

DAMAGING OF DYED COTTON FIBERS WITH DIRECT DYE IN SPINNING PROCESSES AND ITS EFFECT ON THE PROPERTIES OF COTTON MÉLANGE YARN

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Abstract The influence of dyeing and spinning on the characteristics of cotton fibers and its impact on the properties of cotton mélangé yarn has been investigated. Grey cotton fibers with mean fiber length and fineness of 29 mm and 4.2 micronair were pre-treated and dyed. Three ring yarns were spun from 100 % grey cotton (R.R.Y), 50-50 % blend of dyed and grey cotton (M.R.Y) and 100 % dyed cotton fibers (D.R.Y). The extent of fiber damage was assessed by measuring the length and the mechanical characteristics of cotton fibers after passing the lap machine and the draw frame II. Consequently, properties of R.R.Y, M.R.Y and D.R.Y yarn samples were examined. According to the results, the tenacity and elongation at the break of grey and dyed cotton fiber were very close together. Differences between fibers length by weight and number, nep, short fiber content of grey and dyed cotton fiber were meaningful. There is not a meaningful difference between the elongations of three yarn samples. Tenacity of the R.R.Y yarn sample was the highest and coefficient of mass variation (Cv %), imperfections and hairiness of this yarn sample was the lowest in comparison with those parameters for M.R.Y and D.R.Y yarn samples respectively.

Keywords Cotton Mélangé Yarn-Dyed Cotton Fibers-Grey Cotton Fibers-Extent of Fibers Damage-Short Fiber Content

چکیده در این تحقیق اثرات عملیات رنگرزی و ریسندگی بر خصوصیات الیاف پنبه خام و رنگرزی شده و تاثیر آن بر خصوصیات نخ ملانژ پنبه های مطالعه شده است. الیاف پنبه با طول متوسط ۲۹ میلی متر و ظرافت ۴/۲ میکرونر تحت عملیات شستشو و رنگرزی قرار گرفت. سه نمونه نخ رینگ شامل الیاف پنبه رنگرزی شده ۱۰۰٪، الیاف پنبه خام ۱۰۰٪ و ترکیب ۵۰-۵۰٪ الیاف رنگرزی شده و خام ریسیده شد. شدت آسیب دیدگی الیاف با اندازه گیری خصوصیات طولی و مکانیکی الیاف پنبه رنگرزی شده، خام و ترکیب الیاف پس از عبور الیاف از ماشین بالش پیچ و چند لا کنی دوم ارزیابی شد. در مرحله بعد خصوصیات سه نمونه نخ ریسیده شده نیز مطالعه گردید. بر پایه نتایج آزمایش میزان استحکام و ازدیاد طول تا حد پارگی الیاف پنبه خام و رنگرزی شده پس از مراحل بالش پیچ و چندلاکنی دوم بسیار به یکدیگر نزدیک می باشد. تفاوت میان طول وزنی، طول عددی، درصد الیاف کوتاه و نپ الیاف پنبه خام و رنگرزی شده معنی دار می باشد. به علاوه تفاوت معنی داری در بین ازدیاد طول تا حد پارگی سه نمونه نخ مشاهده نشد. با این وجود میزان استحکام تا حد پارگی نخ ریسیده شده از ۱۰۰٪ الیاف پنبه خام حداکثر مقدار و میزان ضریب تغییرات جرمی، عیوب، پرزآلودگی این نخ در مقایسه با همین پارامترها در دو نمونه نخ دیگر حداقل مقدار است.

1. INTRODUCTION

Technological development has enabled the textile industry to produce various types of fancy yarns [1]. Fancy yarns are those in which some deliberate decorative discontinuity or interruption in either color or yarn structure or both are

introduced [2,3]. Among fancy yarns, mélangé yarns are known for their attractive color and appearance. Mélangé yarns are spun yarns made from two or more fiber groups with different colors or different dye affinities. Such fancy yarns have advantages for fabric appearance and can be used for underwear, outerwear and sportswear, etc [4].

