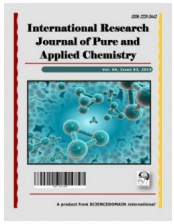


International Research Journal of Pure & Applied Chemistry
8(2): 103-111, 2015, Article no.IRJPAC.2015.078
ISSN: 2231-3443

SCIENCEDOMAIN *international*
www.sciencedomain.org

Dyeing of Nylon 66 Fabrics Using Disperse Dyes by Microwave Irradiation Technology

K. Haggag[1], M. M. El-Molla[1*] and K. A. Ahmed[1]

[1]Dyeing and Printing Department, Textile Research Division, National Research Centre, El- Bohouth St., P.O.12622, Dokki, Giza, Egypt.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2015/17922
Editor(s):
(1) Wolfgang Linert, Institute of Applied Synthetic Chemistry, Vienna University of Technology Getreidemarkt, Austria.
Reviewers:
(1) Tarek Abou Elmaaty, Textile Dyeing Finishing, Damietta University, Egypt.
(2) Oluwayemisi Abiodun Babatunde, Department of Chemistry, Nigerian Defence Academy, Kaduna, Nigeria.
(3) Hai-Yin Yu, College of Chemistry and Material Science, Anhui Normal University, China.
(4) Anonymous, Malaysia.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1050&id=7&aid=9351

Original Research Article

Received 30th March 2015
Accepted 29th April 2015
Published 22nd May 2015

ABSTRACT

Dyeing of nylon66 (polyamide) fabrics with disperse dyes; blue 56 and red 60 was carried out using microwave irradiation technique. Different parameters mainly, dyeing time, dye concentration, power of microwave, and Liquor ratios were studied. The results obtained as a result of the two dyeing technique were compared. The results revealed that, the microwave technique save about 40 min. in the dyeing time; in addition the microwave technique used no carrier and dispersing agent, reduced time, energy and cost effective as well. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples were measured and their values ranged from very good to excellent. The Microwave Irradiation Technique saved time, energy and money.

Keywords: Dyeing; nylon fabrics; disperse dyes; microwave irradiation.

**Corresponding author: E-mail: mohamedelmolla212@gmail.com;*

1. INTRODUCTION

Microwave irradiation is one of powerful techniques of non-contact heating, because the dielectric substances with large dielectric loss constant vigorously fever by vibration and rotation of permanent dipoles in microwave field. Microwave has been used for reacting, heating and drying cellulose materials [1]. The main difference between conventional heating and microwave heating is the way in which heat is generated. In conventional processing, energy is transferred to material through convection, conduction and radiation of heat from the surface of the material. In contrast, microwave energy is derived directly from materials through molecular interactions with the electromagnetic waves. The uniqueness of the microwave is to process materials with selective energy, higher rate, uniform heating and energy conservation [2-7]. The utilization of green chemistry techniques is dramatically reducing chemical waste and reaction times as has recently been proven in several organic syntheses and chemical transformations [8]. Methods to lower the curing temperature have received the most attention because the high temperature cure process not only wastes energy but also creates the risk of destroying substrates that cannot endure high temperature processes. Radiation curing technologies (UV and microwave) are used in much industrial applications as well as in the textile area [9,10] because of low energy consumption, short start-up period, fast and reliable curing, low environmental pollution, fixation at room temperature, space saving, etc. Microwave irradiation is a well-known method for heating and drying materials and is utilized in many private households and industrial applications. It offers a number of advantages over conventional heating**,** such as non-contact heating (circumventing the decomposition of molecules close to the walls of the reaction vessel), instantaneous and rapid heating (resulting in a uniform heating of the reaction liquor), and highly specific heating (with the material selectivity emerging from the wavelength of microwave irradiation that intrinsically excites dipolar oscillation and induces ionic conduction) [11]. The main objective of the present work was to dye the polyamide fabrics with disperse dyes using microwave irradiation to save time, energy and money.

2. MATERIALS AND METHODS

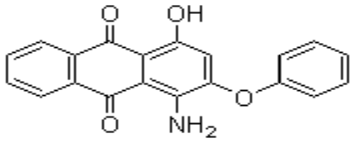
2.1 Materials

2.1.1 Nylon66 fabric

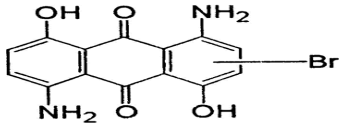
Nylon 66 fabric of about 150 g/m^2 (supplied by El-Nasr Company for spinning, weaving and knitting) was treated with a solution containing 2 g/L detergent, 2 g/L sodium carbonate at 80C for 1 hour, then thoroughly washed and air dried at room temperature.

