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Synergistic Effect of Alkali Treatment and Microwave Irradiation on the Dyeing Properties of Polyester – Wool Blend Fabrics

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Abstract: ***The synergistic effect of alkali treatment and microwave irradiation on the dyeing properties of polyester – wool (PES/W) blend fabrics with reactive and acid dyes under conventional and microwave heating conditions was studied. Critical factors included the mode of treatment, concentration of alkali; time of treatment and time of dyeing are investigated. Morphological structures observations of treated fabrics with potassium hydroxide (KOH) by conventional method (thermal heating) and microwave dielectric heating were examined in order to determine whether the microwave treatment could be used to maintain the morphological architecture of treated fabrics without damage. Results showed that the colour strength of treated fabrics with 4 g/l KOH using microwave heating for 2 min was three times higher than the fabrics treated using thermal heating. Besides, the microwave energy supplied for 20 min is adequate to accomplish the required dyeing balance that can bring about reasonable colour strength, percentage of fixation and fastness properties. However such dyeing balance is not achieved within the range of 5-20 min with thermal heating. The monitoring of morphological changes and physical properties indicated that microwave can guarantee the wool/polyester goods without deterioration inside and outside heat in a very short time with fabric dyeing uniformity, and good colour fastness.***

Keywords: Alkali treatment, Microwave heating, Polyester – wool blend fabrics, Morphological architecture and Reactive & acid dyes.

1. Introduction

During the two decades the use of microwave dielectric heating in the field of chemistry has become a powerful method to enhance chemical processes [1- 4]. This phenomenon is dependent on the ability of a specific material (solvent or reagent) to absorb microwave energy and convert it into heat. The electric component of an electromagnetic field causes heating by two main mechanisms: dipolar polarization and ionic conduction [5].Since the early days of microwave synthesis, the observed rate accelerations and sometimes altered product distributions compared to oil-bath experiments have led to speculation on the existence of so-called “specific” or “nonthermal” microwave effects [6,7]. Historically, such effects were claimed when the outcome of a synthesis performed under microwave conditions was different from the conventionally heated counterpart carried out at the same apparent temperature. Today most scientists agree that in the majority of cases the reason for the observed rate enhancements is a purely thermal/kinetic effect, that is, a consequence of the high reaction temperatures that can rapidly be attained when irradiating polar materials in a microwave field [8]. Polyester fibre (PET) is a polymer prepared from dimethyl terephthalate and ethylene glycol. Because of its compact structure and the absence of hydrophilic groups (since hydroxyl and carboxyl groups may be present in macromolecules only as terminal groups) the fibre acquires hydrophobic properties. By the way, it does not swell in aqueous media and this has an unfavorable effect on the dyeability of these fibers [9]. Polyester fabric (filament by filament) was pretreated in a microwave oven in the presence of solvents and subsequently dyed with commercial disperse dyes at different temperatures and durations of time. It was observed that the solvent interaction with the polyester could be enhanced by using microwave heating. Solvent molecules interact rapidly, not only with the surface of the fiber but also with the interior parts [10].Wool has been widely used as a high – quality textile material, such as suiting, carpet, blankets and shawls due to its good elasticity, flexibility, wettability, biodegradability and biocompatibility. Compared with other natural fibers, wool has a relatively higher dielectric constant and so microwave irradiation can generate heat on wool fiber through non – contact heating. So that the use of high efficient microwave heating method in wool dyeing and finishing achieving energy saving and high efficiency has been the subject of considerable interest [11]. The chemical nature of wool keratin is such that it is particularly sensitive to alkaline substance [12]. It was shown that the combined cystine of wool could be divided into two, approximately equal, main fractions differing in their rate and mode of reaction with alkalis. They also found that reaction previously suggested by linkage with the formation of a sulfhydryl compound and a sulfenic acid according to the following scheme:

$$R – CH2 – S\text{-}S\text{-}CH2 – R \rightarrow R\ CH2\ SH + HOSCH2R \quad [13]$$

Microwave modification improves the dyeability of wool fabrics. The longer the treatment time the greater is the color yield of dyed fabric. The exhaustion and fixation of the treated wool fabrics are improved with microwave irradiation. The microwave treatment also causes a slight damaging effect on the surface scale-like structure of the wool fiber, promoting the adsorption and permeation of the dye molecules into the wool fibers. This improves the extent of reaction between the reactive dye and wool fibers [13]. A microwave heating system has been also used to apply chitosan guanidine hydrochloride derivatives on wool fabric to impart antimicrobial finishing [11]. The effect of microwave irradiation on the physical property, chemical structure, surface morphological structure, and fine structure of wool fabric was investigated. The results showed that the physical properties of the treated wool fabrics as well as the surface morphological structure in term of concentration of cystine S—S bonds and crystallinity were affected with microwave irradiation conditions. However, the chemical structures are not significantly changed [14].The main aim of the present work is to take the advantage of microwave heating with reference to energy and time as well as the alkali treatment to be used as a synergistic effect in dyeing the blend of polyester – wool fabrics by reactive and acid dye in one step without affecting or deterioration the physical properties of the fabrics. The other purpose of the work was also designed to be focused on developing an alternative simple, economical and eco-friendly dyeing process by microwave technology to eliminate the sever dyeing conditions of polyester in its blend with respect to time, temperature, pressure and auxiliaries. It is a green chemistry that it avoids the use of toxic or hazardous reagents and solvents and can be influential in saving time, energy and materials.

