Al-Nahrain Journal for Engineering Sciences **NJES**22(2)73-80, 2019
http://doi.org/10.29194/NJES.22020073

Study the Effect of Using Microwave Energy in Chemical Processes for Dyeing and Printing Pretreatments of Cotton Fabrics

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Paper History:

Received: 25th Nov. 2018

Revised: 15th Feb. 2019

Accepted: 30th April 2019

Abstract

The research focuses on studying the effect of microwave energy as an alternative heating method on dyeing and printing pretreatments of cotton fabrics. In this research, a microwave oven was used to heat the solutions which used in de-sizing, scouring, bleaching and mercerizing processes at different energy levels. The results showed the importance of this heating method in improving desizing efficiency where the best result was obtained at 180 W and 24 min and this method was beneficial in saving energy and time. The best result in scouring was obtained at 720 watts and 24 minutes, whereas at 720 watts and 20 minutes was the best result in bleaching. We can save energy, time and chemicals compared with the conventional method.
The mercerizing by microwave increased the absorption of dye solutions for the samples compared with the traditional method, where the color strength increased by increasing the treatment time and the level of energy in the microwave and the best result was obtained at 900 watts and 90 seconds.

Keywords: Desizing, Scouring, Bleaching, Mercerizing, Microwave Energy.

دراسة تأثير استخدام طاقة الميكروويف في العمليات الكيميائية لتجهيز الأقمشة القطنية للصباغة والطباعة

لينا الميرداش, زياد سفّور

الخلاصة:

يركز البحث على دراسة تأثير طاقة الميكروويف كوسيلة تسخين بديلة على عمليات تجهيز الأقمشة القطنية للصباغة والطباعة. في هذا البحث, تمّ استخدام فرن ميكروويف لتسخين المحاليل المستخدمة في عمليات نزع النشاء والغلي بالقلوي والتبييض والمرسزة عند مستويات مختلفة للطاقة وبيّنت النتائج أهمية هذه الطريقة في التسخين في تحسين كفاءة نزع النشاء حيث كانت أفضل نتيجة عند المستوى 180 واط وزمن 24 دقيقة وبالتالي ساعدت هذه الطريقة في توفير الطاقة والزمن, وكذلك في عملية الغلي بالقلوي فقد كانت أفضل نتيجة عند المستوى 720 واط وزمن 24 دقيقة, أما التبييض فكانت أفضل نتيجة عند 720 واط وزمن 20 دقيقة, وبالتالي ساعدت العمليتان السابقتان في الميكروويف في توفير الطاقة والزمن وكذلك المواد الكيميائية المستخدمة بالمقارنة مع الطريقة التقليدية, أمّا في عملية المرسزة فقد ساعدت هذه الطريقة على زيادة امتصاص محاليل الصبغة للعينات المرسزة في الميكروويف مقارنة بالطريقة التقليدية حيث ازدادت قوة اللون بزيادة زمن المرسزة ومستوى الطاقة في الميكروويف وكانت أفضل نتيجة عند مستوى 900 واط وزمن 90 ثانية.

الكلمات المفتاحية: نزع النشاء، الغلي بالقوي، التبييض، المرسزة، طاقة الميكروويف.

1. Introduction

The pre-dyeing stage includes a series of operations that prepare the textile product for subsequent finishing treatments such as dyeing, printing and finishing. the pre-dyeing stage includes for example desizing, scouring, bleaching and mercerizing. [7] [8]

Desizing is carried out on woven fabrics to remove the sizing substance from the warp which can be done by using water (rot steeping), acid, enzyme, oxidation chemicals and alkali. The size must be totally eliminated since the fabric must absorb the liquor of subsequent processes homogeneously. [7] [8]

On cotton fibers, scouring removes fatty, waxy and pectic substances, softening motes and preparing the material to absorb the subsequent treatment agents. This treatment is usually carried out in soft water additivated with textile auxiliaries such as absorbing agents, detergents, emulsifying agents, caustic soda and sequestering agents. Alkali make the fiber swell and enhance the action of surfactants. Incomplete scouring processes usually originate dyeing and printing defects due to different degrees of wettability and to inconsistent affinity for dyes of the material. [7] [8]

