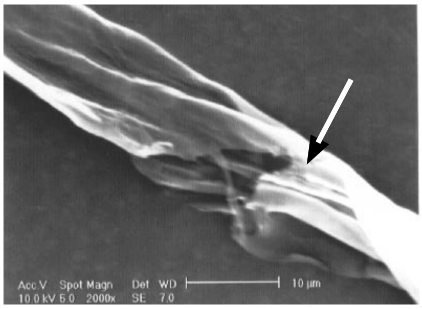

Figure 6. *Saw tooth effect (dyed fibre).*

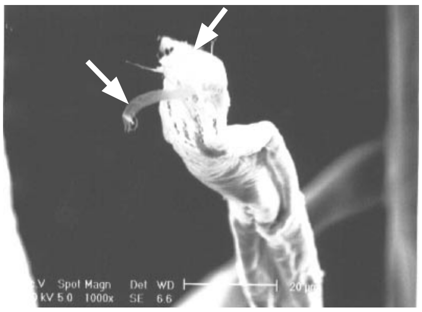

Figure 7. *Tip fibrillation (grey fibre).*

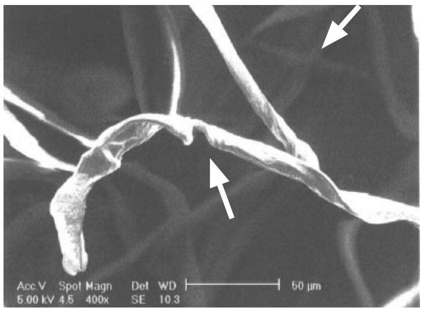

Figure 8. *Saw tooth effect (grey fibre).*

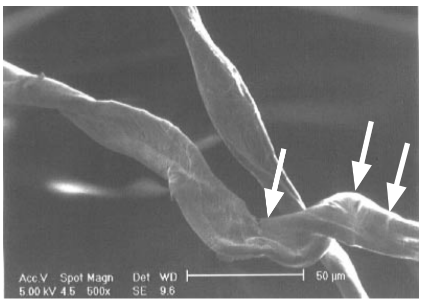

Figure 9. *Rippling damage (dyed fibre).*

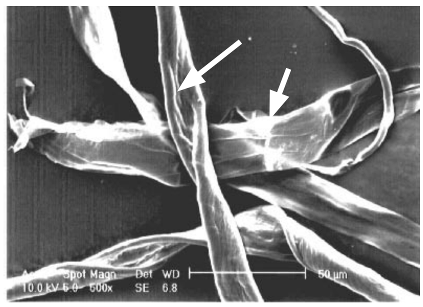

Figure10. *Transverse cracks (dyed fibre).*

bres after the blending, carding and opening roller of the rotor spinning machine. It proved very difficult to classify the types of damage according to the processes. However, as is seen from the SEM micrographs, the types of damage can be classified into categories such as tip fibrillation, end rupture, transverse cracks, deep cracks, saw tooth effect and rippling damage. SEM studies indicate the severe damage that fibres experience during various stages of yarn manufacturing. After dyeing, the fibre compactness is increased and the fibres experience various stresses during the opening and cleaning processes. Thus the dyed fibres are more vulnerable to damage than the undyed ones. It must be emphasised that even before blending, the cotton fibres may experience some damage during previous processes, such as ginning. As far as the preparation and spinning processes are concerned, it seems that the spikes of kirschner in blending, the clothing elements of carding and the opening roller of the rotor spinning machine cause most of the damage induced.

Effective length and percentage of fibres with length shorter than 12 mm

Figure 11 and 12 show the spun length 2.5% and of the fibres the percentage of fibres shorter than 12 mm from the samples of white, melange and black cotton fibres before and after blending, carding, drawing, and in the rotor groove of the rotor spinning machine respectively. As can be seen, the samples containing dyed fibres suffered a noticeable reduction in their effective length. This reduction increases from melange yarn to the yarn with 100% dyed cotton fibres. Also, the damage inflicted upon even the white cotton fibres by the beater of the rotor spinning system is considerable.

