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Microwave assisted synthesis of some azo disperse dyes part 2: Eco-friendly dyeing of polyester fabrics by using microwave irradiation

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RESEARCH ARTICLE

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ABSTRACT

This study aimed to use microwave irradiation as a green technique, not only to enhance the dyeing efficiency of disperse-colored polyester fabrics, but also to conserve resources and minimize the environmental effects. Arylazopyrazolopyrimidinones dyes 1-9 were applied to polyester fabrics at 2% shade using conventional method and microwave at 100 °C. Both the color intensity expressed as dye absorption and the fastness characteristics of the dyed fabric were investigated. The K/S values are increased by increasing the time of irradiation from 10-60 minutes. The dyed substrate displayed good light fastness, and very good fastness levels to rubbing, perspiration washing, and sublimation, respectively.

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1. Introduction

In the past two decades, the use of microwave heating in the chemistry field has become a strong chemical application to improvement chemical processes [1-4]. Microwave irradiation is an alternative to traditional approaches, since heating or energy input into the system. This utilizes the ability to convert electromagnetic energy into heat from mobile electric charges present in a liquid or conductive ion in solids. Microwave assisted reactions are fast, clean, economical, and environmentally friendly [5]. By using microwave irradiation, most obstacles resulting from conventional heating can be overcome, due to the ability of the energy resulting from microwave radiation to penetrate all material particles easily, which results in a uniform heating of all material particles and immediately compared to conventional heating [6-15]. When utilized microwave heating as a green method in dyeing processes, it can be encouraged exhaustion dyeing levels [16]. It was reported that preparation of disperse dyes and using them for dyeing polyester fabrics via microwave heating to facilitate the dyeability of polyester fabric and also to improve the fastness properties of the dyed fabrics [17]. In this study, some of the dyes that we prepared before [18] using microwave irradiation were used in dyeing polyester fabrics using microwave radiation and compared to the traditional method, to show the benefit in the process of using microwave radiation as an environmentally safe way.

2. Experimental

2.1. Synthesis

All the dyes used in the dyeing process were prepared as we published before [18].

2.2. Dyeing

Fabric scoured and bleached 100% polyester fabric (149 g/m^2) was supplied by El-Mahalla El-Kobra Company, Egypt.

2.2.1. Conventional dyeing

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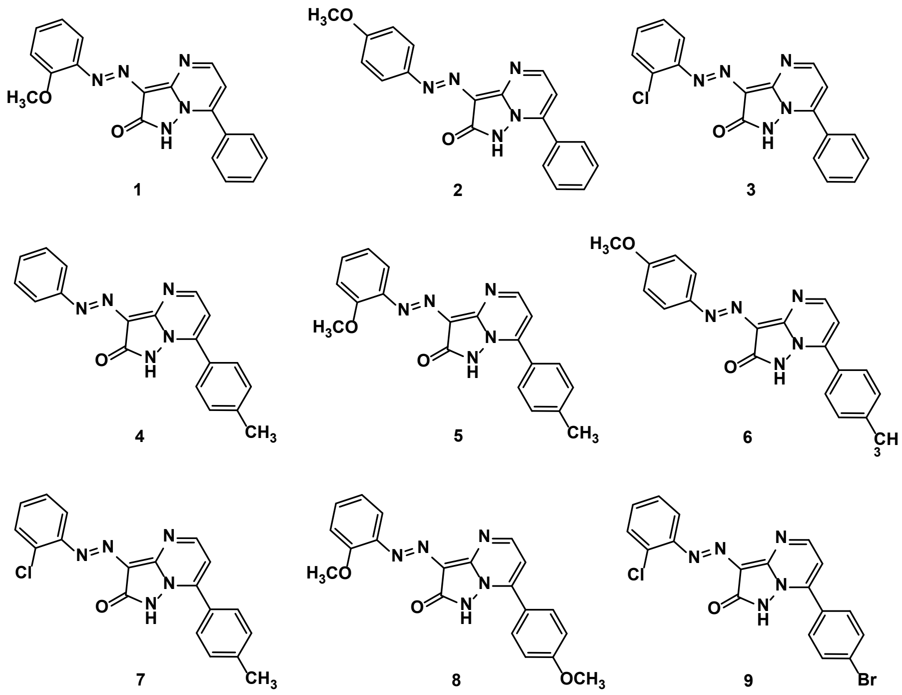

Figure 1. Chemical structure of the disperse dyes.

