Improvement of Dyeing Characteristic of Cotton/Acrylic Blend Fabric

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Abstract :

Dyeing formulations of Cotton/Acrylic blends are very difficult and can involve a different dye class for each component in one or two baths. The dyeing process is complicated owing to the difference in the nature of these two fibres. Union dyeing for knitted Cotton/Acrylic blend fabric was achieved using one dye (cationic dye) and one bath through a chemical treatment of cotton with an anionic agent (tannic acid). The effect of tannic acid concentration on the color strength of dyed Cotton/Acrylic fabric was carried out. The factors affected the dyeing operation of Cotton/Acrylic fabric with cationic dye in one bath such as dye concentration, salt concentration , pH value, temperature and dyeing time were studied. The optimum condition of dyeing were carried out at 4% dye concentration, 6gm/l Na_2SO_4, pH6 at 90^OC for 75 min. The fastness properties of dyed Cotton/Acrylic blended fabrics dyed with three different cationic dyes at the optimum condition after the treatment with tannic acid were studied.

This work tend to dye Cotton/Acrylic blend fabrics with one dye in one bath to save time , energy and water with soled shad for blend fabrics

Key words

Knitted Cotton/Acrylic fabric- Cationic dyes - Anionization-Dyeing in one bath-Colour strength- Colour fastness properties.

1-Introduction:

Cotton/acrylic blends are widely used in the rapidly expanding sports wear and leisure wear sectors. Fine spun 20:80 to 50:50 cotton/acrylic yarns are used in light weight woven suiting, dress wear and sports wear or knitted underwear, leisure wear and swim wear. (7). The dyes for acrylic fiber are from the cationic or disperse class while those for cellulosic fiber are from the direct, vat, reactive, or sulphur class. This blend always dyed with two dyes in one bath two stages or in two- bath method. Demand has been increasing for active agents which can be imparted to textile materials (fabric and nonwovens) by chemical means in order to create additional properties (functional textiles) (4,3,20). A reactive anionic agent containing dichloro-s-tiazinyl reactive group was synthesized and applied to the cotton fabric .Berberine as a natural cationic colorant showed considerable substantivity towards anionic agent modified fabric(13). Sodium styrene sulphonate , a polymersable anionic surfactant , was polymerized on cotton to get negative charge on the fiber surface. This enabled the fabric to be dyed with a cationic dye with no addition of salt (16). The dyeability of cotton fabrics with natural basic dye, phellodendron amurense rupr, was improved by applying anionic and hydrophobic groups on cotton fibers(12) The anionic properties of cellulosic fabric can be easily and permanently enhanced by using carboxymethylcellulose and Na-HDCT (Sodium hydroxy-2,6-dichloro triazine) as the anchoring chemical. This treatment provides a polymeric anionic layer on the cotton surface, which can even form a basis for introducing further layers of the opposite charge. There is also an improvement in textile properties, such as for example the crease recovery angle (wet and dry), and the wetability and K/S values of cationic dyeing(10).

2-The Aim of work:

This work tends to dye knitted cotton/acrylic fabrics with cationic dye in one bath after the treatment with anionic agent (tannic acid) to get solid shade, improving the dye ability of cotton fibers towards cationic dyes , saving dyeing time,

energy and water by using one-bath one-stage dyeing method and determining the most suitable dyeing conditions.

METHODOLOGY

3- Experimental:

3-1 Materials :

3-1-1 Fabric:

Three different types of knitted fabrics were used throughout this work, namely: Cotton/Acrylic blended fabric (50% cotton and 50% acrylic), 100% Cotton and 100% Acrylic fabric. These fabrics were received from Delta Textile Egypt Company, Cairo, Egypt

3-1-2 Cationic Dyes :

Cationic dyes under trade name of Maxilon produced by Ciba Specialty Chemicals Co. were used throughout this study:

[1] Maxilon Blue GRL(C.I. Basic Blue 41**)**

[2] Maxilon Golden Yellow GL(C.I. Basic Yellow 28)

[3] Maxilon Red GRL(C.I. Basic Red 46**)**

3-1-3 Chemicals and Auxiliaries

Tannic acid ($C_{76}H_{52}O_{46}$), acetic acid, sodium sulphate, sodium carbonate were laboratory grade chemicals. Non-ionic detergent (Hostapal CV-ET) was used in this work.