2.1.2 Dyestuffs

Disperse red (C.I. Red 60) and Disperse blue dyes (C.I. Blue 56), supplied by Clarinet Co.



Disperse red 60



Disperse blue 56

2.1.3 Chemicals

Carrier, dispersing agent, acetic acid, were all of laboratory grade chemicals.

2.2 Methods

2.2.1 Dyeing procedure

Samples of polyamide fabrics were dyed using disperse dye 0.5- 3% owf,1g/L carrier,1g/L dispersing agent, with L: R 1: 20. The temperature was slowly raised to 100C and dyeing continued further for 45 min., other samples of polyamide fabrics were dyed using disperse dye 0.5- 3% o.w.f., 0 g/L carrier, 0 g/L dispersing agent, with L: R1:5 to 1: 20, using microwave (Milestone Start synthesis Microwave Synthesis Lab station, USA) irradiation with power 200-600 Watt, for 1-5 min., hot rinsing and air-dried. Finally the samples were dried and assessed for color strength and over all fastness properties.

2.3 Measurements and Analysis

2.3.1 Color measurements

Color strength expressed as K/S was measured according to a previously reported method [12].

2.3.2 Fastness properties

Fastness properties to washing, rubbing and perspiration were measured according to a standard method [13].

3. RESULTS AND DISCUSSION

3.1 Dyeing of Nylon Fabric Using Conventional Heating Technique

Polyamide obtained from poly condensation of hexamethelene diamine with adipic acid, so the nylon contains amide groups, carboxylic end groups, amino end groups, amide end groups, a greater part of the polar groups are amide groups. There are few strongly hydrophilic groups, fiber swelling is little and dye penetration is difficult.

The effect of dye concentration on the color strength of dyed polyamide fabrics at Liquor ratio 1:20, dyeing temperature of 100ºC, dyeing time 45 minute, carrier 1 g/L, dispersing agent 1 g/L at pH=4.5, using disperse dye blue 56. It was noticed that an increase in the dye concentration increases the color strength. Increase in the dye concentration from 0.5, 1, 2 and 3% increases the color strength to 3.5, 7.9, 12.37 and 14.6 K/S respectively as shown in Fig. 1.

Table 1, shows the effect of dye concentration on the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye blue 56 using conventional heating technique. Generally speaking, the fastness properties to rubbing, either wet or dry, washing, light fastness and color fastness properties to both acidic and alkaline perspiration for the dyed samples ranged from very good to excellent.

3.2 Dyeing Polyamide Fabric Using Microwave Irradiation Technique

3.2.1 Effect of dyeing time on the color strength

The effects of dyeing time on the color strength of the dyed polyamide fabrics upon using disperse blue 56 using microwave irradiation as presented in Fig. 2. There is an increase in the time up to 3 min with a corresponding increase in the color strength (K/S) which remains constant up to 5 minutes for 0.5 percent shading while a slight increase was observed for 3.0 percent shading. This suggests that the time of dyeing should not be more than 5 min.