The dye baths were created from the dye (2% weight of fabric) to a final liquor proportion of 50:1 (*w*:*w*). Fabrics were dyed by using a 2% dispersing agent and 2% carrier in a pH = 4.5-5.0 and were dyed at 100 °C, and the dyeing process time was 60 minutes. For treatment of the dyed fabric, the fabrics were neatly rinsed by water and then placed in a solution consisting of 2 g/L sodium hydroxide and 2 g/L sodium hydrosulphite for 30 minutes at a temperature of 50 °C, and then neatly washed and air-dried.

2.2.2. Microwave dyeing

The dye baths were created from the dye (2% weight of fabric) to a final liquor proportion of 50:1 (w:w). Fabrics were dyed by using a2% dispersing agent and a 2% carrier in a pH = 4.5-5.0 and fabrics were dyed without dispersing agent and carriers in the same pH. Fabrics were dyed at 100 °C, and the dyeing process time was 60 minutes by using microwave. A Samsung oven model MS404MADXXBB was utilized and the dyeing time was from 10-60 min. The same post-dyeing treatment characterized in the conventional method was utilized in current method here.

2.3. Color measurements

A reflectance spectrophotometer was utilized for measuring colorimetric factors of the dyed polyester fabrics. By using light reflection technology, the yield of dye on the dyed fabric was measured by UltraScan PRO D65 UV/VIS spectrophotometer. Kubelka-Munk Equation (1) was applied to obtain the color strengths of dyes which Symbolized by K/S [19].

$$K/S = [(1- R)^2 / 2R] - [(1- R_o)^2 / 2R_o] \quad (1)$$

where R is the reflectance of dyed samples, K is the absorption coefficient, S is the scattering coefficient, and R_o = decimal fraction of the reflectance of the undyed fabric.

2.4. Fastness properties

2.4.1. Color fastness to washing

The color fastness to washing was obtained by applying the technique of ISO 105-C02:1989 [20]. Between two bleached pieces, one of them is cotton fabric and the other of the wool fabric, a sample of the dyed fabric was placed and fixed with sutures, and then it was soaked in an aqueous solution consisting of 5 g/L of nonionic detergents at a liquor ratio of 1:50 for 30 minutes at of 60 °C and then sample was rinsed thoroughly with manual squeeze, and then sample was allowed to dry. Gray scale was applied to assess the color fastness to wash.

2.4.2. Color fastness to rubbing

Color fastness to rubbing was obtained by applying the technique of ISO 105-X12:1987 test. By applying this test, it is possible to assess how far the dye can transfer from the surface of the dyed fabric to another surface by rubbing. This test was performed on dry and wet fabrics.

2.4.3. Color fastness to perspiration

By following the technique of ISO 105-E04:1989 test, two artificial perspiration solutions were prepared, one of them in acidic medium and the other in basic. Where the acidic perspiration solution consists of L-histidine monohydrochloride monohydrate (0.5 g), sodium chloride (5 g), and sodium dihydrogen orthophosphate dihydrate (2.2 g) in one liter of distilled water. The pH of the solution was adjusted by0.1 N NaOH and the pH value was 5.5. While the basic perspiration solution was composed of L-histidine monohydrochloride monohydrate (0.5 g), sodium chloride (5 g), and sodium dihydrogen orthophosphate dihydrate (2.2 g) in one liter of distilled water. The pH of the solution was adjusted by 0.1 N NaOH and the pH value was 8.0.

Table 1. Effect of dyeing time of microwave on the K/S value of dyeing polyester fabric.