Bleaching treatments are applied to eliminate any impurity and obtain a pure white tone, to prepare substrates for low-density dyes or prints and to level off undesired tone variations. Bleaching agents mainly used for cellulosic fibers are sodium hypochlorite and hydrogen peroxide. They both require the addition of sodium hydroxide in the bleaching liquor to make it alkaline by favoring the formation of the bleaching ion, which in the first case is the hypochlorite ion and in the second one the perhydroxyl ion. [7]

Mercerizing is a typical treatment for cotton yarns and fabrics, which improves the fabric luster and wettability, ensures a covering effect for dead cotton, improves dimensional stability and dyeing efficiency. This treatment is carried out using caustic soda (28 - 30° Bé), which determines the contraction and swelling of the fibres; they become translucent and increase their tensile strength, but reduce their flexural and torsion strength. The bean-like section of the fibre becomes first elliptic then circular, allowing a better reflection of light with a consequent increase of luster. The treatment is usually carried out under tension, with caustic soda at 28°- 30° Bé (approx. 270- 330 g/l). The liquor temperature usually ranges between 15-20° C and its uniform absorption are assured by adding mercerizing wetting agents stable in alkaline environment. Once the operation has been carried out, alkalinity must immediately be neutralised by means of a diluted acid solution. From a chemical point of view, alkali cellulose is the first material to form; the next material, which forms after repeatedly being washed with water, is hydrocellulose, which is more reactive than natural cellulose. [7]

Microwaves are electromagnetic irradiation in the frequency range 0.3–300 GHz (wavelengths of 1mm to 1 m), between infrared radiation and radio frequencies. [1] [5] Over the last decade, microwave dielectric heating as an environmentally benign process has developed into a highly valuable technique, offering an efficient alternative energy source for numerous chemical reactions and processes**.**

Microwave heating is based on dielectric heating, the ability of some polar liquids and solids to absorb and convert microwave energy into heat.

Textile processing consumes huge amount of energy as in dye fixation and heat setting. Heat can be transferred to material by radiation, conduction and convection and these three ways of heat transfer can be employed in either separately or in combination. Saving time and energy is of immediate interest to the textile industry. The introduction of new techniques which will allow less energy to be used is a highly important area of activity to consider. A relatively short section of properly designed microwave heating can increase production speed.

In microwave processing, energy is supplied by an electromagnetic field directly to the material. This results in rapid heating throughout the material thickness with reduced thermal gradients. Volumetric heating can also reduce processing time and save energy. [1] [6]

Advantages of using microwave energy in dyeing and finishing of the fabrics include the following:

- improving the physical properties of the treated cellulose fabrics (The crystallinity and preferred orientation of the treated cotton cellulose increased). [1] [2] [11]

- increasing the tensile strength of cellulose fabric with the increase of temperature and processing time. [1] [2]

- Microwave irradiation technique was used for the chemical modification and grafting of protein fibrous materials, such as domestic silk. [1]

- Microwave processing technology has speed, efficiency and regularity. [1]

- The microwave dyeing technique showed a reduction in dyeing time and a better penetration of dye, giving higher coloration and enhance fast coloring. [1] [3]

- The use of thermal energy in the form of microwave energy improves quality and reduces cost by reducing large quantities of dyes and chemicals during the processes of fabric treatment and dyeing. [1]

- The microwave treatment system has been found to be useful in the production of cotton fabrics with anti-bacterial properties. [1]

- 100 % isotactic polypropylene (iPP) which is widely used in technical textiles, 80/19/1 and 60/30/10 % iPP/ LLDPE (linear low-density polyethylene polymer fibres) / EVA (elastomer of ethylene-vinyl acetate) ternary polymer blend fibres were dyed using conventional and microwave heating methods under atmospheric condition with C.I. Disperse Yellow 114, Red 60 and Blue79, where the process time was reduced almost 90% by microwave heating. [4]

- Results of performed investigations are indicating that microwaves are suitable for drying as well as curing processes of textile finishing. [5]

- Application of microwaves in Durable Press finishing offers significant improvement in comparison to the classical curing method and microwave treatment reduces formaldehyde release. [5]