2. Materials and Methods

2.1. Material

Polyester / wool (55-45) (PES/W), Blend fabrics were supplied by Misr EL – Mahalla CO., Egypt. The fabrics were soaped with (2g/l) nonionic detergent solution (with a liquor ratio 1: 25, at 60˚C , for 45 min. , then rinsed twice in cold water , and dried at room temperature .. The commercial dyes samples are used C.I. Reactive violet 5, C. I. Acid Blue 203, C.I. Acid Red 315 from Egypt Colors (Egypt) and C.I. Reactive Red 84 from Ciba – Geigy (Switzerland) and C.I. Reactive Red 24 from Isma dye (Egypt) . All other chemicals are laboratory grade ones.

2.2. Methods

Alkaline treatment

One series blend fabrics are subjected for alkali pretreatment by thermal heating in water solution containing 5 g/l of KOH for 30 min at 98 ◦C with a liquor ratio 1:25. Another series of blend fabrics were alkali pretreated in water solution containing different concentration 1,2,3,4, 5 g/l of KOH for different time intervals 2, 3, 5 min in microwave with a liquor ratio 1:25. Subsequently, the samples were rinsed twice in cold tap water and then dried at room temperature.

2.3. Dyeing process

The dye bath was prepared by accurately weighing the dyestuff to give the prescribed shade. The dye was pasted with small amount of water and wetting agent. The paste was then dissolved by adding hot boiling water. The dye solution was then added to the dyeing bath, adjusted to pH 4-4.5 using acetic acid for acid dye and 4. 5- 5 for reactive dye.

2.3. 1.Dyeing using conventional method

The dye bath was heated to 98°C for 1 h. Then added the dye solution (1% shade) L.R. 1:50. The dyed samples were then thoroughly washed in warm and cold water and air-dried.

2.3. 2.Dyeing using microwave method

The dyeing process was applied to the fabric via exhaustion technique by using microwave irradiation. The dye solution (1% shade) L.R. 1:50 at power level 90%, for different time (5-30 min.). After dyeing, the fabrics were removed, rinsed and dried at room temperature.

3. Measurements

3.1 Colour strength

Spectral reflectance measurements of the dyed fabrics were carried out using a recording filter Spectrophotometer Hunter lab (The Colour Management Company, USA). The colour value expressed as K/S of the dyed samples was determined by applying the Kubelka-Munk equation (Judd & Wyszecki , 1975) [15].

$$K/S = \frac{(1-R)^2}{2R} - \frac{(1-R_o)^2}{2R_o}$$

Where R: is the decimal fraction of the reflectance of the dyed substrate.

R_o: is the decimal fraction of the reflectance of the undyed substrate

S: is the scattering coefficient

K: is the absorption coefficient

3.2. Exhaustion &Fixation% measurement

The reflectance of dyed fabric was measured on reflectance spectrophotometer Model Ics-Texicon Ltd. The percentage of dye exhaustion (E %) was calculated according to Eqn. 1:

$$E\% = \left\| A_0 - A_f / A_0 \right\| \times 100$$

Where A_0 and A_f are the absorbance of the dyebath before and after dyeing, respectively, at λmax of the dye (355-400 nm). The absorbance was measured on a Shimadzu UV-2401 PC UV/Vis spectrophotometer

The extent of dye fixation ratio of Sumcron Orange HSR (220%) on polyester fabric was determined by measuring K/S values of the dyed samples before and after soaping using Eqn. 2:

$$F\% = \left[\frac{(K/S)_{after\ soaping}}{(k/s)_{before\ soaping}} \right] \times 100$$

3.3. Washing Fastness

The washing fastness of the dyed blend fabrics are assessed according to the AATCC test method 61–1075 using a laboratory laundrometer [16].

3.4. Tensile strength and Elongation

The tensile properties of polyester / wool blend fabrics before and after treatment were evaluated using an Instron Tensile Tester (USA) according to ASTM D 76 Standard Specification for Textile Testing Machines.