Dyeing no	K/S						
	10 min	20 min	30 min	40 min	50 min	60 min	Conventional dyeing at 60 min
Microwave dyeing without disperse agent							
1	1.53	2.97	2.06	3.38	3.82	3.63	4.08
2	7.42	7.20	8.21	8.31	17.26	8.63	21.56
3	3.34	2.88	5.61	6.17	6.02	8.16	7.11
4	8.45	7.13	8.89	7.97	19.92	20.34	22.82
5	1.68	2.55	1.90	3.78	5.31	5.11	5.40
6	3.04	7.25	9.41	10.67	15.29	11.57	18.17
7	2.01	2.33	2.94	2.26	3.25	4.64	4.77
8	1.18	1.13	1.29	1.35	1.54	1.49	1.18
9	1.77	2.49	2.80	3.04	3.02	2.60	3.26
Microwave dyeing with disperse agent							
1	1.89	2.25	3.36	4.46	2.83	2.95	4.08
2	7.92	14.39	11.18	19.61	13.14	20.13	21.56
3	1.66	3.11	3.95	6.55	3.42	8.81	7.11
4	5.25	6.81	12.96	13.15	17.07	17.97	22.82
5	5.23	2.89	3.94	2.35	4.86	5.67	5.40
6	5.67	10.74	6.99	9.71	8.42	20.32	18.17
7	2.29	2.43	2.71	3.74	3.11	3.09	4.77
8	1.08	1.23	1.17	1.29	1.32	1.41	1.18
9	2.60	3.40	3.41	4.09	4.26	4.00	3.26

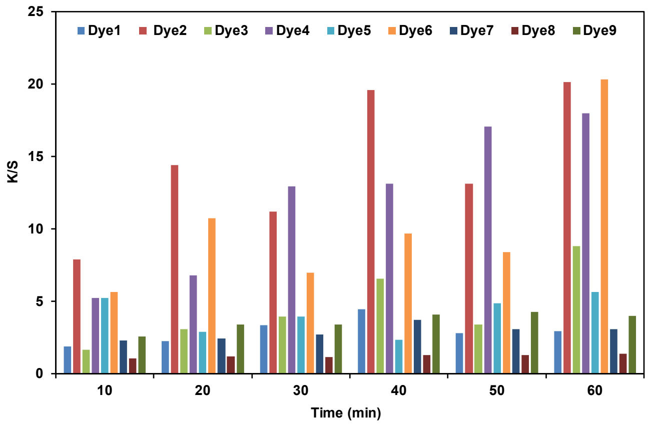

Figure 2. Effect of dyeing time of microwave on the K/S value of dyeing polyester fabric with using disperse agent.

The fastness test was carried out according to the following steps: Between two different slices of uncolored patterns a sample of dyed fabric (5×4 cm) was sutured. The samples were soaked in both solutions undergoing agitation and pressing for 15-30 min to assure perfect wetting. A load of 4-5 kg was applied to the tested sample while the sample was placed between two plates of plastic or glass. Then these plates were placed at a temperature of 37 °C vertically for four hours, and then a gray scale change technique was used to assess the color fastness to perspiration

2.4.4. Color fastness to light

The ISO 105-B02:1988 test technique was applied to screen the stability of color fastness to light by exposing the dyed sample for 35 hours to a carbon arc lamp and then using the blue color scale to study color change of the tested samples.

3. Results and discussion

Arylazopyrazolopyrimidinones dyes **1-9** (Figure 1) were applied to polyester fabrics at 2% shade using conventional method and microwave at 100 °C. The data listed in Table 1 and Figures 2 and 3 show that the K/S values are increased by increasing the time of irradiation from 10-60 minutes. The increase in the K/S values when the dyeing process takes place in a microwave oven may be because the outside of polyester is equally tuned, which assists with changing the texture to make the critical association with color. Additionally, the particles of disperse color are adequately huge to penetrate into fibers and after the microwave treatment the cluster of molecules are crumbled into a little size that makes them feasible to sorb into the voids of texture and gives the textile significant advantages more than the conventional technique regarding the decrease time and energy that is associated with the conventional technique [21]. Microwave radiation increments the reaction rate which yields high efficiency of colors through even or consistent warming. Moreover, in the disperse coloring of polyester textures the utilization of microwave warming treatment supports the color exhaustion and dyeing rates.