- Dyeing of polyester fabrics with disperse dyes under conventional and microwave heating conditions was studied, and all of results indicate that the microwave dyed samples are better than the conventional samples: in terms of significantly decreasing dying time. [9]

- Microwave energy increases the diffusion of dye molecules in dyeing process when applied to Polyamide fibers, and it is also used in pre- finishing of silk yarns. [11]

- The efficiency of microwave irradiation to heat the polyester hydrolysis process was found to be higher than that of the conventional heating method and greater dye uptake was also achieved by using microwave irradiation. [12]

- the cotton fabric and Reactive Violet H3R dye solution were treated with microwave radiation and it has been concluded that microwave irradiation has a promising potential to improve the color strength and dyeing properties under mild conditions.[13]

- Disperse Yellow 211 has been used to dye the polyester fabric under the influence of microwave treatment and was found that microwave treatment has not only reduced the dyeing conditions but also improved the color characteristics of dyed polyester fabric. [14]

- microwave energy and nanotechnology was used to improve the printability and performance of cotton prints via screen printing technique and the results showed that the prints obtained by using microwave energy and Ag-NPs were having better color strength, fastness properties, antibacterial behavior and surface morphology when they compared to the conventional techniques by using thermo-fixation and steaming. [15]

- microwave pad dyeing process for wool fabric was studied, and it was found that uniform dyeing and deeper color can be achieved throughout the microwave pad dyeing process for wool by using galactomannan, and the novel process could reduce the dyeing time and the energy consumption of the traditional cold pad-batch dyeing process for wool fabric.[16]

- Microwave pretreatment can improve the dyeability of wool fabric and didnot seem to influence the crystallinity of the wool fiber significantly.[17]

- microwave and ultrasound irradiation was used as green methodologies, not only to improve dyeing performance of polyester fabric with disperse red 60, but also to save energy for preserving the environmental impact. Results showed higher fastness properties than the conventional dyeing and the temperature is reduced from 130 °C to 80 °C. Additionally, the new process gives better dye uptake.[18]

Thus, microwave energy can be used as an alternative heating source for reducing processing time, energy and some chemicals saving that used in processes applied in textile industry.

The goal of this work is the use of microwave energy in dyeing and printing pretreatment compared with the traditional method, where the publications in this field are limited.

2- Experimental:

The processes of desizing, scouring, bleaching and mercerizing were done in the conventional method and by using the microwave at different energy levels and times as described below.

2-1- Materials:

A raw woven plain fabric, 100% cotton with the weight of 160 g/cm², was used in this study and the chemicals used are:

1. Pancreatin enzyme where:
   effective pH range: pH= 4.75 to 7.0
   optimum pH: pH= 6.0 to 7.0
   effective Temperature range: up to 65 ℃
   optimum Temperature: 40 ℃
2. sodium chloride salt (NaCl)
3. Acetic acid.
4. NaOH.
5. HCl acid (36 %)
6. hydrogen peroxide (H_2O_2 , 35 %).
7. oxygen stabilizer.

2-2- Devices:

The devices used are:

1. microwave oven from LG MC-9287BR shown in Fig (1) operates at 5 energy levels shown in the table (1):

Figure (1): the microwave oven used in the experiments.

2. Water bath (Cambridge) Ltd. ENGLAND (1500 watt) used in desizing experiences in the traditional method.

3 - electric heater (800 W) used in the experiences of scouring and bleaching in the traditional way.

2-3- procedure:

The energy levels of the microwave oven used in the experiments are shown in the table (1):

Table (1): the energy levels in the microwave.[19]

Power Output (watt)	Power level (%)
900	100
720	80
540	60
360	40
180	20

Water temperature changes with time were studied at the previous five energy levels by placing a water container (as 400 ml) in the microwave and measuring the water temperature changes every minute and at each energy level by using a thermometer as shown in Fig (2).

