

The Influence of the Wet Processing Stages on Yarn Processability

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Abstract

In this study, the influence of the wet processing stages, on cotton yarn processability was investigated. The yarn samples were collected after every treatment and tested for knitability efficiency. The total evaluation of the yarn properties was measured by using performance diagram. It was found that the highest processability index was occurred after mercerization conditions of 26°Be at temperature 19°C, vat dyeing and at temperature 19°C, reactive dyeing. While maximum processability index with reactive dyeing was occurred with mercerization condition of 28°Be at temperature 24°C.

Keywords: Knitability; Wet processing stages; Processability index; Processability chart and performance diagram

Introduction

Single jersey knitted fabrics is generally used to make outerwear garments such as T-shirts. The knitted yarns undergo a series of different processing treatments like scouring, bleaching, dyeing, softener padding and relax drying. These processes are carried out to impart a particular property related to that process like scouring for absorbency, bleaching for whiteness, dyeing to impart color to fabric and finishing for improving softness and handle of the fabric.

Finally, there is the fact that, done right, cotton is really an excellent choice for summer weaving specially to summer knitting (ladies 100% cotton T-shirt).

A T-shirt is something to look forward to at the end of a long day. Slipping in to the soft weave of a jersey knit can take us back in time to childhood, our first rock concert or the summer we fell in love with hot pink.

The properties of knitted fabrics are influenced by various parameters like raw materials, yarn structure, fabric structure, processing stages and finishing. The amount of changes occurred in the properties of the fabric due to these parameters makes the subject complex. Further, the determination of the changes in physical and dyeing properties during different stages of wet processing is important for the control of process parameters to get the final product as the requirements of the customer.

There are limited number of studies on influence of wet processing stages and process sequences on the physical, mechanical properties of knitted yarns has been reported so far.

In this study, the influence of the wet processing stages, on the physical-mechanical-dyeing properties of cotton yarns were investigated.

On the other hand, textile finishing processes are usually used to improve the quality of materials. Among these, mercerization which improves handling and appearance of cotton fibers to simulate the superior properties of synthetic fibers.

The extent of changes that occurs depends on the processing time, caustic concentration, temperature, and degree of polymerization and source of cellulose, and the degree of tension [1].

Bleaching ensures the complete removal of impurities by destroying color matters present in the cotton fibers. The bleaching process can

be applied by using hydrogen peroxide or calcium hypochlorite and sodium hypochlorite.

Dyeing is another important wet processing not only to impart colors to materials but also influences on yarn and fabric properties. Cotton and other cellulosic fibers are dyed with direct, sulphur, vat, reactive and more types than for any other fiber. Furthermore, vat dyes are one of the oldest types of dye. Vat dyes in particular give dyeing on cellulosic fibers with the best overall fastness properties [2].

In previous research works, the accessibility was investigated in terms of monolayer capacity, moisture regain, water retention values and diffusion coefficient of the congo red dye after mercerization and other chemical treatments [3].

Mehdi Akhbari [4] investigated the parameters influencing mercerization using RSM method, in order to increase the tensile strength of mercerized yarn. Nazem Samei [5] compared the effects of hot mercerization on open-end and ring spun yarns in slack and under tension conditions. Mercerized yarns were bleached and dyed with reactive dye.

Besides, the influence of different temperature of drying after mercerization and enzymatic scouring through changes in the surface properties and scouring efficiency were investigated [6]. The effect of chemical finishing treatments like scouring, bleaching, mercerization and dyeing on the properties of ring spun and compact yarns were investigated by Subramaniam [7].

Experimental Part

Before setting a machine with ladies, 100% cotton T-shirt, it is normal to check if the structure, yarn parameters and machine settings are correct. There are three separate but interconnected tasks described the processability of this structure with this yarn on this machine, in order to obtain the best productivity and quality.

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Received September 06, 2015; Accepted September 21, 2015; Published September 27, 2015

Citation: El-Hadidy AM, El-Rys SM, El-Hossiny A (2015) The Influence of the Wet Processing Stages on Yarn Processability. J Textile Sci Eng 5: 214. doi:10.4172/2165-8064.1000214

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How to check the processability of the input data is still an open field for researchers. There are three main trends: 1) Expert system, 2) physical process simulation, 3) an engineering approach. Each of these has its own power and its limitation.