3-2 Methods:

3-2-1Scouring of Cotton/Acrylic Fabrics:

Fabrics were washed at a bath contain 1 gm/l of non-ionic detergent and 2 gm/l Na_2CO_3 for 20-30 min. at 60-70°C. After washing the fabrics were rinsed and dried.

3-2-2 Treatment with Tannic Acid:

The fabrics (cotton, acrylic and cotton/acrylic) were treated with tannic acid as a surface modifier to confer an anionic character to cotton fabric to enhance its dye ability towards cationic dyes.

To determine the effect of tannic acid on the dye ability of acrylic fiber as well as its effect on cotton/acrylic blend and cotton fabrics, the three types of fabrics were treated with different concentrations of tannic acid(zero, 5%, 10%, 15% and 20%) before the dyeing process.The treatments were carried out for 60 min. , 80°C at L.R. 1:50; after which the samples were dyed with Cationic dye (9).

3-2-3 Dyeing Process :

The treated and untreated fabrics were intered into the dye bath which contain the required concentration of cationic dye Maxilon Red GRL (1-5%) and sodium sulphate Na_2SO_4 (zero-10gm/l)with well stirring to ensure good and uniform distribution of the dye within the aqueous dye bath. The pH of the dye bath was adjusted at (4-9) by adding acetic acid or sodium carbonate solution.

The temperature of the dye bath was gradually raised to(40-100^{O}C) The dyeing process was carried out for(30-90min.) The dyed fabrics were well rinsed in cold water and then washed in a fresh bath containing of 1 gm/l soap (nonionic detergent) at liquor ratio 1:50 for 20min. at 70^{o}C .The dyeing procedure is illustrated diagrammatically in **Figure (1)**

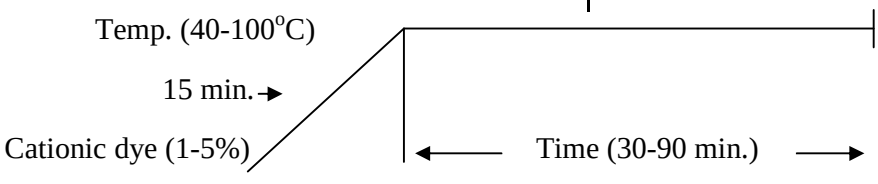


Figure (1): The curve of dyeing procedure

3-3-1 Colour Measurments:

The dyed specimens were subjected to color measurements by using perkin Elmer Spectrophotometer, Model Lambada35 equipped with integrated sphere according to Kubelka- Munk equation .

$$K/S = (1-R)^2 / 2R$$

Where:-

R: Decimal fraction of the reflectance of dyed samples.

K: Absorption coefficient.

S: scattering coefficient

3-3-2 Colour Fastness:

Fastness properties of dyed samples were tested according to AATCC standards.Washing test was carried out according to AATCC test method (Washing Stability P1A) using Shrinkage set.; color fastness to light was according to AATCC test method 16A-1971.color fastness to rubbing was carried out according to Color fastness to rubbing dry & wet C8 using Crock-meter. Color fastness to perspiration was carried out according to AATCC test method 15-1973

4- Results and Discussion:

4-1-Effect of Tannic Acid Treatment:

The word tannin is very old and reflects a traditional technology. "Tanning" **Figure(2).**

The chemical formula for commercial tannic acid is often given as $C_{76}H_{52}O_{46}$, but in fact it contains a mixture of related compounds. Its structure is based mainly on glucose esters of gallic acid . It is a yellow to light brown amorphous powder which is highly soluble in water . Treatment cotton fabrics with tannins either natural or synthetic introduce additional hydroxyl and carboxyl groups on the fiber matrix. Tannic acid is a common mordant used in the dyeing process for cellulose fibers such as cotton especially when using natural dyes for dyeing, since it is used in pretreatment before dyeing or as an after treatment to improve dye fixation and wash fastness properties.