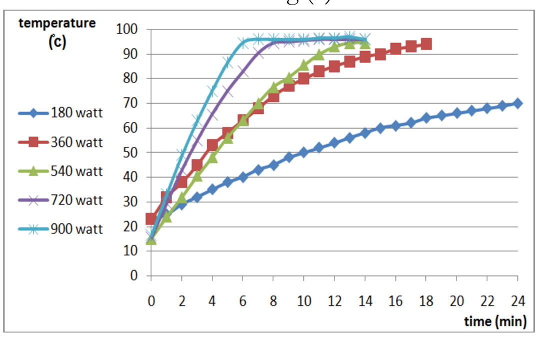

Figure (2): Water temperature changes with time for the five energy levels

The above figure shows the rapid effect of high energy levels in raising the temperature of the liquid while the energy level of 180 watts requires longer than 24 minutes for boiling.
The previous figure gives an approximate idea of the changes of the aquatic solution temperature within the microwave at a given volume of liquid.

2-3-1- Desizing

Pancreatin enzyme and NaCl salt were used in the conventional desizing method (in a water bath) and by using the microwave at the five energy levels. The degree of desizing was determined by using the violet scale (quality method) and then the quantitative method. The conventional treatment temperature was 40 ℃ by using the water bath for 60 minutes (Temperature rise to 40℃ required 15 minutes).
The samples were treated by HCl acid (3 g/l) after desizing for quantitative assessment of desizing degree, the liquor

ratio 1:40 at 70 ℃ for (30 minutes) and then washed and dried to get the weight (w3).
Total Size = W1 – W3
Residual Size = W2 – W3 , where:
W1: The weight of the sized fabric.
W2: The weight of the desized fabric.
W3: The weight of the fabric after acidic treatment.
Desizing efficiency is determined in two ways:
* Conventional Method by using the equation (1).

$$\text{Desizing Efficiency} = \frac{(\text{Total Size} - \text{Residual Size})}{\text{Total Size}} \times 100\% \quad ...(1)$$

* TEGEWA Rating.
for TEGEWA Rating: the reagent was prepared by using potassium iodide (10 g), iodine (0.6358 g) in (water/ ethanol) solution (1000 ml). A drop of this solution (undetermined volume) was placed on the fabric and rubbed it until the drop is absorbed and the color change were evaluated by using the violet scale.
Figure (3) shows the violet scale used to evaluate the degree of desizing of the treated samples.

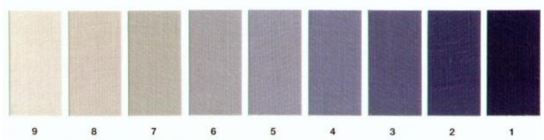

Figure (3): The violet scale used to evaluate the degree of desizing of the treated samples.

2-3-2- scouring

The alkaline boiling process (scouring) was carried out in the traditional method by using NaOH (5 g/l) and a heater (800 watt) for 15 minutes at boiling (the process in the traditional heating method lasted 30 minutes including 15 minutes at boiling), as well as the samples were scoured by using the microwave at two levels of energy (900, 720 watts) and the same concentration of NaOH and wetting agent (0.5 g/l) (this process needs boiling so the other energy levels that need longer time to boil were removed) and the liquor ratio was 1:30.
In addition, the possibility of reducing the used amount of sodium hydroxide in boiling was studied at the concentration of (4 g/ l) for NaOH and (0.4 g/l) wetting agent and liquor ratio (1:30). After scouring, all samples were washed and treated by acetic acid solution, washed and dried. Thus, four groups of samples were obtained, as shown in the results and discussion part.
The absorbency of the fabric was tested by using AATCC Test Method 79-2000, where a drop of water is allowed to fall from a fixed height onto the taut surface of a test specimen. The time required for the reflection of the water drop to disappear is measured and recorded as wetting time. Five seconds or less is generally considered to represent adequate absorbency.

2-3-3- Bleaching

The bleaching process of the desized and scoured cotton samples was carried out in the conventional method with an electric heater (800 watt) for 15 minutes at boiling (The process lasted 28 minutes from the moment the temperature was raised until the process was completed) and by using microwave energy at (900, 720, 540, 360 watts) according to the quantities listed in the table (2):

Table (2): Quantities of chemicals used in the bleaching experiments

Material	H_2O_2	oxygen stabilizer	NaOH	wetting agent
Cons (g/l)	3	3	0.5	0.5

liquor ratio 1:30.