The advantages of expert system are in their ability to collect and operate with a large no. of rules. knitability=ease to knit = knitting performance of the knitted structure for a given yarn [8].

In this part of the investigation the influence of wet processing stages on yarn quality will be investigated.

Experimental design

Tables 1 and 2 show the relationship between fabric weight per unit area, fabric structure and yarn count respectively.

These values may get up and down. It may be changed.

Plied combed - ring spun cotton yarn with a count of 20/2 Ne was produced. It was spun from Egyptian cotton G86 with (single twist factor $\alpha = 3.6$ and plied twist factor $\alpha = 3.5$). Besides, grey yarn without any treatment was produced for comparison.

$$\text{Yarn Count (Ne)} * \text{Stitch length} * \text{GSM} = "K"$$

Methods

Mercerization: Mercerization was done on jaeggli mercerizing yarn machine. Ten samples of yarn hanks were treated with five caustic soda concentration ranging from (26°Be` to 34°Be`) with 2°Be` intervals, and at two temperatures (19°C and 24°C), using wetting agent [(6-8) g/l of floranit - 4028 of pulcra chemical]. Both of applied tension and time of treatment were constants. To remove the excess caustic soda after the treatment, the yarn hanks were washed with hot and cold water. The hanks were then neutralized with acetic acid solution (0.5 cm/l) to remove any residual alkali. Yarns were finally rinsed with cold water, squeezed with centrifugal forces, dried at 110°C for 2 hrs.

Bleaching: The same ten samples of the mercerized yarns were bleached in an exhaustion procedure, the bleaching bath containing with (0.5%) hydrogen peroxide, (2%) of sodium hydroxide, (2%) of asbicone (detergent used as assistant factor) and (1%) of egypttool

(wetting agent). The bleaching was carried out at 100°C for 1 hr. Acetic acid was used for neutralization.

Dyeing: Half of the quantity of the mercerized and bleached samples of yarns was dyed with vat dyeing and the other half was dyed with reactive dyeing. The final no. of samples was 20 samples (10 samples of vat dyeing + 10 samples of reactive dyeing). Dyeing process was carried out by exhaustion procedure on proteks bobbin dyeing machine with liquor ratio 1:6.

Reactive dyeing: (1.5%) EcoFix.Blue.R, (5 g/l) Na_2CO_3 and (20 g/l) NaCl were adjusted at 50°C and then raised to 60°C and maintained at this temperature for 90 min to dye as reactive dyeing. Dyed samples were then washed in a soap solution, then, boiled and softened by using fatty acid, finally, squeezed and dried at 100°C.

Vat dyeing: Yarns were dyed in a solution containing (1.5%) Ind.Blue.CLF.(vat dye), (0.1%) NaOH and (5 g/l) Sodium hydro-sulphite. As known vat dyeing is based on the principle of converting water -insoluble vat dye by alkaline reduction to water-soluble leuco compound having affinity to cotton. Sodium hydro-sulphite is used to the reduction process at 60°C then raised to 80°C for 20 min, then washed. Finally, it is oxidized by using H_2O_2 at 50°C for 30 min, then washed and softened by using fatty acid.

Testing methods

Testing methods were carried on the treated yarns after each treatment and compared to grey yarns. Breaking – load was measured by using USTER @ Tensorapid 4. Color strength and degree of whiteness of yarns were observed by using Data color International SF 600 at D65. Yarn abrasion resistance was measured according to ASTM D6611. In order to measure the coefficient of friction of yarns, friction Coefficient meter F-Meter R-1183. The friction coefficient is determined on the F-meter by using the eytwein formula as follow:

$$T2/T1 = e^{\mu\alpha}$$

Where:

T1: tension beyond the friction point.

T2: tension before the friction point.

α : friction angle in rad.

μ : the dynamic coefficient of friction.

Experimental Results and Discussion

At the end of each treatment process, the yarn samples were collected and tested for some of mechanical and color properties. To compare between the effect of mercerization and the effect of bleaching on the yarns, each of braking-load, coefficient of friction, abrasion resistance, yarn count and color properties were measured. These measured properties are considered as index for ability of yarns to work in the next processes.