In spite of many advantages, there is a restriction on developing cotton specialty yarn and many products of fine cotton *mélange* yarn counts because of spinning difficulties. During the manufacture of cotton *mélange* yarn by blending dyed and grey cotton, fibers damaged by the dyeing and spinning degrade the properties of the specialty yarn. Therefore a technology for fine yarn counts is a necessary technique for producing high quality fabrics [4].

It is very important to study and investigate the characteristics of grey and also dyed cotton fibers at spinning stages to control and optimize the spun yarn properties [5]. Behera's et al [1] studies show that, the number of broken and damaged dyed cotton fibers in the spun yarn is more than the number of damaged fibers in cotton bale. Also the strength at the break of dyed fibers in yarn decreases in comparison with that of cotton fibers in bale. Yarn tenacity improves when both grey and dyed cotton fibers go through the blow room and carding machines only once while fiber blending is taking place in the blow room [1]. In addition, combing processes improve yarn quality and strength [4].

Koo's et al [5] studies indicate that it is possible to combine dyed and grey cotton fibers by different processes such as drawing, spinning and blending, depending on the final products. To have more uniformity and consistency in fiber blends in lateral and longitudinal directions it is useful to mix the dyed and grey cotton fibers in the blow room stages instead of mixing them in the drawing stage [5]. Yarn imperfections are low in the case that mixing of dyed cotton and grey cotton fibers take place in the drawing stage [1].

In order to improve dyed cotton spinability and its blending with grey cotton fibers, it is necessary to treat the fibers with lubricants, but the type and amount of lubricant affects the efficiency of spinning processes, fiber cohesion and running performance [4]. Among the ambient conditions, the relative humidity and temperature of the spinning section are very important. Yarn properties and fiber arrangement in the yarn structure change with the change in relative humidity during spinning [7]. Cotton *mélange* yarn spinning performance changes with the change in dyed and grey cotton fibers blending ratio. The strength and elongation at the break of the cotton

mélange yarn, spinning processes efficiency and yarn evenness decreases by increasing the blending ratio of dyed cotton fibers [4].

The properties needed to produce a high quality specialty yarn were investigated by testing strength, elongation, evenness and hairiness of the cotton *mélange* yarn. The length and the mechanical characteristics of grey, dyed and blend cotton fibers during spinning operations was assessed using fiber selected from lap and sliver after draw frame II in order to study and compare the extent of fiber damage and its impact on the cotton *mélange* yarn properties.

2. MATERIALS AND METHODS

Three different ring yarns were spun from cotton fibers with 29 mm mean fiber length, 4.2 micronaire fineness and 0.89 fiber maturity index. The abbreviations (R.R.Y), (M.R.Y) and (D.R.Y) were used for ring spun yarn with 100 % grey cotton fibers, 50-50 % blend of grey and dyed cotton fibers and 100 % dyed cotton fibers respectively in order to simplify the results analysis.

Because of existing dyed cotton fibers in the structure of M.R.Y and D.R.Y yarn samples, part of the cotton fibers used in spinning, were dyed before blow room stages. Grey cotton fibers passed through the bale breaker, Axi-flo, Kirschner opening and cleaning machines before dyeing for better dyestuff absorption. Cotton fiber impurities and entanglement decreases after these machines.

At the next step, cotton fibers for dyeing were pretreated with 3 g/l sodium carbonate and 1 g/l scouring agent (containing NaOH and anionic detergent) at 100°C for 45 minutes and washed at 45-55°C for 10 minutes (Figure 1a). The pretreated cotton was dyed with 5 % direct dye (Benzonazol Direct Black/ VSF 600) at 100°C for 60 minutes. In the dyeing process, 6.5 g/l sodium sulfate was used as an accelerating agent. In dyeing, the material-to-liquor ratio was 1: 30 (Figure 1b). After dyeing, cotton fibers were dried with a centrifuge machine at room temperature.