3.5 Moisture Regain

Measurements of moisture regain of the fabrics were performed using the standard ASTM method 2654-76 (West, 1981) [17]. Moisture regain of the samples was calculated according to the following equation:
The moisture regain of the samples were calculated according to**:**

$$\text{Moisture regain \%} = \frac{W_1 - W_2}{W_2} \times 100$$

Where:
W1: Weight of sample after saturation in the standard humidity atmosphere.
W_2 : Constant weight of dried sample.

3.6 Scanning electron microscopy

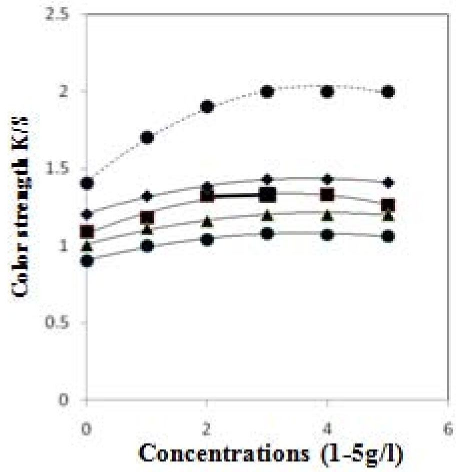
The surface morphology of the treated fibers was examined using scanning electron microscopy (SEM; Model JSM-5600LV, Jeol, Tokyo, Japan).

4. Results and Discussion

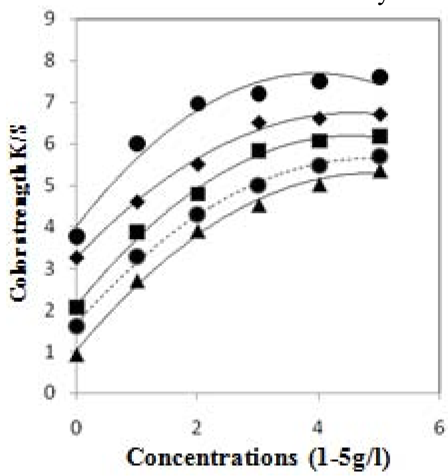
As, polyester is a low cost, high performance semi-crystalline thermoplastic polymer with excellent properties, the difficulty in dyeing of polyester and its blends as it inquire a high temperature and pressure combined with a lot of auxiliaries has been the subject of considerable important. Conventional processing of the fabrics has been consumed a large amount of energy and auxiliaries. Microwave heating as an alternative to conventional heating technique, has been proved to be a more rapid, uniform and efficient. The microwave can easily penetrate the particle inside and all particles can be heated simultaneously, thus reducing heat transfer problems. The energy of microwave photons is quite low compared with the chemical bond energies and, thus, microwaves do not directly affect the molecular structure of a compound and cannot deteriorate the physical properties of fabrics and they do not change the electronic configuration of atoms [18-21].

4.1. Effect of varying the concentration of KOH on the color strength of dyed polyester /wool blend fabric

To optimize the alkali concentration in the treatment conditions, PES/W was pretreated at different concentrations of KOH (1-5g/l) using thermal and microwave heating. The pretreated samples were then dyed by Reactive dyes, C.I. Reactive violet 5, C.I. Reactive Red 84 and C.I. and acid dyes, C.I.Acid Blue 203 and C.I. Acid Red 315 using the conventional thermal dyeing method as described in the experimental section. The results are presented in Figures 1, 2 for thermal and microwave treatments respectively. The results clearly demonstrate that alkali treatment using microwave heating enhances the colour strength of acid and reactive dyestuffs (Fig 2). The average increase in color strength was approximately about ca. 90% in short time treatment of microwave heating (2 min) which is clearly more important commercially. On the other hand, there is no any significant increase in color strength using the thermal treatment (Fig1). It is clear from Figure 2 that the K/S value increases when the KOH concentration increases to 4g/l, irrespective of the type of dye used. The K/S values are ranged from 2 to 7 and 1 to 2 for the microwave treated fabrics and the conventional treated fabrics, respectively. The superiority of microwave heating could be arisen from that, the materials can absorb microwave energy directly and internally and convert it into heat. This leads to advantages such as rapid, controlled, selective and uniform heating in a short time. In conclusion, the alkali treatment and microwave heating increases the swelling degree of PES/W in a short time, accelerate the dye uptake and reach equilibrium swelling on using 4g/l of KOH. However, the thermal treatment did not affect the fabric swelling or a limited swelling has been obtained. The result also reveals some variation between the different kinds of dyes in the colour strength value acquired. This may be attributed to the variation between them in their chemical structures, substantively and dye infusibility. Therefore the alkali treatment by microwave heating became the method of choice for further experiments in this study.