Breaking-force

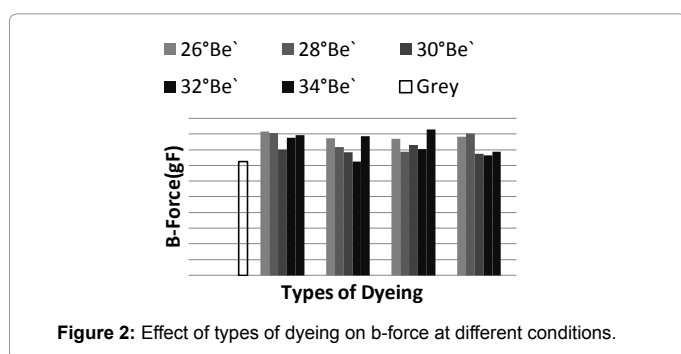
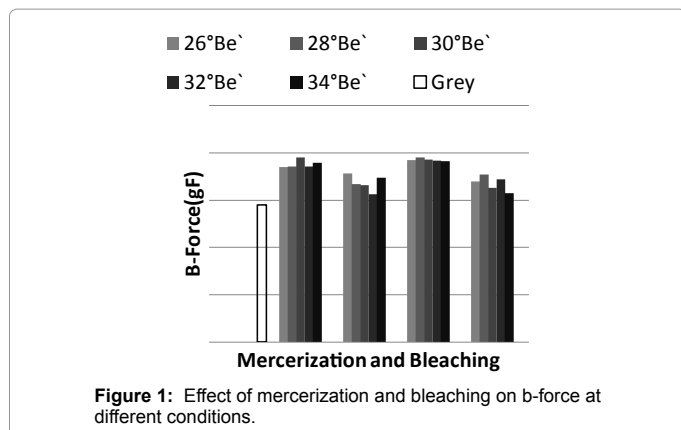
Figure 1 shows the effect of mercerization and bleaching on the breaking force of mercerized yarns at temperatures (19°C, 24°C) and at five different NaOH concentrations. It can be clearly seen that there was an increase in the breaking-load at temperature 24°C more than 19°C compared to unmercerized (grey) yarn. This increase may be due to the effect of mercerization which causes swelling and transforms the cross section of the fibers from bean-shaped cross section to a circular cross section.

Fabrics GSM	Plain (Single Jersey)	Rib (1*1)	Pique	Interlock
100	36.12	47.27	47.27	59.96
120	33.30	39.81	44.32	55.84
140	30.48	37.35	40.98	51.72
160	27.66	34.89	37.64	47.60
180	24.84	32.43	34.30	43.48
200	22.02	29.97	30.96	39.36
220	19.20	27.51	27.62	35.24
240	16.38	25.05	24.05	31.12

Table 1: Selection of yarn count for various GSM for different fabrics.

Fabrics	Constant "K"
Plain Jersey	12068.509
Rib 1*1	16431.497
Rib 1*2	19005.333
Interlock	24013.800

Table 2: Values of constant "K".



Since the surface area of contact of swollen fibers becomes higher, consequently each of inter fiber friction and cohesion are improved which in turn improves the breaking-load. In addition, raising the temperature of mercerization treatment lowers the viscosity of caustic soda solution; hence it facilitates the penetration of NaOH in to the fibers and the swelling of fibers is increased as well. As known, increasing the swelling leads to increasing the degree of mercerization.

After bleaching, there was a slightly decrease in the breaking -load compared to mercerized yarn but still more than the breaking -load of grey yarn for both cases 19°C and 24°C. Breaking-load increased from (1564 to 1786)gF with average value (1684)gF at temperature 19°C, and from (1573 to 1774)gF with average value (1679)gF at temperature 24°C. This decline was occurred because the bleaching using hydrogen peroxide (H₂O₂) may leads to formation of Oxi- Cellulose which known that it decreases the tensile strength of materials.