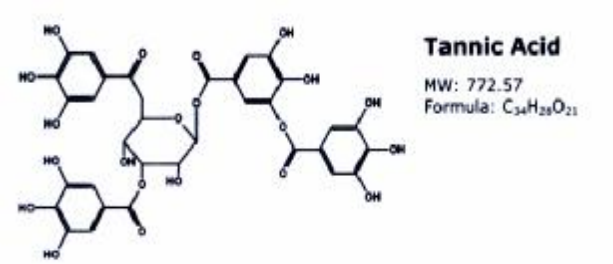
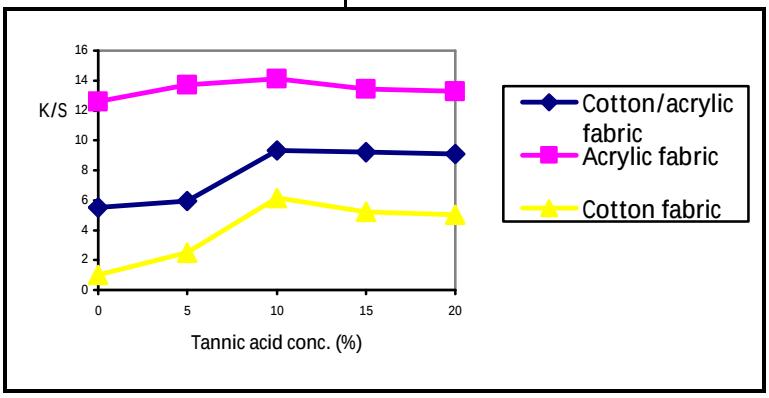


Figure (2): Tannic acid formulas

The fabrics were treated with different concentrations of tannic acid (zero -20%), owf the effect of this treatment on the color strength of dyed fabrics with cationic dye (Maxilon Red GRL) was cited in **Figure(3)** . It can be noticed that the color strength for all treated fabrics used (cotton, acrylic, cotton/acrylic) showed higher color strength than untreated ones. The color strength of dyed cotton fabric increases as the concn. of tannic acid increase till reach 10%, after which there is some decrease in K/S, while in case of acrylic fabrics the color strength showed a slight increasing as the concn. of tannic acid increase. The color strength of cotton/acrylic blend fabrics increase as the concn. of tannic acid increase till 10% then levels off

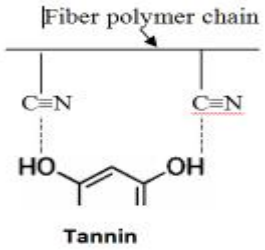


Figure(3): Effect of tannic acid concentration on the color strength (K/S) of dyed cotton/acrylic blend, acrylic and cotton fabrics with cationic dye(Maxilon Red GRL).

Treatment condition: **X %Tannic acid, 80°C, 60min.L R 1:50**

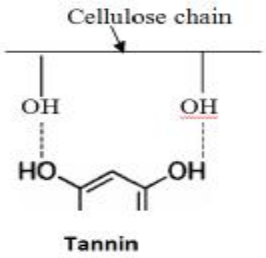
Dyeing condition: **5% Dye , 6 gm/l Na_2SO_4, pH 5,80°C, 60 min., L.R : 1:50**

The adsorption of tannic acid on both cotton and acrylic fibers depend essentially on physical adsorption due to the formation of hydrogen bonding between the aromatic hydroxyl groups of tannin and the polar nitrile (-C≡N) groups present along the polyacrylonitrile polymer chains as follows:



Tannin

On the other hand, hydrogen bonding may also be formed between tannin and the hydroxyl groups of cotton cellulose as follows:



Tannin

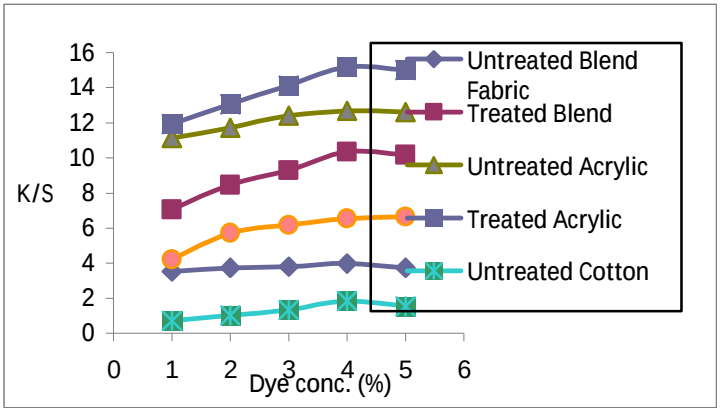
In both cases, the number of anionic sites on both fibers i.e. acrylic and cotton, will be increased as a result of pretreatment with tannic resulting in increasing the receptivity and accessibility of these fibers to cationic dyes.

At higher concentration of tannic acid, it would be expected that problems associated with aggregation would be much pronounced, leading to reduce the substantivity of tannic acid to cotton fabrics and equilibrate its concentration in water and on fiber (14).

4- 2 Effect of Dye Concentration:

Treated and untreated samples were dyed with different concentrations of cationic dye (Maxilon Red GRL) (1-5%) to study its effect on the color strength. **Figure(4)** present the results of this study.

It was found that the color strength (K/S) increases as the concentration of dye increase. The color strength of treated samples were higher than untreated ones for all fabrics used .This results may be due to the electrostatic attraction between the positive charge of cationic dye and the negative charge of treated fabrics .



Figure(4): Effect of dye concn. on the color strength (K/S) of dyed cotton/acrylic blend, acrylic and cotton fabrics with cationic dye(Maxilon Red GRL).

Dyeing conditions:
x% dye concn., 6gm/l sodium sulphate, pH5, 80°C, 60min.L R 1:50

4-3 Effect of Sodium Sulphate Concentration:

The treated and untreated samples dyed with 4% cationic dye (Maxilon Red GRL) using different concentrations of sodium sulphate (0-10gm/l) to study its effect on the color strength. The obtained results are showed in **Figure(5).**

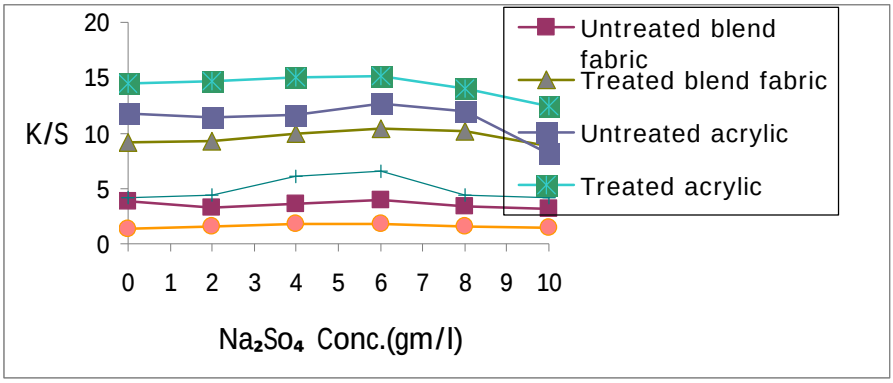
It is clearly noticed, from **Figure(5)** that a noticeable decrease in color strength occurs with addition of sodium sulphate over 6gm/l,

this result is observed for all the used fabric either tannin- treated or untreated.