• C.I .Acid Red 315 ♦C.I. Reactive Violet 5 ■C.I. Acid Red 203 •---• C.I. Reactive Red 84 Δ C.I. Reactive Red 24
Figure 1: Effect of KOH concentration (1-5g/l) by using thermal heating on color strength dyeing of polyester/ wool blend fabric with reactive & acid dyestuff



• C.I .Acid Red 315 ♦C.I. Reactive Violet 5 ■C.I. Acid Red 203 •---• C.I. Reactive Red 84 Δ C.I. Reactive Red 24
Figure 2: Effect of KOH concentration (1-5g/l) by using microwave irradiation on color strength dyeing of polyester/ wool blend fabric with reactive & acid dyestuff

Treatment condition: Two series of blend fabrics were carried out in water solution containing 1-5 g/l of KOH with a liquor ratio 1:25 at 98 ˚C and 30min., in case of using

thermal heating. But for 2 min. in case of using microwave Irradiation.
Dyeing condition: 1 % dye, pH 5-5.5 for reactive dye, 4-4-4 for acid dye, L.R 1:50 using thermal heating at 95 ^oC for 1 h.

4.2. Effect of pretreatment time of microwave heating on the color strength of dyed polyester/wool blend fabric

To determine the effect of pretreatment time of microwave heating on K/S values, PES/W samples are pretreated by KOH (4g/l), for time range between 2-5 min. The pretreated samples were then dyed by reactive and acid dyes, using the conventional thermal dyeing method. The results are given in table 1. It is clear that the K/S of dyed polyester/wool is not affected by increasing the time of exposure for microwave irradiation. It is worthy to mention that the microwave energy supplied for 2 min for alkali treatment of PES/W is adequate to accomplish the required swelling balance that can bring about reasonable color strength. On other word, microwave radiation processing can heat up in a very short time, and then achieve the effect of rapid swelling without deterioration of fabric blend under the effect of alkali. It seems that such balance is not affected by further increase of microwave irradiation time. Accordingly, further studies of the pretreatment conditions were carried out in microwave for 2 min.

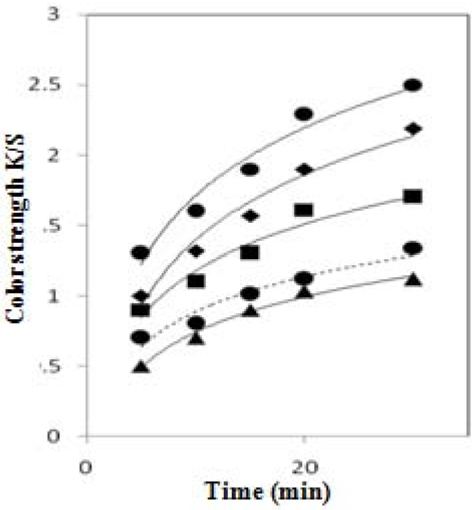
Table 1: Effect of time on treatment of polyester/ wool blend fabric using microwave irradiation

Dyes / Time (min.)	C.I .Acid Red 315	C.I. Reactive Violet 5	C.I. Acid Red 203	C.I. Reactive Red 84	C.I. Reactive Red 24
2	7.6	6.8	6.1	5.3	5
3	7.7	6.9	6.3	5.3	5.2
5	7.7	6.9	6.3	5.3	5.2

Treatment condition: Blend fabrics were carried out in water solution containing 4 g/l of KOH with a liquor ratio 1:25 for
different time (2, 3, and 5) min., by using microwave irradiation.
Dyeing condition: 1 % dye, pH 5-5.5 for reactive dye, 4-4-4 for acid dye, L.R 1:50 using thermal heating at 95 ^oC for 1 h.

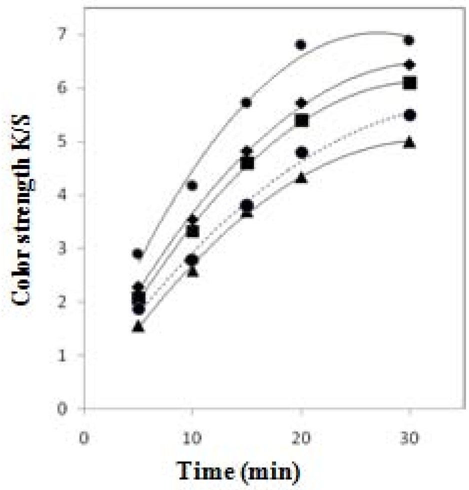
4.3. Effect of microwave and conventional dyeing time on the color strength of dyed polyester/wool blend fabric