Two samples were bleached at the energy level of 720 watts and at the time of 24 and 28 minutes to study the effect of microwave in saving the energy, time and chemicals according to the table (3):

Table (3): Experimental data for the sixth group of bleached samples.

Material	H_2O_2	oxygen stabilizer	NaOH	wetting agent
Cons (g/l)	2.5	2.5	0.42	0.42

liquor ratio 1:30.
six groups of bleached samples were obtained as shown in the table (4).

Table (4): Experimental data for bleached samples.

number	group	sample	power output (watt)	bleaching time (min)	chemicals (g/l)
1	I	Traditional	800	28	3 g/l H_2O_2 + 3g/l oxygen stabilizer + 0.5 g/l NaOH + 0.5 g/l wetting agent
2A	II	Bleached in the microwave	900	4	
2B				8	
2C				12	
2D				16	
2E				20	
3A	III	Bleached in the microwave	720	4	
3B				8	
3C				12	
3D				16	
3E				20	
4A	IV	Bleached in the	540	8	
4B				12	

4C		microwave		16	
4D				20	
5A	V	Bleached in the microwave	360	20	
5B				24	
6A	VI	Bleached in the microwave	720	24	2.5 g/l H_2O_2 + 2.5 g/l oxygen stabilizer + 0.42 g/l NaOH + 0.42 g/l wetting agent
6B				28	

2-3-4- Mercerizing:

The desized and scoured cotton samples were mercerized in the microwave. six groups of samples were mercerized by using NaOH at a concentration (270 g/l) under the tensile. perforated wooden frames were used to fix the samples by threads and then immersed them in NaOH solution in the traditional cold method (at room temperature) as well as in the microwave at the five energy levels for 30, 60 and 90 seconds for each group of samples (each group consists of 3 samples) and then the previous samples were dyed with an non-mercerized sample (a comparative sample) to study the effect of the mercerization in this way on the dyeability for mercerized samples in comparison with non-mercerized sample.

Direct Red 4BS was used in the dye experiments and the color strength (k/s) of the dyed samples was measured by using X-Rite spectrophotometer by GretagMacbeth with iQC Color program, where the comparison sample is (sample 0) as shown in the table (10) where:

$$\frac{K}{S}=\frac{(1-R)^2}{2R} \quad ……(2)$$

where;
K: absorption coefficient.
S: scattering coefficient.
R: the reflection coefficient value at λ_{max}.

3- Results and discussion:

The table (5) shows the experimental data of desizing by using the microwave energy comparing with the conventional method and the results of the experiment based on the violet scale.

Table (5): Experimental data of desizing process by using the microwave energy comparing with the traditional method, and the evaluation was by using the violet scale (where: pH =5.7, liquor ratio (1:40), NaCl cons= 4 g/l, Enzyme cons= 1 g/l)

number	sample	Power Output (watt)	Desizing time (min)	TEGEWA rating
1	Traditional method	1500	60	4
2	Treated in the microwave	180	4	2
3			8	3
4			12	4
5			16	5
6			20	5
7			24	6
8	Treated in the microwave	360	4	3
9			8	5
10			12	5
11			16	5
12	Treated in the microwave	540	4	3
13			8	5
14			12	5
15	Treated in the microwave	720	4	4
16			8	5
17	Treated in the microwave	900	4	4
18			8	5

The table (5) shows that:
- The desized sample by the conventional method has a moderate result on the violet scale (value of 4) and was not commercially acceptable. Therefore, the treatment time had to be increased by more than 60 minutes to obtain a commercially acceptable result and this is one of the disadvantages of enzymatic treatment in the traditional method that require a long time. [10]
- The best result of desizing by using the microwave is at 180 watt and 24 min (for the sample 7). The evaluation on the violet scale (value of 6) is commercially acceptable and logical. At this energy level, the temperature was gradually and slowly increasing compared with the other energy levels in which the temperature of the solution rises faster and therefore the level of 180 watts provides a longer period within the field of the effective work of the enzyme, unlike the higher energy levels where the temperature in which rises faster and larger.
- The quantitative method was used to determine the efficiency of desizing for the conventional sample and the sample (7) which showed the best result for the treated samples in the microwave as shown in table (6):

Table (6): Desizing efficiency of the conventional sample comparison with the sample (7) in the microwave.

number	Method of the processing of the sample	W1 (g)	W2 (g)	W3 (g)	Desizing efficiency (%)
1	Traditional	7.0742	6.6155	6.4728	76.3
7	in the microwave	6.9746	6.5432	6.4496	82.2

where:
W1**:** the weight before enzymatic treatment (g).
W2: the weight after enzymatic treatment (g).
W3: the weight after acidic treatment with HCl (g).