It is known that acrylic fabrics have negative charge according to the presence of (acidic) groups, in its structure which leads to high attraction with cationic dye so adding salt will decrease the ionic attraction between the dye and acrylic fabrics (1).
The decreasing in the ionic attraction between the positively charged dye cations and the negatively charged fiber surface may be attributed to the following:
a) Sodium ions of the electrolyte compete with the dye cation for acidic sites within the fiber, thus prevent the salt formation with dye cation or retard its formation (2,15)

b)Electrolytes reduce the equilibrium uptake of cationic dyes (2), and diffusion coefficient (2,18).

c)Electrolytes also reduce the zeta potential of the fiber and its effect will depend upon the valency of the electrolyte cation (6) .
In practice, electrolytes is often used to weakly retard dye uptake and thus promote level dyeing , the retarding effect of electrolytes being greatest for cationic dyes of high K-value



Figure(5): Effect of Na_2SO_4 concn. on the color strength (K/S) of dyed cotton/acrylic blend, acrylic and cotton fabrics with cationic dye(Maxilon Red GRL).
Dyeing conditions:
4%dye, xgm/l sodium sulphate, pH5, 80°C, 60min. L. R. 1:50

For cotton fabric, the situation is observed to be different since addition of sodium sulphate to the dye bath causing a substantial increase in dye uptake and subsequently the obtained color strength. The increase of K/S reach its maximum by using 6 g/l Na_2SO_4 over which any further increase in electrolyte concn. may cause a decrease in K/S.

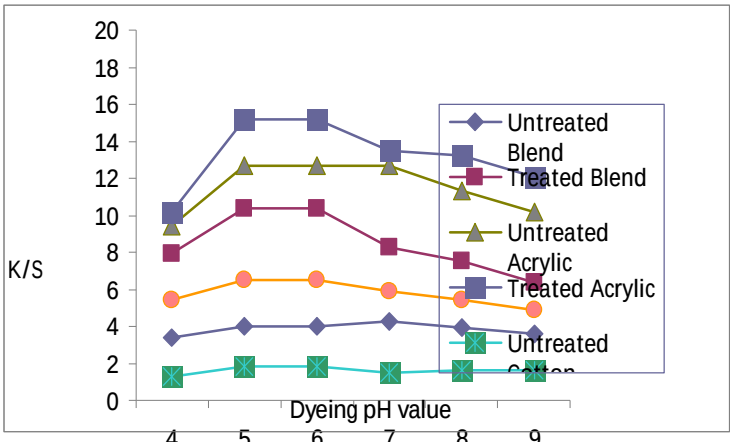
4-4 Effect of Dyeing pH :

For revealing the effect of pH on the dyeing process with cationic dye , dyeing was carried out at different pH values and under constant conditions of treatment with tannic acid. The color strength of the dyed samples were measured and the results are plotted in **Figure(6)**.

It is observed, from the results, that maximum color strengths are attained at pH 5-6 beyond which there is significant decrease in K/S for all the dyed fabrics. The decreasing in K/S below pH 5 may be attributed to the competition between hydrogen ions and dye cations for occupying the negative dye-sites inside the fiber especially the acidic groups present in acrylic fibers (-COOH and $-SO_3H$). Thus by increasing the concentration of hydrogen ions as a result of lowering the pH of the medium the rate of dye uptake on acrylic and cotton/acrylic blend will be reduced. On the other hand, the high adsorption of hydrogen ions will decrease the degree of ionization of the acidic groups in acrylic fibers and thus the zeta potential of the fiber will be changed and reduced (17,5).

It is well known that the exhaustion of cationic dyes on acrylic fiber depends greatly on the ionic attraction between the negatively charged fiber surface and the

positively charged dye cation, therefore, decrease in zeta potential of fiber will be accompanied with reduction in rate of dyeing and dye uptake. It is also observed, from **Figure(6)** that with increasing the pH of dyeing over pH 6 there is a gradual decrease in dye uptake and color strength for all the used fabrics. The decrease in K/S with increasing the pH of dye bath may be explained on the fact that most of cationic dyes are sensitive to alkaline solutions. It was showed that some benzothiazolyl-azo cationic dyes decomposed during dyeing in the pH range 6.6 to 7, since the stability of the dyes in aqueous solution depend on the nature of quaternary groups present in dye molecule(8) Therefore cationic dyes are applied to acrylic fibers under acidic conditions in the range pH=3.5-6 (the range of highest stability for both fiber and dye) and preferably between pH 4.5 and 5.5 (18).It may be concluded from the obtained results and previous discussion that the most suitable pH value for achieving maximum color strength on the tannin-treated cotton/acrylic blend is at pH=5-6



Figure(6): Effect of pH values on the color strength (K/S) of dyed cotton/acrylic blend, acrylic and cotton fabrics with cationic dye(Maxilon Red GRL).