The appropriate dyeing time by conventional and microwave method was determined by alkaline pretreatment of PES/W (4g/l) in microwave for 2 min. The pretreated samples were then dyed by reactive and acid dyes, using the conventional and microwave dyeing method for time range between 10-30 min. The results are presented in Figures 3, 4 for conventional and microwave dyeing respectively. It is clear that the microwave dyed samples acquire color strength higher than the conventional samples at the same dyeing time, irrespective of the dye used. Microwave technology for dyeing of PES/W solid color processing, mainly uses the help of thermal effect mechanism. The dyeing process by microwave irradiation appears as a repeatedly polarization process, the microwave energy is converted into heat energy in a fast time. At this point, part of dye molecules with the effect of microwave can easily induced and the temperature is raised. Dye molecules can quickly get the maximum kinetic energy which is accompanied by a gradual fiber expansion, thus achieve the result of rapid dyeing and solid color in a short time. However, the short dyeing time by thermal heating is not adequate to achieve the required dyeing balance and bring reasonable color strength. The thermal dyeing looks to need longer time than 30 min to reach equilibrium dyeing compared to the microwave dyeing. This may be also attributed to the presence of macromolecule hydrophobic polyester.It does not swell in aqueous media by thermal heating using the normal conditions cited for microwave irradiation and this has an unfavorable effect on the dyeability of its blend. On other word, the conventional thermal dyeing needs a sever conditions of temperature, pressure and auxiliaries. It is also clear that the required dyeing balance was attained at 20 min of microwave heating (Fig4) to accomplish reasonable colour strength. Here too, the slight increase of dyeing time by microwave may be attributed to the presence of hydrophobic polyester, which needs a time to attain adequate crystallinity and orientation to facilitate its dyeing by non conventional dye. The aforementioned results provided supporting evidences for the synergistic effect of alkali treatment and microwave irradiation on the color strength of dyed PES/W. The superiority of microwave dyeing than the conventional dyeing, also support the findings of many researchers [22-24].



- C.I .Acid Red 315 ♦C.I. Reactive Violet 5 ■C.I. Acid Red 203 •---• C.I. Reactive Red 84 Δ C.I. Reactive Red 24

Figure 3: Effect of time of dyeing (10- 30) on color strength dyeing of polyester/ wool blend fabric with reactive & acid dyestuff by using thermal heating



- C.I .Acid Red 315 ♦C.I. Reactive Violet 5 ■C.I. Acid Red 203 •---• C.I. Reactive Red 84 Δ C.I. Reactive Red 24

Figure 4: Effect of time of dyeing (10- 30) on color strength dyeing of polyester/ wool blend fabric with reactive & acid dyestuff by using microwave irradiation

Treatment condition: Blend fabrics were carried out in water solution containing 4g/l of KOH using microwave irradiation with a liquor ratio 1:25 for 2 min.

Dyeing condition: 1 % dyes (1-5), pH 5-5.5 for reactive dye, 4-4- 4 for acid dye, L.R 1:50 for (10- 30) by using thermal
heating or using microwave irradiation

4.4. Exhaustion and Fixation percentage of color on dyed PES/W

The fixation of dyes on the fabrics plays a vital role for considering suitability of any dyestuff for continuous processing. During dyeing, the dye molecule has to enter the intercellular spaces of the fibre in which it has to be fixed. Relevant researches show that microwave heating caused certain effect on dyeing rate and fixation. It is known that microwave heating enhances diffusion of organic molecules in polymers and this can increase the fixing rate of dyes into the polymeric textiles [20]. In order to verify the above viewpoint, alkaline pretreatment of PES/W (4g/l) in microwave for 2 min was carried out. The pretreated samples were then dyed by reactive and acid dyes, using the conventional and microwave dyeing method for 20 min. Fig 5, 6 show the mode of dyeing and their effect on exhaustion and fixation % of color on PES/W fabrics. It is clear that the acid and reactive dyes exhausted and fixed on PES/W fabrics by microwave dyeing more than thermal heating. It seems that the alkaline pretreatment increases fixation and exhaustion % of dyes, irrespective of the mode of dyeing used. This finding supports the synergistic effect of alkali with microwave heating. The fixation% values are ranged from53 to 92 and from 44 to 67 for the microwave and conventional dyeing, respectively. The increase of fixation % with microwave dyeing can be attributed to the increase of dye penetration and its interaction with fibres. The heating mechanism is through ionic conduction, which is a type of resistance heating. Depending on the acceleration of the ions trough the dye solution, it results in collision of dye molecules with the molecule of the fibre. In other word, the fixation rate is accelerated by microwave energy, which can be explained in a strong physical attraction between dye molecules and treated fabrics. Rapid heating with microwave changes additives molecular orientation, and makes it speed up the movement and increase friction, and then achieves the goal of rapid dyeing fixation. It is found that, compared with reactive dyes, acid dyes achieve the highest fixation rate in 20 min of microwave heating. The small size of acid dyes helps and affects the penetration of the dye and also the depth to which the penetration takes place in the fabric. This makes microwave superior to conventional dyeing techniques. Microwave is a volumetric heating (fast) whereas conventional is a surface heating (slow).