Figure 2 shows the effect of two types of dyeing on the breaking -load of this yarn. The results showed that the increasing in the breaking-load after vat dyeing was higher than reactive dyeing in both cases 19°C and 24°C compared to grey yarn. This increase in vat dyeing is arranged during washing with alkali soap after dyeing process. In addition, the increase of these spaces between fibers with the presence of vat dyeing may be the reason for the rise of the breaking-load. After vat dyeing, the breaking -load raised from (1596 to 1828)gF with average value (1753) gF at temperature 19°C, and raised from (1575 to 1854) gF with average value (1686)gF at temperature 24°C. On the other hand, after reactive dyeing, the breaking-load raised from (1446 to 1767) gF with average value (1631)gF at temperature 19°C, and raised from (1529 to 1800)gF with average value (1642)gF at temperature 24°C.

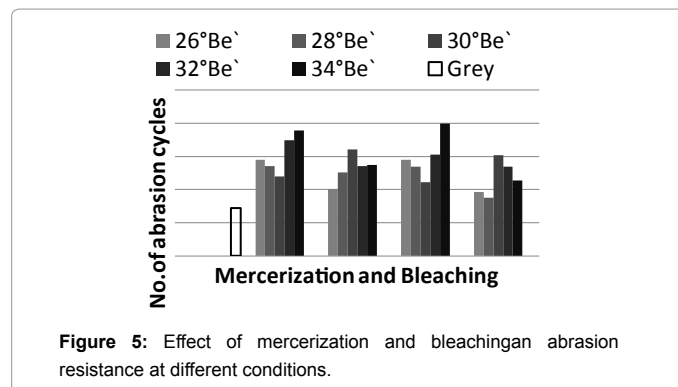
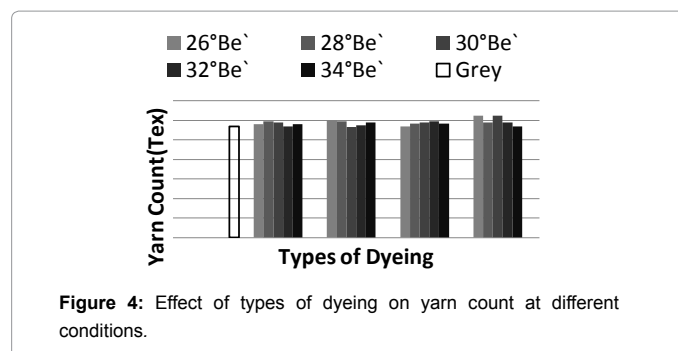
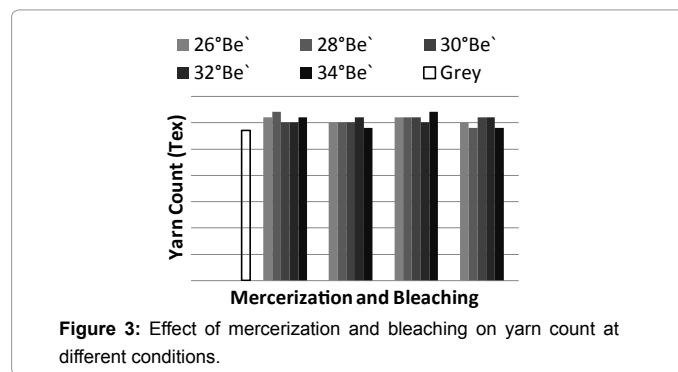
Yarn count

Figure 3 shows the effect of mercerization and bleaching on the yarn count of mercerized yarns at temperatures (19°C, 24°C) and at five different NaOH concentrations. As shown the yarn count increased after both mercerization and bleaching compared to grey yarn, where, after mercerization it ranged between 60 tex and 64 tex in both cases 19°C and 24°C. This means that the temperature of mercerization didn't affect the yarn count here. However, this increase in yarn count was occurred generally due to the effect of mercerizing process which increases the diameter because of swelling with NaOH molecules.

Figure 4 shows the effect of two types of dyeing on the yarn count of this yarn. After vat dyeing, the yarn count raised from (57 to 59.5) tex in both cases 19°C and 24°C, whereas after reactive dyeing, it raised from (56.5 to 60) tex at temperature 19°C and from (57 to 62.5) tex at temperature 24°C.

