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Cold Pad-Batch Dyeing Method for Dyeing Cotton Fabric with Reactive Dye Using Microwave Irradiation Technique

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Abstract: ***Dyeing of cotton fabrics with reactive dyes using padding method was done; the fixation of dyeing fabric had been done using either thermo fixation or microwaves irradiation technique. Different parameters such as dyeing time, dye concentration, power of microwave used, alkali concentration, and salt concentration were studied. Compared the results obtained upon using conventional and microwave technique, was done. From the results obtained, the microwave irradiation technique give higher in K/S about 14%, also increase the time of fixation using microwave up to 10 min. give higher in K/S about 70%, the microwave technique save about 35% from the salt used and 20% from alkali used, this means that save in energy and money. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent.***

Keywords: Dyeing, cotton Fabrics, reactive dyes, microwave irradiation, clean production

1. Introduction

Dyeing cotton with reactive dyes is widely practiced, mainly because the covalent bond that is formed between the fiber and the dye molecules leads to excellent color fastness to washing. However, considerable quantities of inorganic electrolyte (such as sodium chloride and sodium sulphate), as electrolyte, and inorganic alkali (such as sodium bicarbonate, sodium carbonate and sodium hydroxide), as the dye–fibre reaction activator, are required [1, 2].

Cold pad–batch dyeing is a more environmentally sound and higher-quality dyeing method for cotton fibers. The process removes salt from the effluent, reduces the use of water, energy and the volume of effluent and occupies less space on the production floor [3].

Cold Pad Batch (CPB) dyeing offers the most economical and convenient method of dyeing cotton with reactive dyes. The energy and water consumptions are at the lowest and salt addition is eliminated, thus rendering it more eco friendly [4] and the dye fixation is also high [5]. The CPB procedure is simple since the only step involved is the passage of fabric through the dye bath and squeezing through the dyeing padder with subsequent batching for twelve hours. The long batching time makes CPB procedure less attractive to many dyers seeking high production rates. This creates a serious need of reduced batching time.

The microwave irradiation has been used in the dyeing processing of cellulose fabric. In the conventional processing of fabric, a large amount of energy is consumed. Some new techniques and methods for saving energy were investigated[6-8] Microwave heating, as an alternative to conventional heating technique, has been proved to be more rapid, uniform and efficient. The microwave energy can easily penetrate to particle inside and all particles can be heated simultaneously, thus reducing heat transfer problems. However, the microwave irradiation could affect the chemical and morphological structure of cellulose, including some physical properties. The report of the effect of microwave irradiation on the physical properties and morphological structure of cellulose was scarce.

The purpose of this work is using cold pad –batch dyeing method of cotton fabrics with reactive dyes by using microwave irradiation and its comparison with the conventional method.

2. Experimental

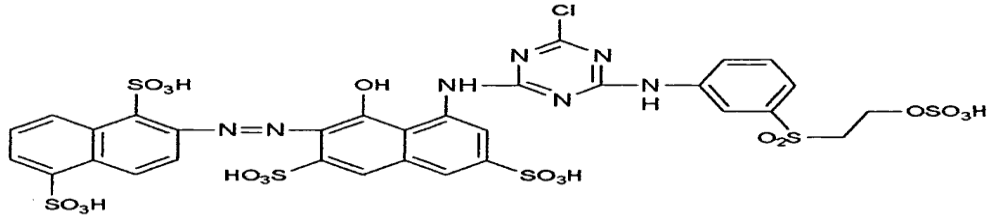
2.1. Materials

Cotton Fabric:

The grey cotton fabric of about 140g/m2(supplied by the Miser Helwan Company) was bleached by a combined scouring and bleaching method with the bath liquor containing 0.75% of the wetting agent sandozin NIE, 4.0% hydrogen peroxide and 2.5% sodium hydroxide at pH 10.5, liquor ratio was 1:10 at temperature 90°C. for 60 min.

Dyestuffs

Solazol Red SP-3B (C.I. Reactive Red 195) was supplied by new trend Co. Egypt.



C.I. Reactive Red 195

Chemicals:

Sodium chloride, sodium carbonate, acetic acid, were of laboratory grade chemicals were used.