Based on the above results few points may be concluded; (1) the alkaline thermal treatment did not affect the fabric swelling and microwave heating increases the swelling degree of PES/W in a short time. (2) Microwave energy supplied for short time is adequate to accomplish the required swelling balance of PES/W fabrics that can bring about reasonable color strength without deterioration. (3) The conventional dyeing looks to need longer time than 30 min to reach equilibrium dyeing compared to the microwave dyeing. It needs a sever conditions of temperature, pressure and auxiliaries, and required dyeing balance was attained at 20 min of microwave heating (4) the fixation rate of dyes on PES/W is accelerated by microwave energy. (5) The above mentioned results provided supporting evidences for the synergistic effect of alkali treatment and microwave irradiation on the dyeing of PES/W.

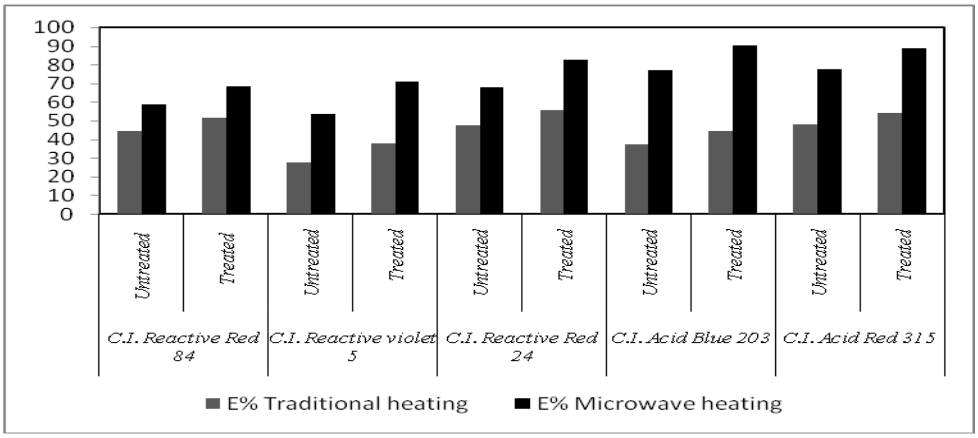


Figure 5: Effect of dyeing time on Exhaustion of polyester/ wool blend fabric with reactive & acid dyestuff dyed with conventional heating and microwave irradiation

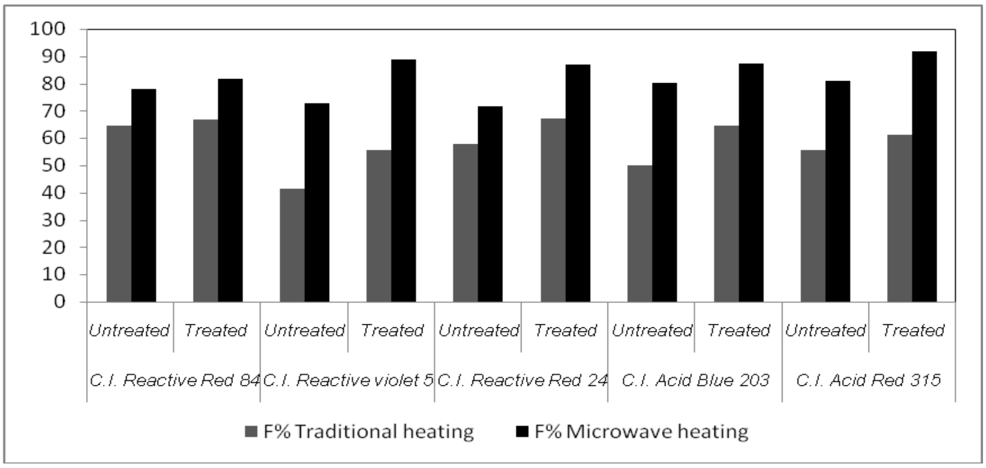


Figure 6: Effect of dyeing time on Fixation of polyester/ wool blend fabric with reactive & acid dyestuff dyed with conventional heating and microwave irradiation.

Treatment condition: Blend fabrics were carried out in water solution containing 4 g/l of KOH with a liquor- ratio 1:25 for 2 min, by using microwave irradiation at 90% Watt.

Dyeing condition: 1 % dyes (1-5), pH 5-5.5 for reactive dye, 4-4- 4 for acid dye, L.R 1:50 for 20min., by using thermal heating at 98^{o}C or using microwave irradiation at 90% Watt.