Abrasion resistance

Figure 5 shows the effect of mercerization and bleaching on the



abrasion resistance of mercerized yarns at temperatures (19°C, 24°C) and at five different NaOH concentrations. It can be clearly seen that there was a greatly increase in the abrasion resistance of the yarns after both mercerization and bleaching compared to grey yarn. This increase in the abrasion resistance after NaOH treatment can be attributed to the degree of substitution of O-Na groups in the cotton fiber. This finding was in agreement with that of Subramaniam [7]. The abrasion resistance increased after mercerization from (48 to 76) no. of abrasion cycles with average value (61) at temperature 19°C, and from (45 to 80) no. of abrasion cycles with average value (60) at temperature 24°C.

After bleaching, abrasion resistance decreased compared to mercerized yarns. This is in fact normally because there is a relation between the strength and abrasion of yarn. As shown, abrasion resistance of bleached yarn increased from (41 to 64) cycles of abrasion with average value (53) cycles of abrasion at temperature 19°C, and from (35 to 61) cycles of abrasion with average value (47) at temperature 24°C.

Abrasion of the yarn is followed by the gradual removal of fibers from the yarns when they are subjected to repeated distortion. Factors affecting the cohesion of the fibers in the yarn and yarn to yarn friction will have influence on the abrasion resistance.

Figure 6 shows the effect of two types of dyeing on the abrasion resistance of this yarn. After vat dyeing the abrasion resistance raised from (89 to 155) cycles of abrasion with average value (106) at temperature 19°C, and from (31 to 97) cycles of abrasion with average value (56) at temperature 24°C.

On the other hand, after reactive dyeing, the abrasion resistance

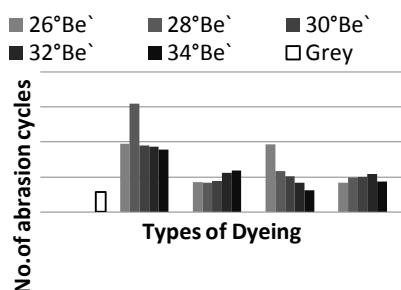


Figure 6: Effect of types of dyeing on abrasion resistance at different conditions.

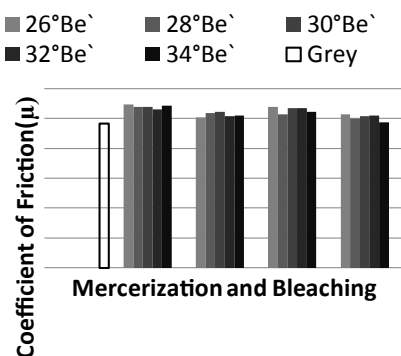


Figure 7: Effect of mercerization and bleaching on coefficient of friction at different conditions.

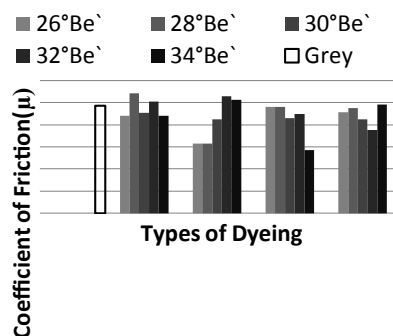


Figure 8: Effect of types of dyeing on coefficient of friction at different conditions.

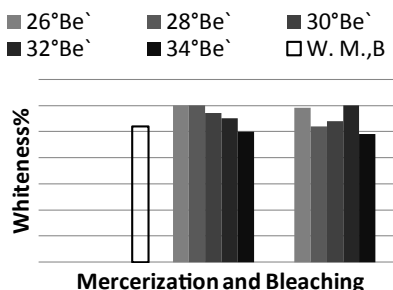


Figure 9: Effect of mercerization and bleaching on the degree of whiteness at different conditions.

increased from (42 to 59) cycles of abrasion with average value (49) at temperature 19°C, and from (42 to 54) cycles of abrasion with average value (48) at temperature 24°C.

Coefficient of friction

Figure 7 shows the effect of mercerization and bleaching on the coefficient of friction of mercerized yarns at temperatures (19°C, 24°C) and at five different NaOH concentrations. The results showed that coefficient of friction increased after mercerization and bleaching compared to grey yarn. After mercerization, it ranged between 0.266 and 0.274 at temperature 19°C, and between 0.258 and 0.27 at temperature 24°C. Similarly to abrasion resistance, the coefficient of friction of yarns after bleaching decreased compared to mercerization, where, the coefficient of friction of yarns after bleached ranged between 0.252 and 0.262 at temperature 19°C, and between 0.244 and 0.258 at temperature 24°C. These findings were in agreement with those of Subramaniam [7].