Grey cotton fibers were fed manually to the bale breaker to produce (R.R.Y) a yarn sample. There were Axi-flo, Kirschner cleaning and opening machines between the bale breaker and

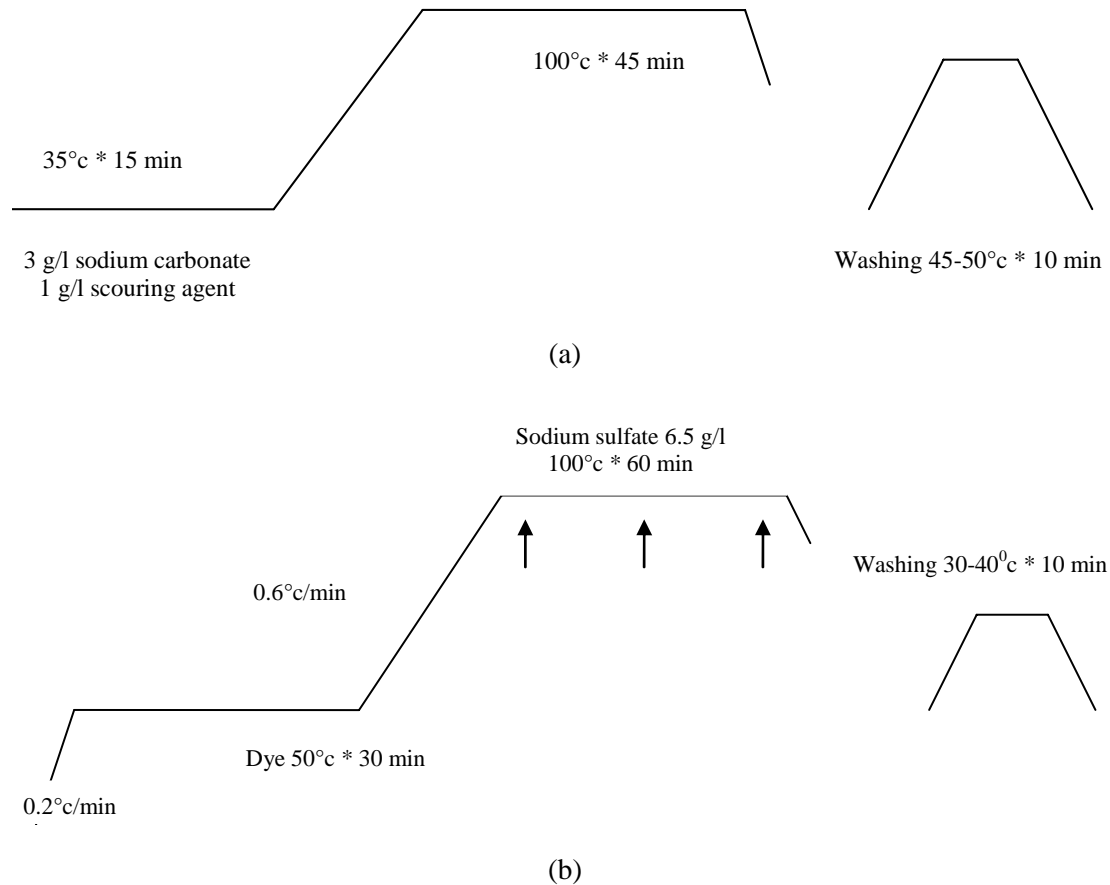


Figure 1. Profile of pre-treatment (a) and dyeing conditions (b) for kg grey cotton fibers.

lap machine. Yarn was spun from lap with 255 g/m linear density. Spinning was carried out at a speed of 10 m/min to produce a 20 Ne yarn while the twist was 720 tpm. The spindle speed was (7250) rpm. Dyed and grey cotton fibers were blended equally (50-50 %) at the beginning of the blow room in order to M.R.Y the yarn sample production. Before blending, dyed cotton fibers were opened manually. An M.R.Y yarn sample was spun through the spinning line described above. Also a D.R.Y yarn sample was spun from 100 % dyed cotton fibers through that spinning line.