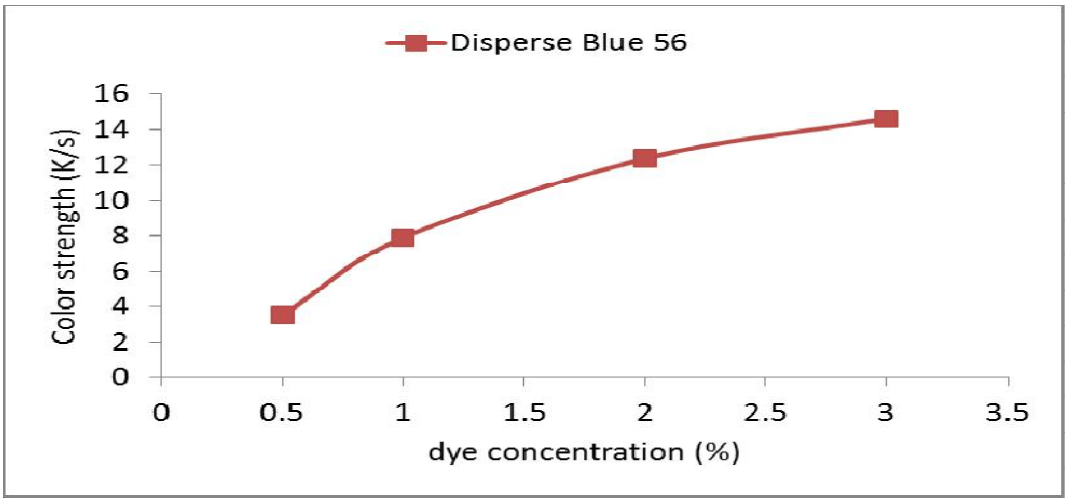


Fig. 1. The effect of dye concentration on the color strength of dyed polyamide*fabric with disperse dye blue 56 using conventional method

**Liquor ratio1:20, Temperature 100°C, dyeing time; 60 minute, Carrier 1g/L, dispersingagent 1g/LpH = 4.5*

Comparing between the conventional and microwave technique as shown in Tables 1 & 2, the color strength and the overall fastness properties of dyeing polyamide fabric using disperse blue 56 using conventional technique at Liquor ratio 1:20, Temperature 100ºC, dyeing time 45 minute, Carrier 1 g/L, dispersing agent 1 g/L , pH = 4.5 and dye concentration 0.5 & 3%) and the color strength and the overall fastness properties of dyeing polyamide fabric using disperse dye blue 56 using microwave irradiation technique i.e.(Microwave power 200, Liquor ratio 1:20, Temperature 100ºC, dyeing time 5 minute , Carrier 0 g/L, dispersing agent 0 g/L, pH=4.5, and dye concentration 0.5 & 3%) are 3.5&14.6 and 5.6 &15.5 K/S respectively , the increase in the color strength upon using microwave irradiation may be due to the fact that microwaves chemically modify textile surfaces and provide significant advantages over conventional systems with regard to reducing the time and energy that is associated with conventional system [14].

Table 2 shows, the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranging from very good to excellent. From the data we found that using microwave irradiation technique saves about 40 min., zero carrier and dispersing agent used. This resulted in a reduction in time and energy used for complete dyeing process.

3.2.2 Effect of liquor ratio on the color strength

The effect of liquor ratio on the color strength of the dyed polyamide fabrics upon using dispersed dye blue 56 using microwave irradiation was shown in Fig. 3. It was observed that there is an increase in the liquor ratio from 1:5 to 1:20, which led to a slightly decrease in the color strength (K/S). For example increasing the liquor ratio from 1:5, 1:10, and 1:20 led to increase of color strength of 16.2, 15.9, and 15.5 K/S up on using 3% dye concentration. This suggests that using L: R 1:5, will save water.

The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranged from very good to excellent as presented in Table 3.

3.2.3 Effect of power of microwave used on the color strength

The effect of power of microwave used on the color strength of the dyed polyamide fabrics upon using disperse dye blue 56 as shown in Fig. 4. An increase in the power from 200 to 600 watt, led to slightly increase in the color strength. Fig 4 shows that increasing the power from 200, 400, and 600, the color strength (K/S) increases to 16.2, 16.2, and 16.4 respectively. This suggests that the power used in case of dyeing polyamide fabric should not exceed 200 watt. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values also ranged from very good to excellent as shown in Table 4.

3.3 Dyeing of Polyamide Fabric by Conventional Heating Technique and Optimum Condition of Microwave Irradiation Technique Using Disperse Red 60

3.3.1 Dyeing of polyamide fabric using conventional heating technique

The effect of dye concentration on the color strength of dyed polyamide fabrics at Liquor ratio 1:20, Temperature of dyeing 100^{o}C, dyeing time 45 minute, carrier 1 g/L, dispersing agent 1 g/L at pH=4.5, using disperse dye red 60. The results presented in Fig. 5 show that the increase in the dye concentration led to an increase in the color strength. An increase in the dye concentration from 0.5, 1, 2 and 3% increases the color strength to 4.5, 8.5, 11.47 and 15.6 K/S respectively.