Figure 8 illustrates the effect of two types of dyeing on the coefficient of friction of this yarn. After vat dyeing, it ranged between 0.22 and 0.27 at temperature 19°C, and between 0.142 and 0.24 at temperature 24°C. Besides, after reactive dyeing, coefficient of friction ranged between 0.158 and 0.264 at temperature 19°C, and between 0.188 and 0.246 at temperature 24°C.

Degree of whiteness

Figure 9 shows the effect of mercerization and bleaching on the degree of whiteness of mercerized yarns at temperatures (19°C, 24°C) and at five different NaOH concentrations. The degree of whiteness was measured compared to the standard degree of whiteness of

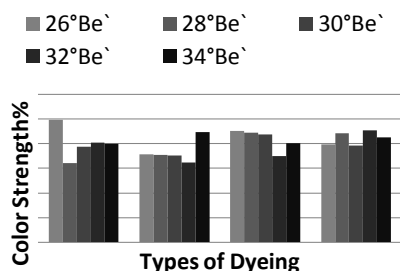


Figure 10: Effect of types of dyeing after mercerization on color strength at different conditions.

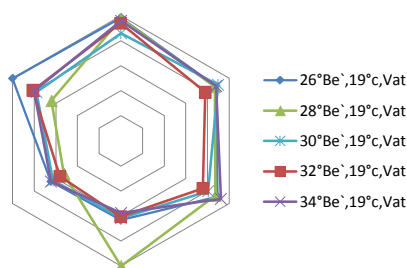


Figure 11: Overall evaluation of yarn properties at 19°C, vat dyeing.

spectrophotometer tester which equals to (189). As shown the degree of whiteness improved after mercerization and bleaching more than after bleaching without mercerization. This improvement occurred due to the effect of mercerizing process which removes some color materials from cellulosic fibers.

After mercerization and bleaching, the degree of whiteness increased from (50% to 60%) at temperature 19°C, and from (49% to 60%) at temperature 24°C.

Color strength

Figure 10 shows the effect of types of dyeing after mercerization on the color strength of mercerized yarns at temperatures (19°C, 24°C) and at five different NaOH concentrations. Color strength was measured compared to two dyed samples with vat and reactive dyes but without mercerization. In general, there was an increase in color strength in reactive dyeing more than vat dyeing. It can be clearly seen that after vat dyeing, color strength increased from (160% to 248%) with average value (201%) at temperature 19°C, and from (161% to 223%) with average value (183%) at temperature 24°C.

This increase may be because mercerizing process converts fibers to cylindrical shape leading to increase the spaces between the fibers, so the dye molecules can easily penetrate to the fibers and increase the color strength of this vat dye. Also, results showed an increase in color strength of reactive dyeing from (174% to 226%) with average value (208%) at temperature 19°C, and from (195% to 227%) with average value (210%) at temperature 24°C because molecules of this reactive dye are bonded with covalent bonds with the fibers.

Overall Evaluation of Yarn Properties

In order to evaluate the overall effect of chemical treatments on the final properties of the yarns, the radar chart statistical method was used. For each level of each of the three parameters of the treatment,

the processability index i.e. The ratio of the yarn polygon area before and after treatment was determined.

Figure 11 represents the processability chart for each level of NaOH concentrations at temperature 19°C and vat dyeing. It was found that the highest area of radar chart was occurred at 26°Be as shown in Table 3 while the lowest area was occurred at 32°Be.

Figure 12 represents the process ability chart for each level of NaOH concentrations at temperature 19°C and reactive dyeing. It was found from the determined index that shown in Table 3 the highest area of radar chart was occurred at 26°Be while the lowest area was occurred at 32°Be.

Figure 13 represents the processability chart for each level of NaOH concentrations at temperature 24°C and vat dyeing. It was found from the determined index that shown in Table 3 the highest area of radar chart was occurred at 34°Be while the lowest area was occurred at 32°Be.