The extent of fiber damage and change in the characteristics of grey and dyed cotton fibers during spinning processes were studied and compared by assessing some of the fiber's characteristics. These characteristics were fiber

length, short fiber content, strength and elongation at break of grey, blend and dyed cotton fibers selected after the lap machine and draw frame II. These properties were obtained by Zellweger Uster AFIS pro and Uster tensorapid3. At the next step, yarn count and twist per meter were measured. The load-elongation characteristics of yarns were examined with a Zwick tensile tester (CRE) according to ASTM D2256. The unevenness and imperfections of 5 yarn samples for each group were measured with the Uster tester 4 with a test speed of 400 /min for 2.5.min. The hairiness of the yarns was measured with Shirley YO9810 yarn hairiness friction tester. In the hairiness test, 10 samples with 150 m length were examined. Statistical analysis carried out to analyze the differences between the test results.

3. RESULTS AND DISCUSSION

3.1. Study and Comparison Between the Extent of Fiber Damage for Grey and Dyed Cotton Fibers

It is necessary to have information about the characteristics of grey and dyed cotton fibers and the extent of fiber damage which occurred after dyeing and passing the fibers through a spinning line for explaining the results obtained from the spun yarn samples experiments. Therefore, during the first step of the study, some fiber characteristics that probably change during spinning and dyeing processes were measured. These experiments help to understand and compare the extent of fiber damage. Table 1 shows the results of the experiments applied on gray, blend and dyed cotton fiber samples selected from web and sliver after lap machine and draw frame II.

According to these results and statistical analysis in 95 % level of significance, there is a meaningful difference between the amount of nep per unit weight of grey, blend and dyed cotton fibers examined after both lap machine (web) and draw frame II (sliver). The fiber nep of grey cotton is less than the amount of nep of dyed and blend

cotton fibers. This may be attributed to the dyed cotton fiber entanglement and to the dyed fiber damage caused by high pressure and centrifugal force in dyeing processes. Also the amount of fiber nep in sliver after drawing frame II is less in comparison with the fiber nep in web after lap machine for gray, blend and dyed cotton fibers. Results indicate that the carding machine opens and eliminates some of fiber nep. The mean fiber length by number and by weight for three fiber samples (grey, dyed and blend of cotton fibers) examined after the lap machine was very close together. But the difference between short fiber content (fiber length less than 0.5 inch) by number and short fiber content by weight is significant in the fiber web. These results indicate that cotton fiber dyeing and spinning processes cause fiber shortening and breakage because of an increase of short fiber content after the lap machine for blend and dyed cotton fibers (see Table 1). The extent of fiber damage is less in blow room machines in comparison with the next step (carding machine) because of the low speed of opening elements at this step, sharpness and closer setting of card clothing in carding machine. Fiber damage and

TABLE 1. Characteristics of Grey and Dyed Cotton Fibers After Lap Machine and Draw Frame II.

Fiber Properties	Cotton Fiber Samples					
	G.C.S	G.C.D	B.G.D.C.S	B.G.D.C.D	D.C.S	D.C.D
Fibers Nep/g Sample	529.4	112.4	716.8	121	740.2	155.6
Mean Length by Weight (L_w , mm)	23	23.8	22.6	21.3	22.4	21.7
Short Fiber Content by Weight (sfc _w , %)	10.9	10	9.2	11.3	10.4	12.3
Mean Length by Number (L_n , mm)	18.1	19.8	18.2	17.7	17.4	17.3
Short Fiber Content by Number (sfc _n , %)	29.7	27.9	26.1	27.9	30.5	29.5
Elongation (%)	5.58	6.22	-	-	5.00	6.18
Strength (cN/tex)	33.46	21.39	-	-	26.54	18.66

G.C.S: Grey cotton after lap machine G.C.D: Grey cotton after draw frame II B.G.D.C.S: Blend of grey and dyed cotton after lap machine B.G.D.C.D: Blend of grey and dyed cotton after draw frame II
D.C.S: Dyed cotton after lap machine D.C.D: Dyed cotton after draw frame II.

short fiber content increases in carding machines due to high speed and closer setting of carding surfaces. Therefore after the carding machine, the mean fiber length decreases. The results indicate that, the mean fiber length of grey cotton fibers is greater than that of dyed and blended cotton fibers. Also the mean fiber length and short fiber content of dyed and blend of cotton fibers was nearly the same.