2.2. Methods

Dyeing Procedure:

Samples of cotton fabrics were dyed using cold pad –batch dyeing method, 70% liquor pick-up with reactive Dye (1-5% owf, Na Cl 10-50 g/l, Sodium carbonate 5-20 g/l, then dry at room temp. and fixation at 160 ^{0}C for 5 min. Another samples of cotton fabrics were dyed using cold pad –batch dyeing method, 70% liquor pick-up with reactive Dye (1-5 % owf, Na Cl 10-50 g/l, Sodium carbonate 5-20 g/l, then fixation using microwave (Milestone Start synthesis Microwave Synthesis Lab station, USA) irradiation with power 150 W, for 5-12 min. Then the all dyed samples was rinsed, and neutralized by acetic acid 1 g/L, soaped (Ciba pone R), 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 [9].

2.3.2. Fastness Properties

Fastness properties to washing, rubbing and perspiration were measured according to a standard method [10].

3. Results and Discussion

3.1. Cold pad –batch dyeing cotton fabric and fixation using thermo fixation

Figure 1 show the effect of dye concentration on the color strength of dyed cotton fabrics, using cold pad –batch dyeing method, 70% liquor pick-up with Solazol Red SP-3B (1- 5% owf, Na_2SO_4 10-50 g/l, Sodium carbonate 5-20 g/l, then dry at room temp. and fixation at 160 ^{0}C for 5 min. It is noticed that the increase in the dye concentration this is lead to increase in the color strength, for example the increase the dye concentration from 1, 2, 3,4 and 5% the K/S increase from 2.04, 4.15, 5.75, 6.01 and 7.49 respectively.

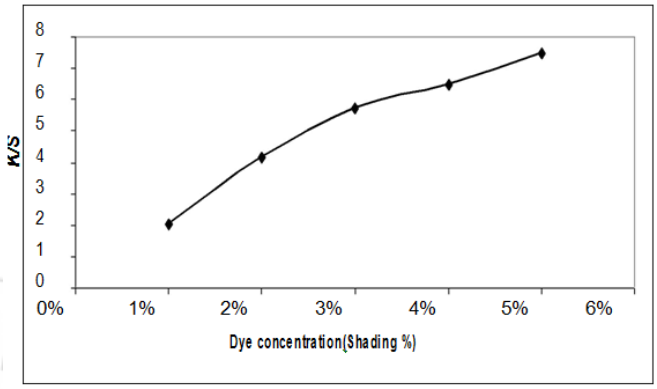


Figure 1: Effect of dye concentration, on color strength of cold pad –batch dyeing cotton* fabrics using Solazol Red SP-3B

*Fixation at 160 ^{0}C for 5 min.

Table1, show the effect of dye concentration on the color strength and the overall fastness properties of dyeing cotton fabric using Solazol Red SP-3B using conventional heating technique**.** Generally speaking, the fastness properties to rubbing, either wet or dry, washing, light fastness and colour fastness properties to both acidic and alkaline perspiration for the dyed samples their values ranging from very good to excellent.

Table1: Effect of dye concentration on the color strength and the overall fastness properties of cold pad –batch dyeing cotton* fabrics using Solazol Red SP-3B

Dye conc. (Shading %)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt	St.	Alt	St.
1%	2.04	6	4-5	4	4-5	4	4-5	4-5	4-5	4-5	4-5
2%	4.15	6	4-5	4	4-5	4	4-5	4-5	4-5	4-5	4-5
3%	5.75	6	4-5	4	4-5	4	4-5	4-5	4-5	4-5	4-5
4%	6.01	6	4	3-4	4	3-4	4	4-5	4-5	4-5	4-5
5%	7.49	6	4	3-4	4	3-4	4	4	4	4	4

* Fixation temperature 160^{o}C, Fixation time 5 minute, Na Cl 10-60 g/l, Na_2CO_3 8-20 g/l.

3.2. Cold pad –batch dyeing cotton fabric and fixation using microwave irradiation technique.

3.2.1. Effect of dyeing time on the color strength

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. Microwave-assisted organic synthesis [11, 12], has gained popularity in recent years because microwave irradiation was found to accelerate remarkably a wide variety of reactions.

Figure 2 shows the effect of dyeing time on the color strength of the dyed cotton fabrics upon using Solazol Red SP-3B and using microwave irradiation.