Waste percentage

Waste percentage can be considered as the sum of fibre waste extracted by the suction devices of different machines from the stream of fibre flow in each process and the non-fibre waste such as trash. Figure 13 shows the fibre waste, non-fibre waste and their sum, i.e. the waste percentage of white, melange and black cotton samples up to the ring- and rotor-spinning machine. The higher degree of damage suffered by the dyed fibres can be related to the higher degree of the fibres' entanglement and the formation of clusters of fibres as a result of the movement of the dye bath liquor in reciprocating directions in and out from the flock of fibres during dyeing. However, it must be pointed out that factors such as the type of cotton, the temperature and moisture conditions of the spinning plant and the quality, as well as the settings of the preparation and spinning machines, do play a role in determining the extent of fibre damage which the fibres suffer.

Tenacity and elongation at break of yarns

Figures 14 and 15 (see page 66) show the tenacity and elongation at break for ring and rotor yarns respectively. It is seen that among the ring yarns, the 100% white and 100% black ones shows the highest and lowest strength respectively. As for extension at break, the 100% dyed and melange yarns show the lowest and highest values respectively.

Evenness

Figures 16 to 20 (see page 66) show the average of coefficient of variation (CV%), the irregularity index (U%), the number of thin places (-50%), the number of thick places (+50%) and the number of neps for five test specimens of

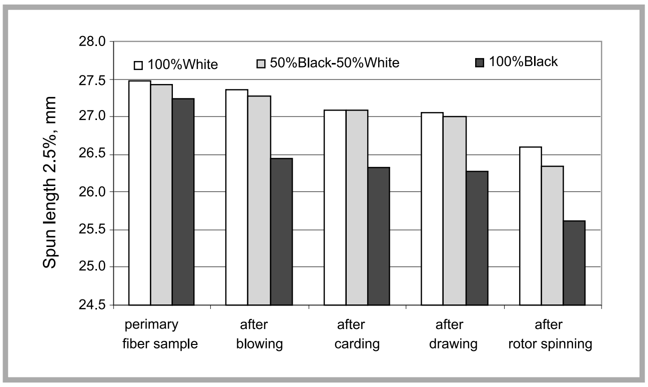

Figure 11. Spun length 2.5% .

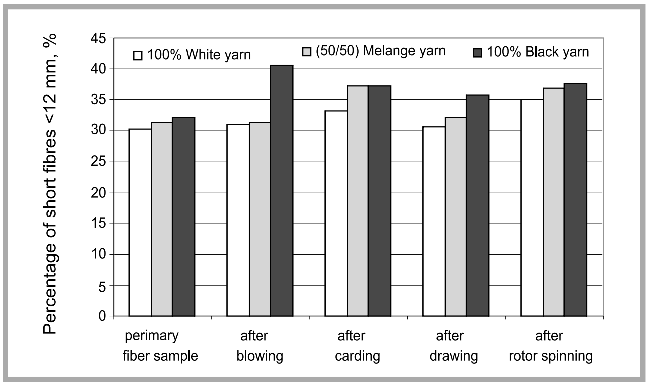

***Figure 12.** Percentage of fibres with length shorter than 12 mm.*

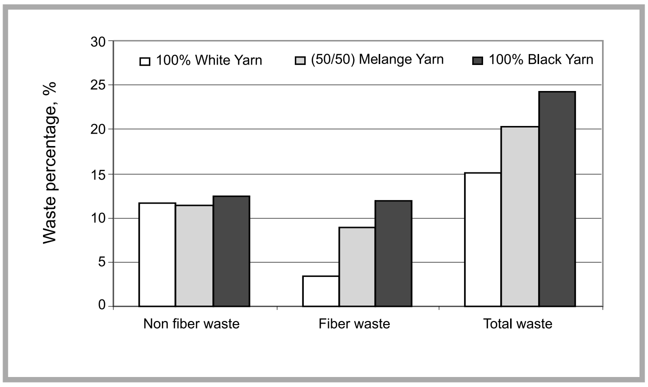

***Figure 13.** Waste percentage.*

***Remark:** denotations used for designation of the chart-bars identifying the yarns in Figure 14 - 21 on page 66: RRY - 100% white ring yarn, MRY - 50% white, 50% black ring yarn blended during blowing, CRYDII - 50% white, 50% black ring yarn blended in two drawing passages, CDYDIII - 50% white, 50% black ring yarn blended in three drawing passages, DRY - 100% black ring yarn, ROY - 100% white rotor yarn, MOY - 50% white, 50% black rotor yarn blended during blowing, COY - 50% white, 50% black rotor yarn blended in two drawing passages, DOY - 100% black rotor yarn.*