The effect of dye concentration on the color strength and the overall fastness properties of dyeing polyamide fabric using disperse dye red60 using conventional heating technique. The result presented in Table 5 shows that the fastness properties to rubbing, either wet or dry, washing, light fastness and color fastness properties to both acidic and alkaline perspiration for the dyed samples ranged from very good to excellent.

3.3.2 Dyeing of polyamide fabric using microwave irradiation technique

The effects of dye concentration on the color strength of the dyed polyamide fabrics upon using disperse dye red 60 and using Microwave Irradiation as shown in Table 6. An increase in the dye concentration led to an increase in the color strength (K/S). This was shown by increasing the dye concentration from 0.5, 1, 2 and 3%, the Color strength increased to 4.9, 8.9, 11.9 and 16 K/S respectively. The result in Table

6 shows that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranged from very good to excellent.

Comparing the conventional technique with microwave technique as shown in Tables 5 & 6, the color strength and the overall fastness properties of dyeing polyamide fabric using disperse dye red 60 using conventional technique at Liquor ratio 1:20, Temperature 100°C, dyeing time 45 minute, Carrier 1 g/L, dispersing agent 1 g/L, pH = 4.5 and dye concentration 0.5 & 3% and the color strength and the overall fastness properties of dyeing polyamide fabric using disperse dye red 60 using microwave irradiation technique at Microwave power 200 w, Liquor ratio 1:5, Temperature 100ºC, dyeing time 5 minute, Carrier 0 g/L, dispersing agent 0 g/L, pH = 4.5, and dye concentration 0.5 & 3% are 3.5 & 14.6 and 4.9 & 16 K/S respectively. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranged from very good to excellent for both techniques but with the use of microwave irradiation technique, about 40 min., zero carrier and dispersing agent used were saved. This suggests that time and energy used for complete dyeing process was saved.

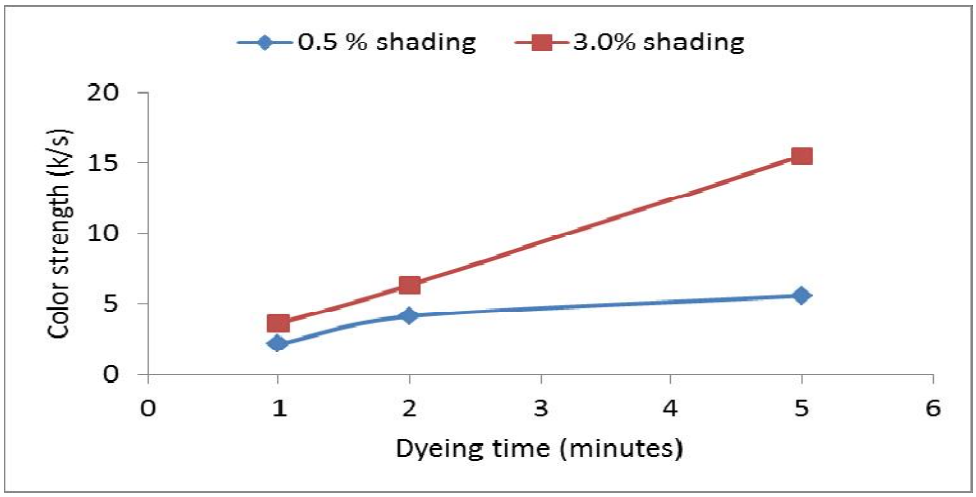


Fig. 2. Effect of dyeing time on the color strength of dyed polyamide* fabrics using disperse blue56 using microwave irradiation technique