Dyeing conditions: 4%dye, 6gm/l sodium sulphate, pH x, 80^{o}C, 60min., L .R. 1:50.

4-5 Effect of Dyeing Temperature:

Treated and untreated fabrics were dyed with 4% cationic dye (Maxilon Red GRL), 6gm/l sodium sulphate, pH6 at different temperature degrees (40-100^{o}C). The results are cited in **Figure(7)**

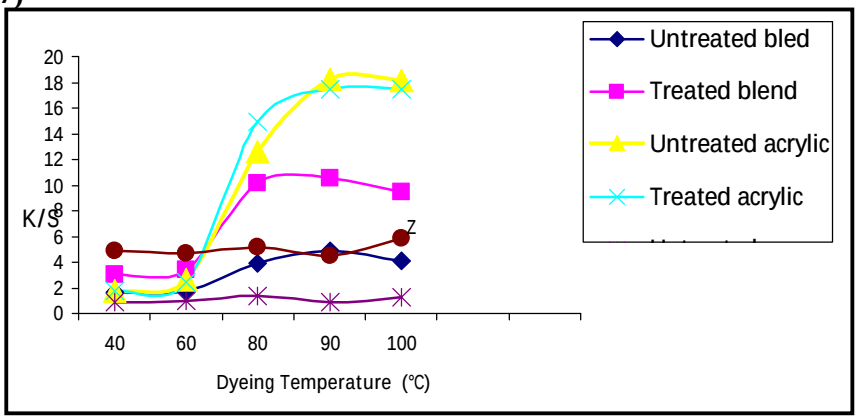


Figure (7): Effect of dyeing temperature on the color strength (K/S) of dyed cotton/acrylic blend, acrylic and cotton fabrics with cationic dye(Maxilon Red GRL**).**

Dyeing conditions: 4%dye, 6gm/l sodium sulphate, pH6,x OC temperature, 60min .L.R. 1:50 .

From **Figure(7)** it can be seen that the color strength increases as the temperature increase till 90°C after which there is no substantial change in color strength. It may be concluded from the results, that 90°C is found to be the most suitable dyeing temp. for giving maximum color strength especially with acrylic and its blend with cotton fiber.

It is well observed from the figure that the K/S of the pretreated samples dyed with cationic dye increase by raising the dyeing temperature till 90oC. There was a remarkable increase in K/S between 60°C and 90°C.This results confirm that dyeing acrylic and cotton/acrylic fabrics was effectively performed when temperature exceed 60°C to reach its maximum at 90°C. This could be due to the possibility of existence of dye molecules in an aggregated form at lower temperatures and the dye solubility will be increased at higher temperature of dyeing (8). On the other hand in case of acrylic fabric, temperature plays a very effective role in determining the state of the molecular polymer chains , by raising the temperature the movement speed of segment polymer chains is increased resulting in such reduction in glass transition temp.(Tg) as well as dyeing transition temp.(Td).As a result the number and volume of voids will be greater and the diffusion of dye molecules will be easier and faster leading to higher amount of dyes inside the fiber (19) The influence of temp. on the rate and magnitude of dyeing process, expressed as %increase in K/S as a result of raising the dyeing temp. from 40°C up to 100˚C is formulated in **Table (1)**

Table (1): Percentage increase in K/S as a function of raising dyeing temperature