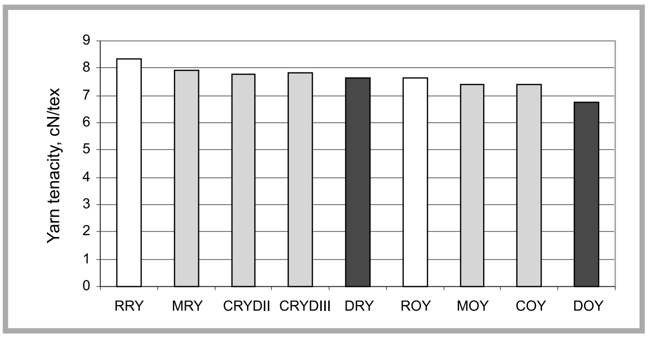

Figure 14. Strength of ring and rotor yarns.

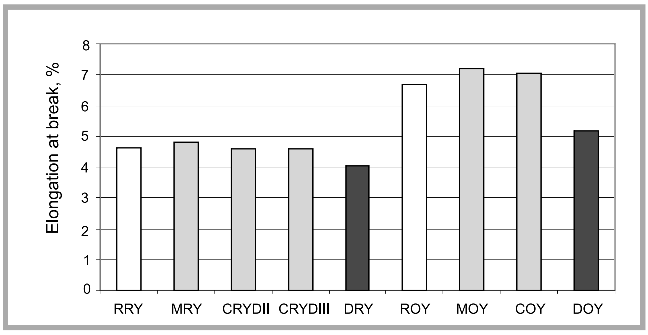

Figure 15. Elongation at break of ring and rotor yarns.

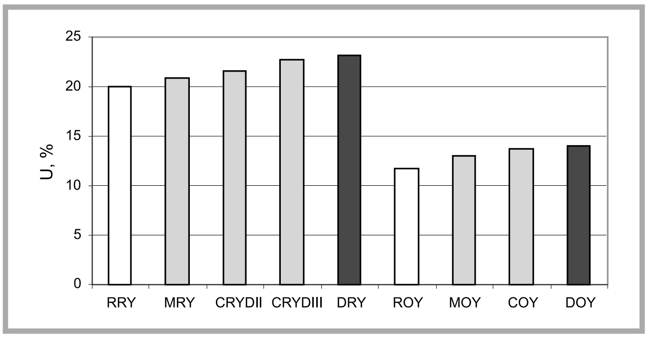

Figure 16. Irregularity index (U%) of ring and rotor yarns.

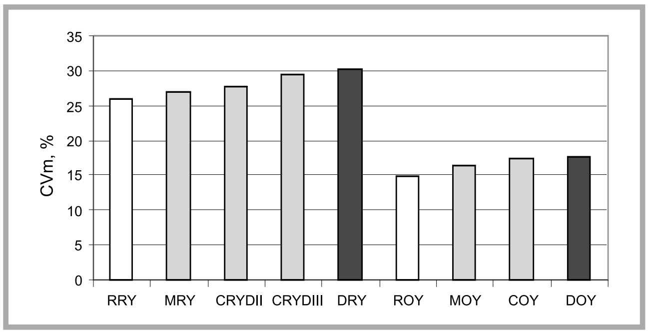

Figure 17. Coefficient of variation (CV%) of ring and rotor yarns.

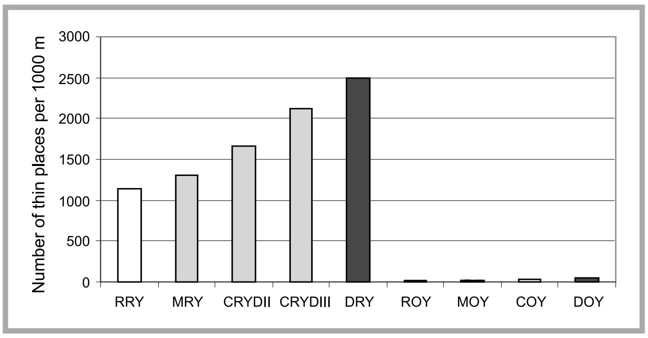

Figure 18. Number of thin places (-50%) of ring and rotor yarns.