**Microwave power 200 w, Liquor ratio1:20, Temperature100°C, Carrier 0 g/L, dispersing agent 0 g/L, pH=4.5*

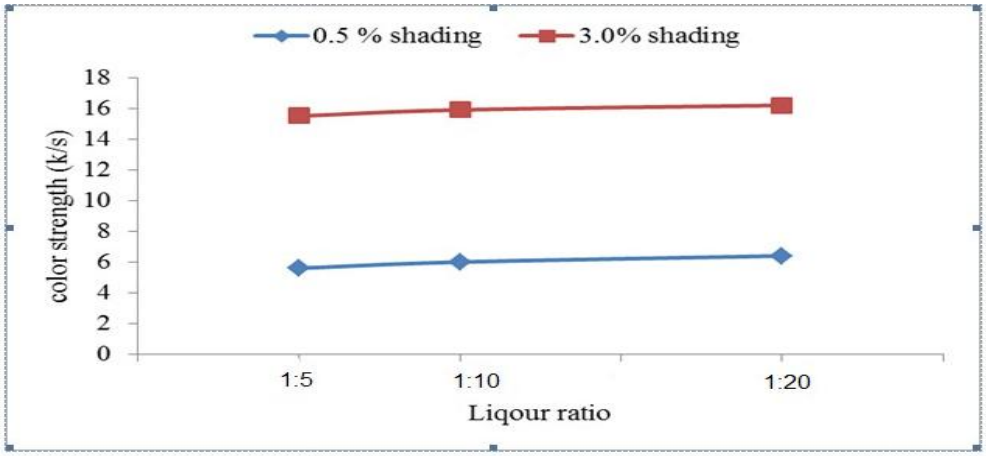


Fig. 3. Effect of liquor ratio on the color strength of dyeing*polyamide fabric using disperses dye blue 56 using microwave irradiation technique

**Microwave power 200, dyeing time 5 minute, Carrier 0 g/L, dispersing agent 0 g/L pH=4.5*

Table 1. Effect of dye concentration on the color strength and the overall fastness properties of dyeing*polyamide fabric using disperse dye blue56 using conventional technique

Dye conc. (%)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			Dry	Wet	St. on cotton	St. on Wool	Alt.	Acidic		Alkaline	
								Alt.	St.	Alt.	St.
0.5	3.5	5	5	4-5	4	4	4-5	4-5	4-5	4-5	4-5
1	7.9	5	4	4	4	4	4	4-5	4-5	4-5	4-5
2	12.37	5	4-5	4	4	4	4	4-5	4-5	4-5	4-5
3	14.6	5	4-5	4	4-5	4	4	4-5	4-5	4-5	4-5

**Liquor ratio 1:20, Temperature 100ºC, dyeing time 45 minute, Carrier 1 g/L, dispersing agent 1 g/L pH=4.5*

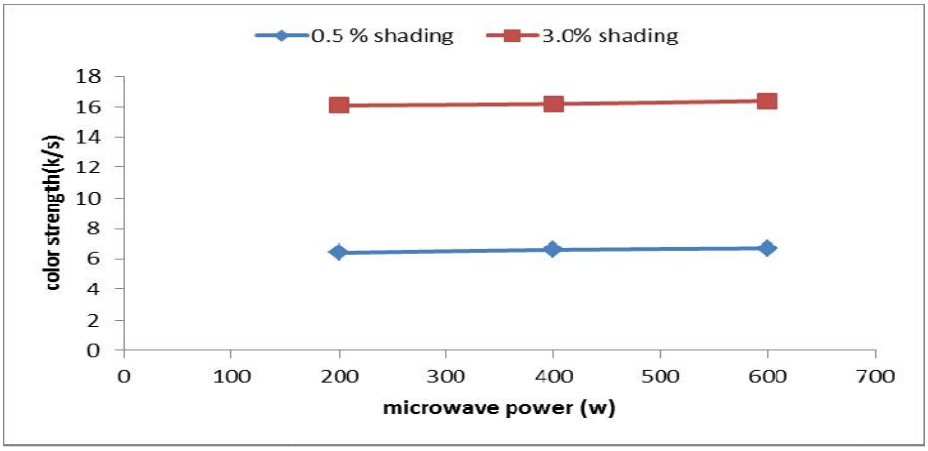


Fig. 4. Effect of microwave power on the color strength of dyed polyamide*fabrics using disperse dye blue56 using microwave irradiation technique