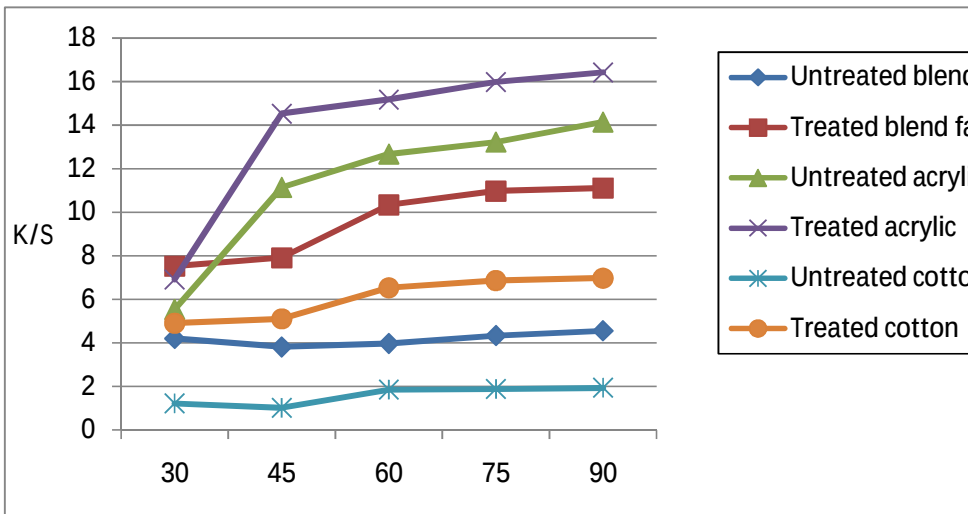
Dyeing Temp. (˚C)	(%) increase in K/S					
	Cotton/acrylic		**Acrylic**		**Cotton**	
	Untreated	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**
40	_	_	_	_	_	_
60	5.88	13.33	44.44	33.33	11.11	_
80	129.41	236.67	600	727.78	55.55	6.12
90	188.23	250	911.11	872.22	_	_
100	141.18	216.67	905.55	872.22	44.44	20.41

It is well noticed from **Table (1)**, that the rate of dyeing is greatly increased at 80°C and reach its maximum at 90˚C which reflect the effect of temp. on both (Tg) and (Td) especially with acrylic fiber

4-6 Effect of Dyeing Time:

Treated and untreated fabrics were dyed with 4% cationic dye (Maxilon Red GRL), 6gm/l sodium sulphate, pH6, at 80°C for different dyeing times (30-90 min.) the results are illustrated in **Figure(8).** It is showed from the figure that color strength increases as the time of dyeing increase .These are predictable results since prolonged dyeing time gave the dye the opportunity to penetrate and diffuse inside the fibers, attaining maximum dye absorption capacity when reaching the dynamic dyeing equilibrium state (19) It is concluded from the previous results that the optimum dyeing time is 75 minutes since the percent increase in K/S as a result of increasing dyeing time from 75 min. to 90 min. is very small and is found to be as follows:

5%, 1.3%, 6.95%, 2.75%, 2.6% and 1.6% for untreated blend, treated blend, untreated acrylic, treated acrylic ,untreated cotton and treated cotton respectively .



Figure(8): Effect of dyeing time process on the color/ strength (K/S) of dyed cotton/acrylic blend, acrylic and cotton fabrics with cationic dye(Maxilon Red GRL).
Dyeing conditions: 4%dye, 6gm/l sodium sulphate, pH 6, 90^{o}C, x min., L.R. 1:50

4-7 Fastness Properties of Dyed Cotton /Acrylic Fabrics:

The fastness properties (washing, rubbing, perspiration and light) of dyed cotton/ acrylic blended fabrics with three different cationic dyes at the optimum condition after the treatment with tannic acid were cited in **Table(2)**

It is clearly noticed from **Table(2)** that the wash fastness, wet and dry rubbing fastness gave ratings between 2 and 4-5 while fastness to acidic and alkaline perspiration showed good results as well as the fastness to light.