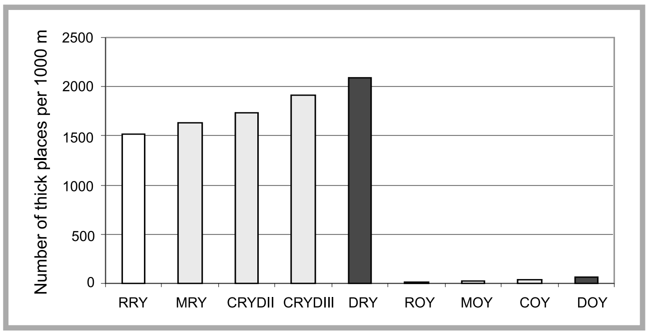

Figure 19. Number of thick places (+50%) of ring and rotor yarns.

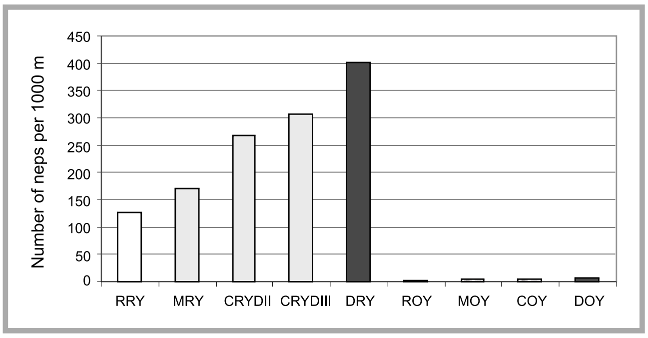

Figure 20. Number of neps of ring and rotor yarns.

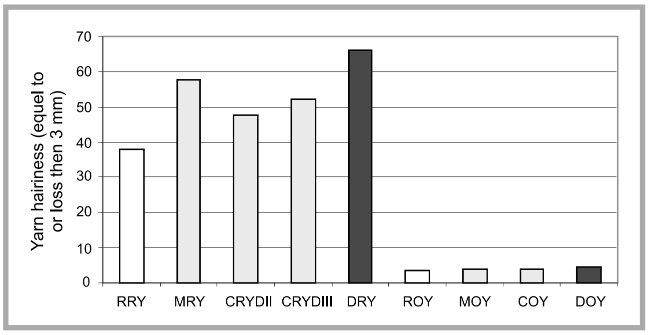

Figure 21. Hairiness of ring and rotor yarns.

each ring and rotor yarn samples. Each test specimen was 1000 metres in length.

Yarn hairiness

Figure 21 shows the hairiness (equal to or less than 3 mm) of the ring and rotor yarns. It is seen that the ring spun yarns show a higher degree of hairiness than rotor yarns. This is due to the fact that shorter and coarser fibres tend to move to the outer surface of the fibre bundle in the spinning triangle, and hence a higher degree of hairiness results. At the same time, the shorter and coarser fibres avoid becoming spun inside the yarn structure. Figure 21 also shows that mixing the white and dyed fibres in the blending stage leads to a higher degree of hairiness in comparison to the mixing of black and white silvers on the draw frames. Moreover, an increase in the number of drawing passages leads to a higher degree of hairiness.

Conclusions

The results obtained from the present study are summarised as follows:

1. Dyeing cotton in the loose state (flock dyeing) leads to an increased amount of fibre damage in comparison to undyed fibres.
2. The quality of the melange cotton yarn suffers to a considerable extent, as a result of the higher degree of damage to the dyed cotton fibres being mixed with the white ones.
3. Mixing the black and white fibres before blending or during drawing, together with the rotor- or ring-spinning systems, affect the quality of the melange yarn to a considerable extent.
4. When mixing black and white fibres in the drawing, an increase in the number of drawing stages leads to better yarn mechanical properties, but at the same time, the hairiness of the yarn increases.
5. In the case of rotor spinning, the presence of dyed fibres leads to a considerable decrease in the mechanical properties of the melange yarns, but no considerable negative effect was seen for the ring spun yarns.

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