**Liquor ratio 1:5, Temperature 100°C, dyeing time 5 minute, Carrier 0 g/L, dispersing agent 0 g/L pH=4.5*

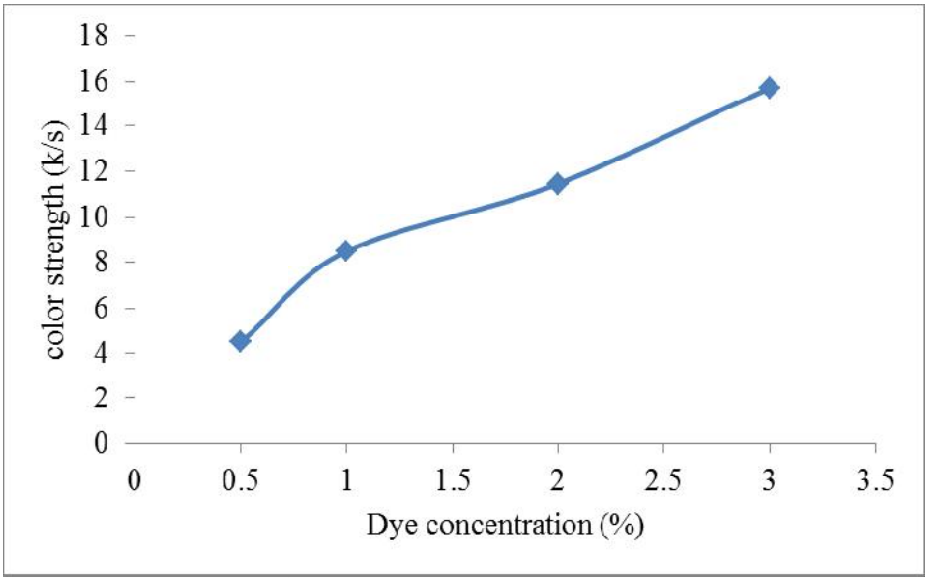


Fig. 5. The effect of dye concentration on the color strength of dyed polyamide*fabric with disperse red 60 using conventional method

**Liquor ratio 1:20, Temperature 100°C, dyeing time 60minute, Carrier 1g/L, dispersing agent 1g/L pH=4.5*

Table 2. Effect of dyeing time on the color strength and the overall fastness properties of dyeing*polyamidefabric using disperse blue 56 using microwave irradiation technique

Dye conc.	Dyeing time (min.)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
				Dry	Wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
									Alt.	St.	Alt.	St.
0.5% shading	1	2.1	5	4	3-4	4	4	4	4	4	4	4
	2	4.1	5	4	4	4	4	4-5	4-5	4-5	4-5	4-5
	5	5.6	5	4	4	5	4	4-5	4-5	4-5	4-5	4-5
3% shading	1	3.6	5	4	3-4	4	4	4	4	3-4	4	4
	2	6.35	5	4	4	4	4	4-5	4-5	4-5	4-5	4-5
	5	15.5	5	5	4-5	4	4-5	4-5	4-5	4-5	4-5	4-5

**Microwave power 200 w, Liquor ratio1:20, Temperature100°C, Carrier 0 g/L, dispersing agent 0 g/L pH=4.5*

Table 3. Effect of liquor ratio on the color strength and the overall fastness properties of dyeing*polyamide fabric using disperse blue 56 using microwave irradiation technique

Dye conc.	Liquor ratio	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
				Dry	Wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
									Alt.	St.	Alt.	St.
0.5% shading	1:20	5.6	5	4-5	4	4	4-5	4-5	4-5	4-5	4-5	4-5
	1:10	6.0	5	5	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5
	1:5	6.4	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
3% shading	1:20	15.5	5	4	4	4	4-5	4	4-5	4-5	4-5	4
	1:10	15.9	5	4-5	4	4-5	4	4	4-5	4-5	4-5	4-5
	1:5	16.20	5	4	4-5	4-5	4	4-5	4-5	4-5	4-5	4-5

**Microwave power 200 w, Temperature 100°C, dyeing time 5 minute, pH=4.5*

Table 4. Effect of microwave power on the color strength and the overall fastness properties of dyeing*polyamide fabric using disperse blue 56 using microwave irradiation technique

Dye conc.	Power (Watt)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
				Dry	Wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
									Alt.	St.	Alt.	St.
0.5% shading	200	6.4	5	4-5	4	4	4-5	4	4-5	5	4-5	5
	400	6.6	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
	600	6.7	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
3% shading	200	16.2	5	4	4	4	4-5	4-5	4	4-5	4-5	4-5
	400	16.2	5	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	600	16.4	5	4-5	4-5	4-5	4	4-5	4-5	4-5	4-5	4-5

**Liquor ratio 1:5, Temperature100°C, dyeing time 5 minute, pH=4.5*

Table 5. Effect of dye concentration on the color strength and the overall fastness properties of dyeing* polyamide fabric using disperse dye red 60 using conventional technique