3.1. Effect of dyeing time of microwave on the K/S value

Through the data of the current survey, it appears that microwave supported dyeing on polyester, while dyeing procedure by microwave, carriers are not included, moreover that dyes **4**, **7** and **8** display good values for K/S when dispersing agents are not included in the dyeing process. It is apparent that increasing the microwave irradiation time from 10 to 60 minutes results in more color output (K/S) on polyester fabric than conventional dyeing under the same conditions when using a microwave oven. The data listed in Table 1 indicates that the studied dyes have different color intensity K/S. The replaceable group presence or its position in the dye molecules leads to the difference in K/S of the synthesized dyes. The color of the studied dye was determined according to the kind and position and number of the auxochromes. When auxochromes absorb higher wavelengths, this raises the color of the dye [22].

Table 2. Fastness properties of disperse dyes on the polyester fabric.

Dyeing no	Washing fastness			Perspiration fastness						Rubbing fastness		Sublimation fastness		Light fastness
				Acidic			Alkaline							
	Alt	SC	SW	Alt	SC	SW	Alt	SC	SW	Wet	Dry	180 °C	210 °C	
1	5	5	5	4-5	4-5	4-5	5	5	5	5	5	4	3	2
2	5	5	5	5	5	5	5	5	5	5	5	3-4	3-4	2
3	5	5	5	5	5	5	5	5	5	5	5	4	4	2-3
4	5	5	5	5	5	5	5	5	5	5	5	2-3	3	4
5	5	5	5	5	4-5	4-5	5	5	5	5	5	4	4	2
6	5	5	5	5	5	5	5	5	5	5	5	3-4	2	3-4
7	5	5	5	5	4-5	4-5	5	5	5	5	5	4-5	4	3
8	5	5	5	5	5	5	5	5	5	5	5	4-5	4	3-4
9	5	5	5	5	5	5	5	5	5	5	5	4-5	4-5	2-3

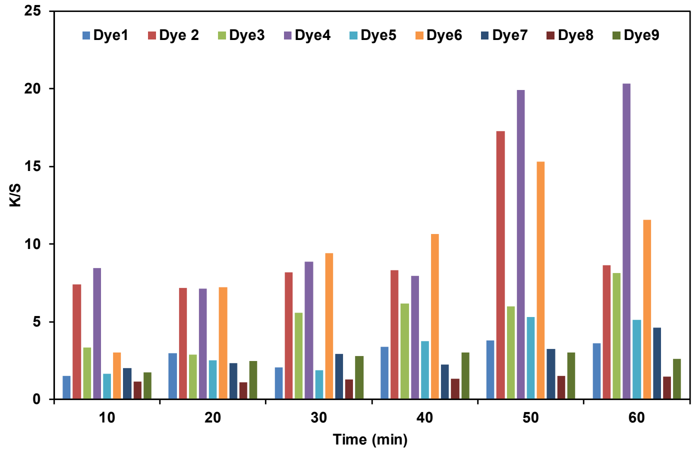

Figure 3. Effect of dyeing time of microwave on the K/S value of dyeing polyester fabric without disperse agent.

3.2. Light Fastness

From Table 2, it clearly that disperse dyes **1-9** have very good fastness for washing, perspiration, rubbing, and sublimation fastness, while showing moderate fastness for light.

3.3. Washing fastness

Dyes **1-9** show very good fastness against wash and perspiration, it may be due to these dyes under investigated are clearly diffused into the pores of the substrate and engaged in their positions by a variety of forces such as Van der Waals.

3.4. Rubbing and perspiration fastness

The data provided described in Table 2 showed that the dyed substratum has very good fastness to rubbing and perspiration, these findings can be attributed to the excellent intra-fiber diffusion of the dye molecules within the substratum, and the particle size of the dye molecule is believed to be comparatively large [23].

3.5. Sublimation fastness

Dyes **1-9** shows a variation in sublimation fastness from mordant to very good fastness for sublimation, it may be referred to intermolecular interactions which affect the sublimation fastness feature [24].

4. Conclusion

A new synthesized pyrazolopyrimidinones disperse dyes were applied to polyester fabrics by two ways, conventional dyeing and microwave radiation to support the dyeing of polyester fabric. Dyed fabric by microwave gives K/S better than which dyes with conventional dyeing. The dyed substrate displayed good light fastness, and very good fastness levels to rubbing, perspiration washing, and sublimation, respectively.