Statistical analysis carried out on the data obtained from load-elongation experiments of cotton fibers during spinning operations indicate that tenacity and elongation at the break of dyed and grey cotton fiber samples selected after both the lap machine and draw frame II were close together. This part of the study shows that the influence of dyeing and spinning processes on fiber length characteristics and entanglement is higher than their influence on tensile properties of the fibers.

3.2. Properties of Spun Yarn Samples The load-elongation experiment results have been illustrated in Figures 2 and 3 for three yarn samples. Statistical analysis shows that there is not a significant difference between elongation at the break of three yarn samples with equal number and twist per meter (Table 2). Tenacity at break of these yarns is different at a 95 % level of significance. Figure 2 shows that tenacity at break decreases from the R.R.Y yarn sample toward the D.R.Y yarn sample.

Fiber length and fiber extent affect strength and elongation at the break of spun yarn. Decrease in fiber length, increase in fiber nep and entanglement after passing fibers through spinning preparation machines and increase in short fiber content, reduce fiber extent in spun yarn structure [8]. Results of experiments carried out in order to investigate the extent of fiber damage indicate that the mean fiber length decreases and short the mean fiber length decreases and short fiber content increases after passing fibers through the lap machine and draw frame II or carding machine for both grey and dyed cotton fibers. The extent of fiber damage and fiber breakage was more for dyed cotton fibers in comparison with grey cotton fibers. Since yarn with the abbreviation D.R.Y has been spun from 100 % dyed cotton fibers, also the amount of fiber nep in web after the lap machine

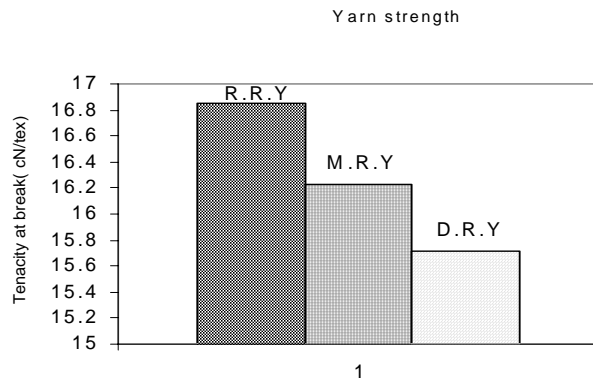


Figure 2. Tenacity comparison between three different yarn samples.

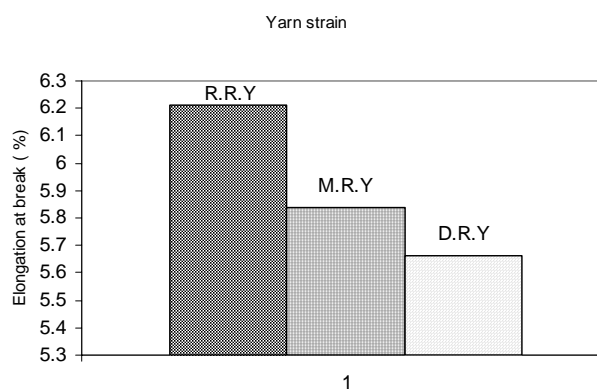


Figure 3. Elongation comparison between three different yarn samples.

and in the sliver after draw frame II was more for dyed cotton fibers therefore tenacity of D.R.Y yarn samples is less than that of two other yarn samples according to the above discussion.