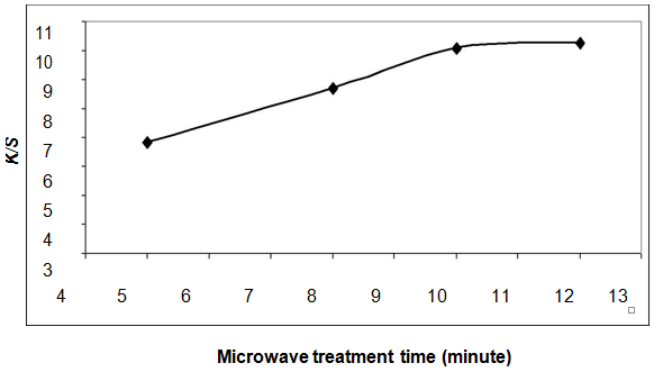


Figure 2: Effect of dyeing time on the color strength of cold pad –batch dyeing cotton* fabrics using Solazol Red SP-3B

* microwave power 150 W, NaCl 60 g/l, Na_2CO_3 20 g/l , dye 4% Shading

From Figure2 we noticed that increase the time up to 10 min. this is lead to increase the K/S, after that increase the time of dyeing this is lead to slightly increase in the K/S, so we recommended that the time of fixation is 10 min.

Comparing between the conventional and microwave technique as shown in Table 1 & 2.

Table 2: Effect of dyeing time on the color strength and the overall fastness properties of cold pad –batch dyeing cotton* fabrics using Solazol Red SP-3B

Dyeing time (minute)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt	St.	Alt	St.
5	6.83	7	3	3	4	3-4	4	4	4	4	4
8	8.68	7	3-4	3	4	3-4	4	4	4	4	4
10	10.07	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5
12	10.28	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5

* Microwave power 150 W, NaCl 60 g/l, Na_2CO_3 20 g/l, dye4 % Shading.

For example, the color strength and the overall fastness properties of dyeing cotton fabric using Solazol Red SP-3B using conventional technique i.e.(fixation temperature 160^{o}C, time of fixation 5 minute and dye concentration 4%) and the color strength and the overall fastness properties of dyeing cotton fabric using Solazol Red SP-3B using microwave irradiation technique i.e. (Microwave power 150 W, dyeing time 5 minute, dye concentration 4%) are 6.01and 6.83 respectively. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent. From the data we found that upon using microwave irradiation technique give higher in K/S about 14%. And also increase the time of fixation using microwave up to 10 min. lead to K/S is 10.07 i.e. give higher in K/S about 70% we cannot make thermo fixation for 10 min because the fabric is burned.

3.2.2. Effect of dye concentration (Shading %) on the color strength

Figure 3 shows the effect of dye concentration on the color strength of the dyed cotton fabrics upon using Solazol Red SP-3B and using microwave irradiation. From Figure3 we noticed that increases the dye conc. this is lead to increases in the K/S, for example increase the dye conc. From 1, 2, 3, 4 and 5% the K/S increase from 4.02, 6.83, 8.4, 10.07 and 11.1 respectively.

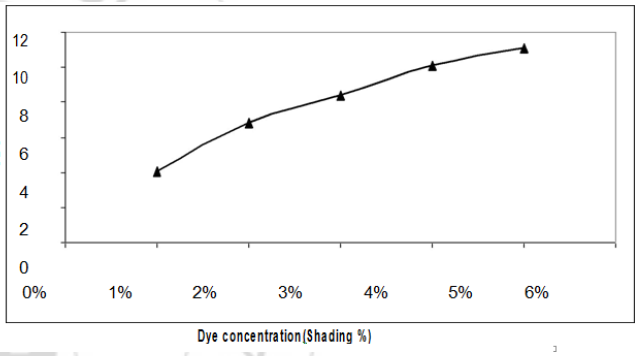


Figure3. Effect of dye concentration on the color strength of dyed cotton* fabrics using Solazol Red SP-3B.
* Microwave power 150 W, treatment times 10 minute, NaCl 60 g/l, Na_2CO_3 20 g/l

From Table 3 we show that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent.