Disclosure statement DS

Conflict of interests: The authors declare that they have no conflict of interest.
Ethical approval: All ethical guidelines have been adhered.
Sample availability: Samples of the compounds are available from the author.

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References

[1]. Corsaro, A.; Chiacchio, U.; Pistara, V.; Romeo, G. *Curr. Org. Chem.* **2004**, *8 (6)*, 511–538.
[2]. de la Hoz, A.; Diaz-Ortiz, A.; Moreno, A. *Chem. Soc. Rev.* **2005**, *34 (2)*, 164–178.
[3]. Oliver Kappe, C. *Chem. Soc. Rev.* **2008**, *37 (6)*, 1127–1139.
[4]. Kappe, C. O. *Chem. Soc. Rev.* **2013**, *42 (12)*, 4977–4990.
[5]. Krstenansky, J. L.; Cotterill, I. *ChemInform* **2000**, *31 (49)*, 454–461.
[6]. Oner, E.; Buyukakinci, Y.; Sokmen, N. *Coloration. Technol.* **2013**, *129 (2)*, 125–130.
[7]. Haggag, K.; Hanna, H. L.; Youssef, B. M.; El-Shimy, N. S. *Amer. Dyest. Rep.* **1995**, *84*, 22–36.
[8]. Kale, M. J.; Bhat, N. V. *Coloration Technol.* **2011**, *127 (6)*, 365–371.

[9]. Al-Mousawi, S. M.; El-Apasery, M. A.; Mahmoud, H. M. *Molecules* **2012**, *17 (10)*, 11495–11506.
[10]. Chiao-Cheng, J. H.; Reagan, B. M. *Chem. Color.* **1983**, *15*, 29–36.
[11]. Yigit, E. A.; Teker, M. *Polym. Polym. Compos.* **2011**, *19 (8)*, 711–716.
[12]. Al-Etaibi, A. M.; Al-Awadi, N. A.; El-Apasery, M. A.; Ibrahim, M. R. *Molecules* **2011**, *16 (6)*, 5182–5193.
[13]. Al-Etaibi, A. M.; El-Apasery, M. A.; Mahmoud, H. M.; Al-Awadi, N. A. *Molecules* **2012**, *17 (4)*, 4266–4280.
[14]. Al-Mousawi, S. M.; El-Apasery, M. A. *Molecules* **2012**, *17 (6)*, 6547–6556.
[15]. El-Apasery, M. A.; Al-Qalaf, F.; Almohammad, K.; Mahmoud, H. *Eur. J. Chem.* **2013**, *4 (3)*, 211–215.
[16]. El-Apasery, M. A. *Pol. J. Appl. Chem*. **2006**, *50*, 75–81.
[17]. Al-Mousawi, S.; El-Apasery, M.; Elnagdi, M. *Molecules* **2013**, *18 (9)*, 11033–11043.
[18]. Elapasery, M.; Hussein, A.; Eladasy, A.; Saleh, M.; Kamel, M. *Egypt. J. Chem*. **2019**, *62*,1253–1259.
[19]. Ashkar, S. M.; El-Apasery, M. A.; Touma, M. M.; Elnagdi, M. H. *Molecules* **2012**, *17 (8)*, 8822–8831.
[20]. Al-Etaibi, A. M.; El-Apasery, M. A. *Inter. J. Environ. Res. Public Health* **2019**, *16 (23)*, 4603, 1–8.
[21]. Haggag, K.; El-Molla, M.; Ahmed, K. *Inter. Res. J. Pure Appl. Chem*. **2015**, *8 (2)*, 103–111.
[22]. Al-Mousawi, S.; El-Apasery, M.; Mahmoud, H. *Molecules* **2013**, *18 (6)*, 7081–7092.
[23]. El-Adasy, A. A. A. M.; Kamel M. M.; Saleh, M. O.; Hussein, A. M.; El-Apasery, M. A. *Inter. J. Chem. Tech. Res*. **2016**, *9*, 31–38.
[24]. Maradiya, H., Raghav; Patel, V., Soma. *J. Serb. Chem. Soc.* **2001**, *66 (6)*, 367–376.