Dye conc. (%)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			Dry	Wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt.	St.	Alt.	St.
0.5	4.5	5	4-5	4	4-5	4	4	4-5	4-5	4-5	4-5
1	8.5	5	4-5	4	4	4	4	4-5	4-5	4-5	4-5
2	11.47	5	4-5	4	4	4	4-5	4-5	4-5	4-5	4-5
3	15.6	5	4-5	4	4	4-5	4	4-5	4-5	4-5	4-5

**Liquor ratio 1:20, Temperature 100ºC, dyeing time 45 minute, Carrier 1 g/L, dispersing agent 1 g/L, pH=4.5*

Table 6. Effect of dye concentration on the color strength and the overall fastness properties of dyeing*polyamide fabric using disperse dye red60 using microwave irradiation technique. (Optimum condition)

Dye conc.%	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			Dry	Wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt.	St.	Alt.	St.
0.5	4.9	5	5	4	4	4-5	4-5	4-5	5	5	5
1	8.9	5	5	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5
2	11.9	5	4-5	4	5	4-5	4-5	4-5	4-5	4-5	4-5
3	16.0	5	4-5	4	4	4	4	4	4-5	4-5	4-5

**Liquor ratio 1:5, Microwave power 200 w, Temperature 100ºC, dyeing time 5 minute, Carrier 0 g/L, dispersing agent 0 g/L pH=4*

4. CONCLUSION

The time of dyeing polyamide fabric using dispersed dyes not more than 5 min. using Microwave Irradiation Technique. The power used in case of dyeing polyamide fabric using dispersed dyes not exceed 200 watt. And the liquor ratio used must be 1:5 which save water. The microwave technique save about 40 min. in the dyeing time and the dyeing process without the use of carrier and dispersing agents. Save time, energy and money, this is true irrespective of the dye used.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Aiqin Hou, Xiaojun Wang, Lianghua Wu, Effect of microwave irradiation on the physical properties and morphological structures of cotton cellulose. Carbohydrate Polymers. 2008;74:934–937.
2. Kong Y, Cha CY. Reduction of NO_x adsorbed on char with microwave energy, Carbon. 1996;34(8):1035–40.
3. Clark LS, Tinga WR, Laia JR. In: Ceramic transaction, Ohio: The American Ceramic Society. 1993;36:3–18.
4. Menendez JA, Menendez EM, Garcia A, Parra JB, Pis JJ. Thermal treatment of active carbons: A comparison between microwave and electrical heating. J Microwave Power Electromagn Energy. 1999;34(3):137–43.
5. Menendez JA, Menendez EM, Iglesias MJ, Garcia A, Pis JJ. NMP-based carbon; (b) PFO-based carbon. Carbon. 1999; 37(8):1115–21.
6. Langa F, Cruz P, Espildora E, Garcia JJ, Perez MC, Hoz A. Carbon. 2000;38(11–12):1641–6.
7. Kim DS, Kim JY, Lee DK. Carbon Sci. 2001;1(3–4):143–7.
8. Ahmed KA, El-Molla MM, Abdel-Mottaleb MSA, Mohamed S. Attia, El-Saadany S. Synthesis and evaluation of novel fluorescent dyes using microwave irradiation. Research Journal of Chemical Science. 2013;3(4):3-18.
9. El-Molla MM, Haggag K, Shaker NO, El-Shall FN. Use of novel synthesized aqueous binders for pigment printing of polyester fabrics. Indian Journal of Fiber & Textile Research. 2013;38:57-65.
10. Li S, Boyter H. Neil Stewart, Ultraviolet (UV) Curing for Textile Coloration, AATCC Review. 2004;4(8):44-9.
11. Belton JG. Microwave-accelerated dye fixation, Int. Dyers Text Printer. 1980;43(5): 662.
12. Judd DB, Wyszenki G. Color in business, science and industry 3rd Ed., John Wiley and Sons, New York. 1975;426–431.
13. J.S.D.C. Standard methods for the assessment of colour fastness of textile. Third report of the fastness tests coordinating committee, Yorkshire, England. 1995;24.
14. Owens J. Microwave promoted addition of organosiloxanes to hydroxyl containing substrates for facile synthesis of chemical and biological warfare agent reactive polymers, in college of science and mathematics. Auburn University, Auburn; 2007.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=1050&id=7&aid=9351