Table3: Effect of dye concentration on the color strength and the overall fastness properties of dyeing* cotton fabric using Solazol Red SP-3B

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Dye conc. (Shading %)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt	St	Alt	St
1%	4.02	7	4-5	4	5	4-5	5	5	5	5	5
2%	6.83	7	4-5	4	5	4-5	5	5	5	5	5
3%	8.4	7	4-5	4	4-5	4	5	4-5	4-5	4-5	4-5
4%	10.07	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5
5%	11.1	7	4	3-4	4-5	3-4	4-5	4-5	4-5	4-5	4-5

* Microwave power 150 W, treatment times 10 minute, NaCl 60 g/l, and Na_2CO_3 20 g/l

3.2.3. Effect of alkali concentration (Soda ash Na_2CO_3) on the color strength

In the dyeing using reactive dyes the raising the pH value by 1 unit corresponds to a temperature rise of 20 °C, the dyeing rate is best improved by raising the dyeing temperature once a pH of 11–12 is reached. Further increase in pH will reduce the reaction rate as well as the efficiency of fixation, different types of alkalis, such as caustic soda, soda ash, sodium silicate or a combination of these alkalis, are used in order to attain the required dyeing pH. The choice of alkali usually depends upon the dye used, the dyeing method as well as other economic and technical factors. Figure 4 shows the effect of alkali concentration on the color strength of the dyed cotton fabrics upon using Solazol Red SP-3B and using microwave irradiation.

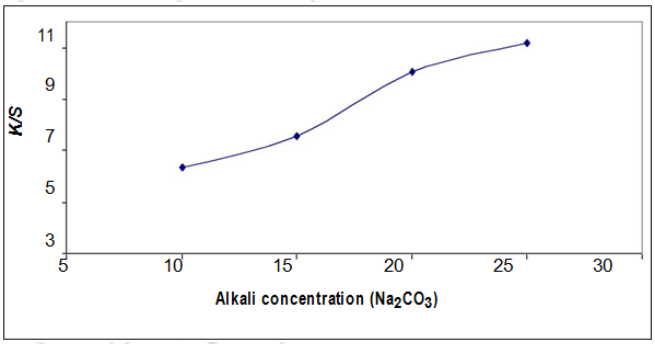

Figure4. Effect of alkali concentration on the color strength of dyed cotton* fabrics using Solazol Red SP-3B using microwave irradiation technique

* Microwave power 150 W, treatment times 10 minute, 4% Shading, NaCl 60 g/l

From Figure 4 we noticed that increase the alkali concentration from 10 to 25 g/l this is lead to increase the K/S, for example increasing the alkali concentration from 10, 15, 20 and 25 g/l the K/S are 6.38, 7.6, 10.07 and 11.1 up on using 4% dye conc., and this is may be due to increase the alkali concentration this is lead to increase the pH of the dyeing path i.e. dyeing rate is increased till reached to the best by raising the pH from11–12.

From Table 4 we show that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent this is true at higher alkali concentration used, but at lower concentration used 10 and 15 g/l the overall fastness properties to rubbing, washing and perspiration for the dyed samples their values ranging from good to very good ,this is may be due at lower alkali concentration used not reactive dye fixed well so lower fastness properties obtained and also K/S.

Table4: Effect of alkali concentration on the color strength and the overall fastness properties of dyeing* cotton fabric using Solazol Red SP-3B

Alkali conc. g/l	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt	St.	Alt	St.
10	6.38	7	4	3-4	4	3	4	3-4	4	3-4	4
15	7.6	7	4	3-4	4-5	3-4	4	4-5	4-5	4-5	4-5
20	10.07	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5
25	11.1	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5

*Microwave power 150 W, treatment times 10 minute, 4% Shading, NaCl 60 g/l

3.2.4. Effect of salt concentration (Common salt Na Cl) on the color strength

The addition of electrolyte results in: increase in the rate and extent of exhaustion, increase in dye aggregation .There are may be impurities present in the salt to be used, such as calcium sulphate, magnesium sulphate, iron, copper and alkalinity, that can be a source of many dyeing problems. Figure 5 shows the effect of salt concentration on the color strength of the dyed cotton fabrics upon using Solazol Red SP-3B and using microwave irradiation. From Figure 5 we noticed that increase the salt concentration from 20 to 70 g/l this is lead to increase the K/S, for example increasing the salt concentration from 20, 40, 60 and 70 g/l the K/S are 7.4, 9.07, 10.07, and 10.9 up on using 4% dye conc., and this is may be due to increase the salt concentration this is lead to increase the exhaustion of the dye from the path dyeing into the fabrics i.e. dyeing rate is increased .