Figure 14 represents the process ability chart for each level of NaOH concentrations at temperature 24°C and reactive dyeing. It was found from the determined index that shown in Table 3 the highest area of radar chart was occurred at 28°Be while the lowest area was occurred at 30°Be. It was noticed that the vat dyeing maintain the physical properties generally more than reactive dyeing. As, the average of improvement in properties of yarns in case of vat dyeing was more

Temperature (°C)	Types of Dyeing	NaOH Conc.(Be [°])				
		26	28	30	32	34
19	Vat	70.90813	66.06878	59.0121	55.78814	64.17274
	Reactive	60.63058	55.17666	54.49425	37.75236	57.82358
24	Vat	60.00243	46.98462	53.61165	46.34582	68.10022
	Reactive	52.55869	64.52037	46.16233	52.45861	48.04597

*Actual area/ideal area.

Table 3: Total area of overall yarn properties.

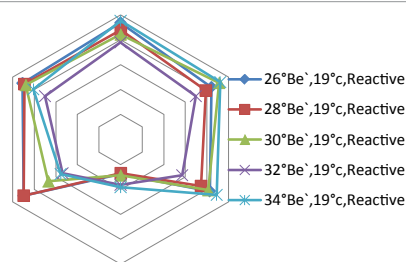


Figure 12: Overall evaluation of yarn properties at 19°C, reactive dyeing.

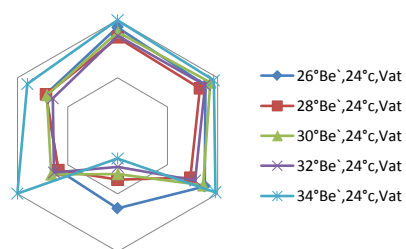
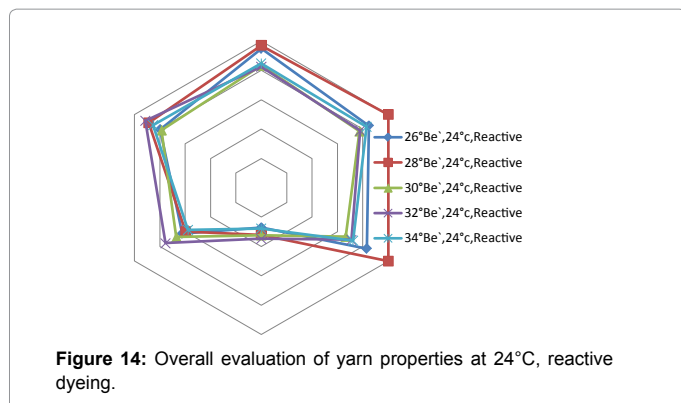


Figure 13: Overall evaluation of yarn properties at 24°C, vat dyeing.



than that of reactive dyeing in both cases 19°C and 24°C (Table 3).

Conclusion

Mercerizing process of yarns at different NaOH concentrations, and at different temperatures, followed by bleaching and dyeing with vat and reactive dyeing have an influence on the final properties of yarns.

After mercerization, there was an increase in the breaking -load in case of 24°C more than 19°C compared to unmercerized (grey) yarn.

- The results showed that the increasing in the breaking -load after vat dyeing was higher than reactive dyeing in both cases 19°C and 24°C compared to grey yarn.
- There was an increase in the breaking force after mercerization more than after bleaching compared to grey yarn.
- The yarn count increased after both mercerization and bleaching compared to grey yarn.
- There was a greatly increase in the abrasion resistance of the yarns after both mercerization and bleaching compared to grey yarn.
- Also after dyeing the abrasion resistance increased compared to untreated yarn.
- The results showed that coefficient of friction increased after mercerization and bleaching compared to grey yarn.

- After dyeing, coefficient of friction had values close to/or less than grey yarn.
- In general, there is an increase of the color properties for both vat and reactive dyeing compared to unmercerized samples because of the mercerization effect.
- The degree of whiteness improved after mercerization and bleaching more than after bleaching without mercerization.
- From the overall evaluation of physical properties by performance diagram, It was found that the highest area of radar chart was occurred at 26°Be` at temperature 19°C, vat dyeing and at temperature 19°C, reactive dyeing.
- The highest area of radar chart was occurred at 34°Be` at temperature 24°C and vat dyeing.
- The highest area of radar chart was occurred at 28°Be` at temperature 24°C and reactive dyeing.
- Vat dyeing maintain the physical properties of the fabric generally more than reactive dyeing.

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