4.5. Fastness Properties

The durability of colors on the treated and untreated PES/W fabrics by microwave and conventional dyeing method was evaluated in term of fastness towards rubbing, washing, and perspiration using the gray scale as shown in Table 4.The standard assessment has the fastness rating 5.,4,3,2 and 1 on the grey scale respectively. As shown in Table 4, the fastness properties of treated PES/W fabrics are more resistant against rubbing, washing and perspiration than those untreated ones, irrespective of mode of dyeing and type of dye. Besides, the dyed PES/W by microwave heating displayed higher color fastness than those dyed with the same color by thermal curing. It was also appeared that the fastness of microwave dyed samples ranged from 3 to 5, while the conventional dyed samples from 2 to 5. The high color resistance of microwave dyed samples may be attributed to the increase of dye penetration and its interaction with fibers, where the fixation rate of the colours is accelerated by microwave energy.

Table 4: Fastness properties of polyester/ wool blend fabric dyed with reactive & acid dyestuff

Dyes	Samples	Washing fastness		Rubbing fastness		Perspiration fastness			
						Acidic		Alkaline	
		Alt	St.	Wet	Dry	Alt.	St.	Alt	St.
Microwave method									
C.I. Reactive Red 84	Untreated PES/W blend fabric	4	4	3-4	4	4	4	4	4
	*Treated	4-5	4-5	4	4-5	4-5	4	4-5	4
C.I. Reactive violet 5	Untreated PES/W blend fabric	4	4	4	4	4	4	4	4
	*Treated	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
C.I. Reactive Red 24	Untreated PES/W blend fabric	3-4	3-4	3-4	4	4	4	4	4
	*Treated	4-5	4-5	4	4	4-5	4-5	4-5	4-5
C.I. Acid Blue 203	Untreated PES/W blend fabric	4	4	4	4	4	4	4	4
	*Treated	4-5	4-5	4	4-5	4-5	4-5	4-5	4-5

C.I. Acid Red 315	Untreated PES/W blend fabric	3-4	3-4	3-4	4	4	3-4	4	4
	*Treated	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Conventional method									
C.I. Reactive Red 84	Untreated PES/W blend	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4
	*Treated	4	4	3-4	4	3-4	4	4	4
C.I. Reactive violet 5	Untreated PES/W blend fabric	3-4	4	3	4	4	4	4	4
	*Treated	4	4	3-4	4	4	4	4	4
C.I. Reactive Red 24	Untreated PES/W blend fabric	3-4	3-4	3	3-4	3-4	3-4	3-4	3-4
	*Treated	4	4	3-4	4	4	4	4	3
C.I. Acid Blue 203	Untreated PES/W blend fabric	3	3	2-3	3-4	3-4	3-4	3-4	3-4
	*Treated	4	4	4	4	4	4	4	4
C.I. Acid Red 315	Untreated PES/W blend fabric	3	3	3	3	3-4	3-4	3-4	3-4
	*Treated	4	4	4	4	4-5	4-5	4	4

***Treatment condition**: Blend fabrics were carried out in water solution containing 4 g/l of KOH with a liquor- ratio 1:25 for 2 min, by using microwave irradiation at 90% Watt..

Dyeing condition: 1 % dyes (1-5), pH 5-5.5 for reactive dye, 4-4- 4 for acid dye, L.R 1:50 for 20min., by using thermal heating at 98^{o}C or using microwave irradiation at 90% Watt

4.6. Tensile strength, elongation% and moisture regain

The most drawbacks of chemical modification of textile fabrics by conventional heating are the slight deterioration of the physical properties; tensile strength, elongation% and moisture regain. For this in mind, the monitoring of physical properties of untreated and alkali treated PES/W under the effect of microwave irradiation has been investigated, to indicate that microwave can guarantee the wool/polyester goods treatment without deterioration. The measurement of the physical properties of treated PES/W under the effect of conventional heating was also performed for comparison. PES/W samples were pretreated with KOH (4g/l) using thermal and microwave heating. The results of tensile strength, elongation % and moisture regain are given in table 2. It is generally clear that, there is no any distinctive increase or decrease in the tensile strength, elongation % of treated fabrics under the effect of microwave irradiation. However, a relative increase of moisture regain has been observed. The results showed that the short time microwave heating maintain the main physical properties and increases the wetability of treated PES/W without deterioration. On the other hand, the conventional heating has a negative impact on the physical properties of treated fabrics. For example, the tensile strength decreased from 76.3 to 45.6 and moisture regain decreased from 4.01 to 2.47 after alkali treatment for 30 min. The deterioration of physical properties under the effect of thermal heating may be attributed to the prolonged long time exposure of wool fabric for alkali which has been seriously affect the main structure of wool chains. The heating mechanism of conventional heating, may be also taken into account, where conventional techniques heat a surface, the microwaves heat the whole volume of the treated object.