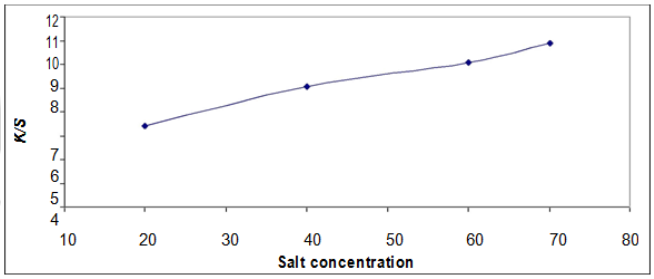

Figure 5: Effect of salt concentration on the color strength of dyed cotton* fabrics using Solazol Red SP-3B using microwave irradiation technique
* Microwave power 150 W, treatment time 10 minute, 4% Shading, Na_2CO_3 20 g/l

From Table 5 we show that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent this is true at higher salt concentration used, but at lower concentration used 20 and 40 g/l the overall fastness properties to rubbing, washing and perspiration for the dyed samples their values ranging from good to very good.

Table 5: Effect of salt concentration on the color strength and the overall fastness properties of dyeing* cotton fabric using Solazol Red SP-3B.

Salt conc. g/l	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt	St.	Alt	St.
20	7.4	7	3-4	3	4	3	4	3-4	4	4	4
40	9.07	7	4	3-4	4	3	4	4-5	4-5	4-5	4-5
60	10.07	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5
70	10.9	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5

* Microwave power 150 W, treatment times 10 minute, 4% Shading, Na_2CO_3 20 g/l

3.2.5. Effect of power of microwave used on the color strength

Figure 6 shows the effect of power of microwave used on the color strength of the dyed cotton fabrics upon using Solazol Red SP-3B. From Figure 6 we noticed that increase the power from 100 to 150 watt, this is lead to increase the K/S, after that the increase the power to 200 watt, this is lead to slightly increase in the K/S, this is may be due to increase the power of microwave used more than 150 watt, this is means that increase in the temperature i.e. increase the hydrolysis of the reactive dye i.e. slightly increase in the K/S. So we recommended that the power used in case of dyeing cotton fabric using padding method not exceed 150 watt.

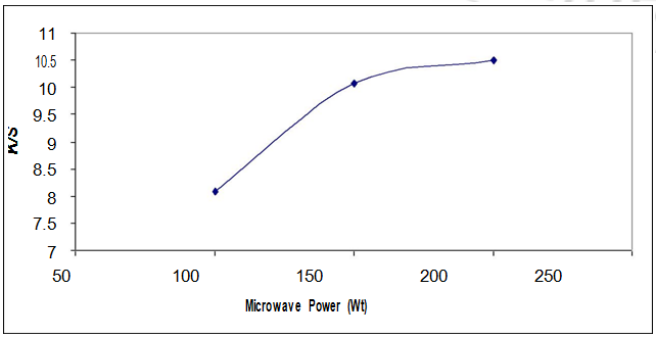

Figure 6: Effect of microwave power on the color strength of dyed cotton* fabrics using Solazol Red SP-3B.
* Treatment time 10 minute, 4% Shading, NaCl 60 g/l, Na_2CO_3 20 g/l

From Table 6 we show that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranging from very good to excellent.

Table6: Effect of microwave power on the color strength and the overall fastness properties of dyeing* cotton fabric using Solazol Red SP-3B

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.
100	8.1	7	3-4	3	3-4	3	3-4	4	4	3-4	4
150	10.07	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5
200	10.5	7	4-5	4	4-5	3-4	4-5	4-5	4-5	4-5	4-5

* Treatment time 10 minute, 4% Shading, NaCl 60 g/l, Na_2CO_3 20 g/l

4. Conclusion

The power used in case of dyeing cotton fabric using padding method not exceed 150 watt. The salt concentration not increases than 70 g/l, and the alkali concentration not increases than 25 g/l. up on using 4% dye conc. Upon using microwave irradiation technique give higher in K/S about 14%. And also increase the time of fixation using microwave up to 10 min. give higher in K/S about 70% compared with dyed cotton fabrics, using cold pad –batch dyeing method, then dry at room temperature and fixation at 160 ^{0}C for 5 min.

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