In addition, the results of the yarn evenness experiments (Figures 4 and 5) show that thin places and coefficient of mass variation (Cv %) increase from yarn with the abbreviation R.R.Y toward yarn with the abbreviation D.R.Y. Statistical tests show that the difference between thin places of three yarn samples is considerable at a 95 % level of significance. With an increase in thin places and coefficient of mass variation (Cv %), critical zone, weak points and probability of yarn breakage under tensile load increase.

TABLE 2. Yarn Linear Density and Twist Per Meter.

Parameter	Yarn Count (Ne)			t.p.m		
	R.R.Y	M.R.Y	D.R.Y	R.R.Y	M.R.Y	D.R.Y
Mean	19.72	19.47	19.52	690.10	691.10	673.25
Cv %	2.10	2.97	2.07	2.75	5.03	5.99

Statistical analysis indicates that elongation at the break of three yarn samples does not have a meaningful difference. This is attributed to low elongation of cotton yarn, deformation and entanglement of dyed cotton fibers due to dyeing and spinning processes. Therefore the elongation at the break of M.R.Y and D.R.Y yarn samples increases due to fiber deformation and it is equal with the elongation at break of R.R.Y yarn samples.

Results show that there is a significant difference between the coefficient of mass variation (Cv %), thin places, thick places and nep for three yarn samples according to the data illustrated in Figures 4 and 5. These parameters increase from R.R.Y toward D.R.Y yarn samples. As indicated above, dyeing processes, existing chemical agents, heat and pre-treatment operations reduce mean fiber length due to fiber weakness especially for dyed cotton fibers. These features increase fibers entanglement and fiber nep. Use of short fibers through drawing processes, increases drafting wave and fault. This leads to uneven fiber distribution in strand cross section and along strand axis. Consequently yarn faults and imperfections increase.

Yarn imperfections and coefficient of mass variation (Cv %) of M.R.Y and D.R.Y yarn samples are greater than those of R.R.Y yarn samples due to existing dyed cotton fibers in the yarn structure. These fibers are smaller than grey cotton fibers. The increase in nep is related to the increase in fiber entanglement and the extent of fiber damage after dyeing processes.

There is meaningful difference between yarns hairiness (S_3) according to results obtained from experiments and statistical analysis (Figure 6).

Yarn hairiness increases from R.R.Y toward D.R.Y yarn samples. Also statistical analysis shows that there is not a significant difference between hairiness of R.R.Y and M.R.Y yarn samples. Probably this is attributed to dyed and grey cotton fibers blending (50-50 %) in M.R.Y yarn sample spinning processes. Fiber blending improves and increases the mean fiber length. Therefore mean fiber length of grey and blend cotton fibers become very close together. In the D.R.Y yarn sample, fiber length is less and short fiber content is higher in comparison with two other yarn fiber samples. Short fibers migrate to surface layers of the yarn structure and resist to torsion in twisting operations. This leads to an increase in yarn hairiness. In addition drafting processes during spinning become uneven due to more short fiber content. Therefore uneven fiber distribution affects twist distribution along the yarn axis and increase yarn hairiness.

4. CONCLUSIONS

The production and usage of fancy yarns achieved a daily growth with a great desire for marketing in recent years, but spinning of dyed cotton fiber or usage in fiber blends has not been considerable due to its problems in spinning processes or its imperfect properties. For investigation of those problems, dyeing processes with direct dye was applied on cotton fiber. Then ring cotton mélange yarn was spun after washing, scouring and passing dyed cotton fiber through preliminary opening and cleaning machines. In addition two other yarn samples from 100 % grey cotton and 100 % dyed

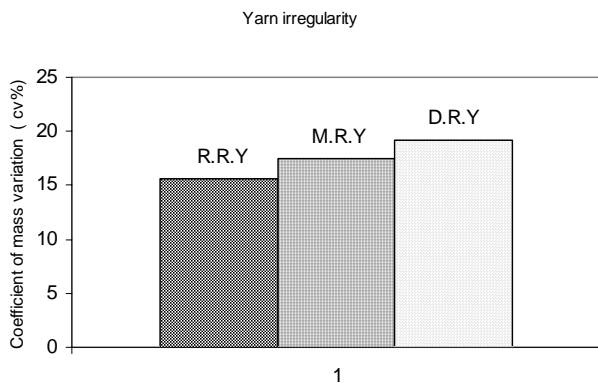


Figure 4. Coefficient of mass variation (Cv %) comparison between three different yarn samples.