Table 3: Effect of treatment on tensile strength, elongation and moisture regain % of polyester/ wool blend fabric by using conventional heating and microwave irradiation respectively

Samples	Tensile strength (kgf/mm2)	Elongation %	Moisture regain %
Untreated polyester/ wool blend fabric	76.3	26.6	4.01
*Treated polyester/ wool blend fabric	45.6	31.6	2.47
**Treated polyester/ wool blend fabric	75.3	25.3	4.16

Treatment condition: Blend fabrics were carried out in water solution containing 4g/l of KOH with a liquor -ratio 1:25 and 98 ^{o}C for 30 min., in case of using conventional heating and for 2 min., at 90% watt in case of using microwave heating

4.7 Morphological observation

The TEM photographs of untreated and alkali treated PES/W under the effect of thermal and microwave heating are shown in Figure 7 (a-c), respectively. It is clear from the morphologies of untreated fibers that untreated PES/W fibers were clean, smooth and have a typical scale pattern. It is also clear that the microwave treatment causes no damaging effect on the surface scale-like structure of the PES/W fiber and relatively maintains the morphological architecture of treated fabrics without deterioration. On the other hand, the scale-like structure of the PES/W fiber was deteriorated under the effect of thermal heating. Here too, this may attributed to sensitivity of wool to alkaline substance and the long time of exposure. It is clearly seen that microwave treatment causes opening up of surface structure compared with untreated one, which has been emphasized by high swelling and an increase of moisture regain.

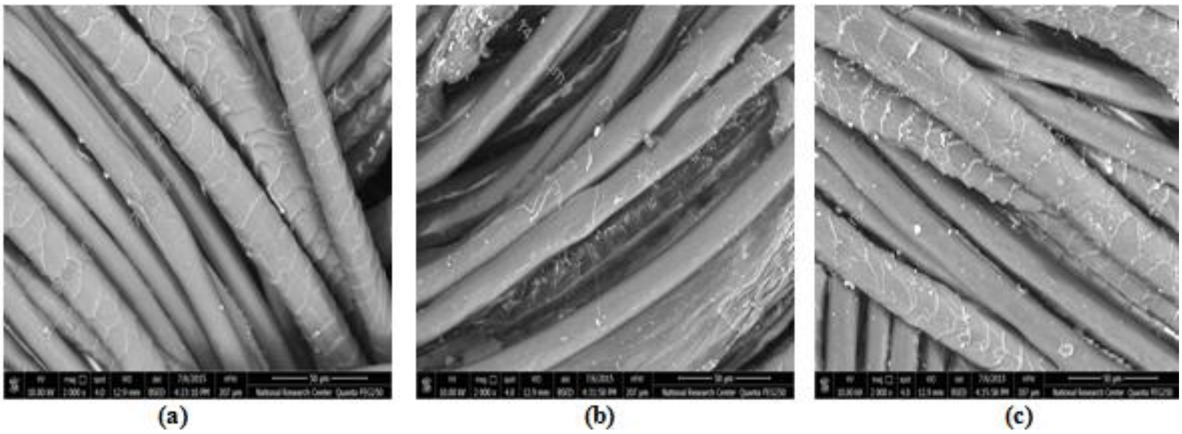


Figure 7: SEM photographs of PES/W fabrics: (a) Untreated, (b) Treated with KOH by thermal heating and Treated with KOH by microwave heating

5. Conclusions

Microwave heating and alkali treatment are used as a synergistic effect in dyeing of polyester/wool blend by reactive and acid dyes in one step without affecting or deterioration the physical properties of the fabrics. The alkali treatment using microwave heating enhances the color strength of acid and reactive dyestuffs. The short time treatment (2 min) of microwave heating is adequate to accomplish the required swelling balance that can bring about reasonable color strength; however, the thermal treatment did not affect the fabric swelling. The conventional dyeing seems to need longer time than 30 min to reach equilibrium dyeing compared to the microwave dyeing. It needs a sever conditions of temperature, pressure and auxiliaries, and the required dyeing balance was attained at 20 min of microwave heating. The fixation rate of dyes on PES/W is accelerated by microwave energy due to the heating mechanism and the increase of dye penetration and its interaction with fibers. The microwaves heating maintain the morphological architecture and physical properties of treated fabrics without deterioration. The results of this study provided supporting evidences for the synergistic effect of alkali treatment and microwave heating on the dyeing of PES/W. Work is currently underway to investigate the the synergistic effect of alkali treatment and microwave heating on the dyeing properties of various fabric blend other than polyester/wool.

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