Table 16: Fastness properties of dyed cotton/acrylic blended fabrics

Name of Cationic dye	Washing fastness			Rubbing fastness		Perspiration fastness						Light fastness
	Color change	Staining		Dry	Wet	Acid medium		Color change	Alkaline medium		Color change	
		Cotton	Acrylic			Cotton	Acrylic		Cotton	Acrylic		
MAXILON Golden Yellow GL	1	4	4-5	4-5	3	3	3	3-4	3	3	3	2-3
MAXILON Red GRL or Red SL	1	3	4-5	4-5	2-3	3	2-3	4-5	3	3	4	1-2
MAXILON Blue GRL or Blue SL	1	2	3	3	2	1-2	2	3-4	2	2	4	2-3

Conclusion:

Cotton/Acrylic blend fabrics were dyed with cationic dye (Maxilon Red GRL) using one bath and one step after the treatment with tannic acid as anionic agent to give the cotton fabric the ability to dye with cationic dye as well as the acrylic fabric .It was found that the treatment with 10% of tannic acid gave higher color strength .The optimum condition of dyeing cotton/acrylic fabric with cationic dye was 4% cationic dye , 6gm/l Na_2SO_4 , pH 6 at 90^{o}C for 75 min. The fastness properties of washing , perspiration, rubbing and light for dyed cotton/acrylic fabrics with three different cationic dyes gave good results

References:

1-Balmforth, D., Bowers, C.A. and Guion, H.T.; "Journal of the Society of Dyers and Colourists", Vol.80, P.577 (1964).

2-Beckmann, W.; ibid. , Vol.77,P.616 (1961).
3-Beichter, S. P.; Wurster, G. Schmidt et al, Der TEGEWA-Tropftest, Melliand Textil Ber, Vol.68,P. 581-583 (1987).
4- Biswal, D.B., Singh, R.P.; "Carbohydrate Polymer", Vol.57, P.379-387 (2004).
5-Carlini, F.M. and Paffoni, C.; "Tinctoria" , Vol.82, p. 102 (1985).
6-Cegarra, J.; "Journal of the Society of Dyers and Colourists" , Vol.87, P. 149 (1971).
7-Charankar, S.P., Verma, V., Gupta M., Mahendra B. ; "Journal of the Textile Association" – Jan.-Feb. (2007).
8- Ding, M., Ma, S., and Lui, D.; "Analytical Science" , Vol.19. P.1163 (2003).
9- El-Gabry, L.K.and El-Zawahry, M.M.; "Research Journal of Textile and Apparel", Vol. 12, P. 4 (2008).
10- El-Shafei, A., Knittel,D., Schollmeyer , E.; "AUTEX Research Journal" , Vol. 6, P. 3(2006) .
11-Gupta, D., Kumari,S., and Gulrajani,M.;"ColorationTechnology", V.117(6),P.333(2001).
12- Kim ,T. K., Son ,Y. A.; "Dyes and pigments", Vol. 64, P.85-89 (2005).
13- Kim, H., Park, S.; "Dyes and pigments", Vol.75, P.351-355 (2007).
14- Mahangad ,P.R.; Varadarajan,P.V. , Verma, J.K. & Bosco H. ;" Indian Journal of Fibre and Textile Research" ,Vol.34, P.279-282 (2009).
15-Neary, J.P. and Thomas, R.J.; "Amer. D. Reptr." , Vol.46, P.625 (1957).
16- Pisuntornsug, C.,Yanumet, N.O.;Rear E. A. ; "Coloration Technology", Vol.118 ,P.64-68 (2002).
17-Rosenbaum, S.; "Textile Research Journal " , Vol.33, P. 899 (1963).
18-Rosenbaum, S.; "Textile Research Journal ", Vol.34, P. 159 (1964).
19- Shahin, M.F., Ahmed, R.M. and Marie, M.M.;" 5th International Confrance of Textile Research Division NRC",Cairo,Egypt,April 6-8 (2008).
20-Tomasino, C.; "Chemistry &Technology of Fabric Preparation"; Department of Textile Eng.Chemistry and Science College of Textile, NCSU, Raleigh, North Carolina ,P.97-108 (1992).