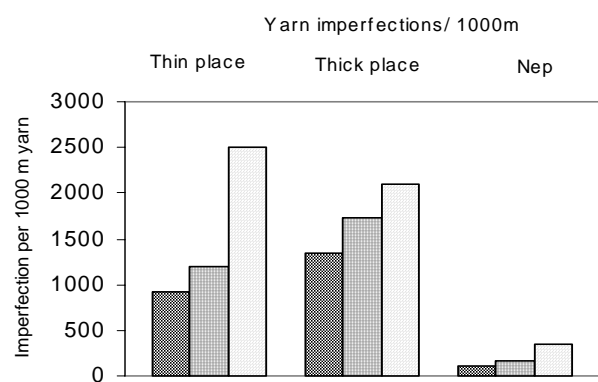


Figure 5. Imperfections comparison between three different yarn samples.

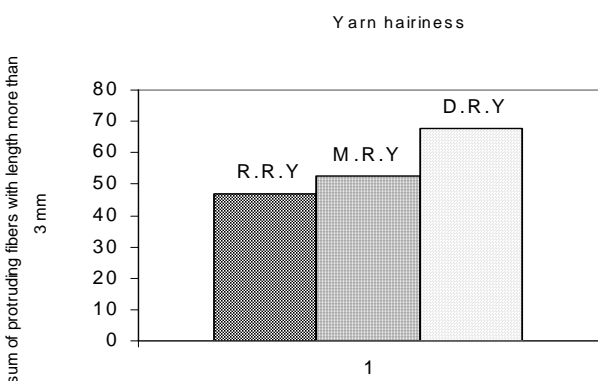


Figure 6. Hairiness (s_3) comparison between three different yarn samples.

cotton fiber were spun for comparison. In order to study fiber damage caused by dyeing and spinning

and also its impact on the yarn characteristics, fibers characteristics and yarns properties were measured and assessed.

The results of this study show that the tenacity and the elongation at the break of dyed and grey cotton fiber selected after the lap machine and draw frame II were very close together. The amount of nep per unit weight of grey, dyed and blend of cotton fibers selected after both the lap machine and draw frame II was different. Also the amount of fibers nep of dyed cotton is greater than that of grey cotton fiber. The amount of fiber nep in sliver after drawing frame II is less than that of the fiber web after the lap machine. Both the mean fiber length by number and by weight for three fiber samples selected from the web was nearly the same. But short fiber content (fiber length less than 0.5 inch) by number and by weight for three fiber samples (selected from web) was different. Also a difference between mean fiber length by number and weight is significant after the carding machine. The mean fiber length and short fiber content of dyed and blend (dyed and grey) of cotton fiber selected from the web and sliver after lap machine and draw frame II were close together. The first part of the study shows that the influence of dyeing and spinning processes on the fiber length characteristics and entanglement is more than their influence on the tensile properties of the fiber.

The elongation at the break of three yarn samples with an equal number and twist per meter was the same but, the tenacity at break decreases from R.R.Y toward D.R.Y yarn samples. The coefficient of mass variation (Cv %), thin places, thick places and nep for three yarn samples were different. These parameters increase from R.R.Y toward D.R.Y yarn samples and was the highest for the D.R.Y yarn sample. Yarn hairiness of the M.R.Y yarn sample was greater than that of the R.R.Y sample and was the highest for D.R.Y yarn sample. Also statistical analysis shows that the hairiness of R.R.Y and M.R.Y yarn samples was the closest together.

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