The two tables show the importance of microwave energy for time saving by 60% and obtaining a better result than the treated sample in the traditional method. The desizing efficiency increased from 76.3% for the treated sample in the traditional method to 82.2% for the sample (7) treated in the microwave. Thus, the treatment with pancreatin enzyme in the microwave is better than the traditional method in terms of efficiency and the process speed.

The table (7) shows the experimental data and results of scouring for the conventional and microwave method as follows:

Table (7): The experimental data and results of scouring for conventional and microwave method

number	group	Treatment method	Scouring time (min)	Power Output (watt)	NaOH cons (g/l)	Absorption time (sec)
1	I	traditional	30	800	5	<1
2	II	In the microwave	4	900	5	30
3			8			18
4			12			13
5			16			7
6			20			<1
7	III	In the microwave	4	720	5	30
8			8			20
9			12			12
10			16			10
11			20			5
12			24			<1
13	IV	In the microwave	20	900	4	4
14			24			2
15			28			1.5

The table (7) shows that:
- The scoured sample in the traditional method showed that the result of absorption was good, but the process lasted 30 minutes.
- The sample (6) in the second group which scoured by the microwave at 900 watt and 20 minutes showed a good result of absorption and 33% time saving, but the energy level was higher compared with the traditional method.
- The sample (12) in the third group which scoured by the microwave at 720 watt and 24 minutes showed a good absorption result, 20% time saving and 10% energy saving compared with the traditional method.
- The amount of sodium hydroxide can be saved by 20% when scouring carried out in the microwave at 900 watt and can be obtained a commercially acceptable samples (the samples 14 and 15) compared with the traditional method.
The results of bleaching of the samples were defined by measuring the degree of optical reflection of the samples by using spectrophotometer from X-Rite, GretagMacbeth, with color IQC, compared with an unbleached sample, and the results are shown in the table (8):

The table (8) shows that:
- By comparing the samples of the second group with the bleached sample in the conventional method, it is observed that the sample (2B) gave a higher reflection of the light by comparison with the conventional sample. Therefore, the bleached sample at 900 watts and 8 minutes in the microwave was better than the traditional sample and time saving of 71.4%.
- It is observed that the increasing of the degree of optical reflection along with increasing the bleaching time in the microwave at 900 watts and the better result was the sample (2D) which showed the highest reflection of light in the second group at a time of bleaching of 16 minutes. Also, it is observed that a slight decrease in the light reflection of the sample (2E) at 900 watts and 20 minutes comparing with the sample (2D).

Table (8): results of the degree of reflection of bleached samples at wavelength (440 nm).

number	group	Power Output (watt)	Bleaching time (min)	Reflection R (%)
0	–	--	--	68.570
1	I	800	28	92.040
2A	II	900	4	86.700
2B			8	92.360
2C			12	94.160
2D			16	98.090
2E			20	96.720
3A	III	720	4	82.640
3B			8	89.570
3C			12	94.440
3D			16	97.050
3E			20	99.990
4A	IV	540	8	90.370
4B			12	94.040
4C			16	97.370
4D			20	99.210
5A	V	360	20	94.960
5B			24	99.900
6A	VI	720	24	95.760
6B			28	95.830

- By comparing the samples of the third group bleached in the microwave at 720 watt with the bleached sample in the traditional method, it is observed that the sample 3C gave a higher reflection of light compared with the traditional sample, and thus at 720 watt and 12 minutes in the microwave can obtain a degree of bleaching better than the traditional sample and saves time by 57.1%, and energy by 10%. By increasing the bleaching time in the microwave, the degree of optical reflection improves, and the better result is obtained from the sample 3E, which gave the highest whiteness and its optical reflection was almost complete.
- It was observed from the samples of the fourth group bleached in the microwave at 540 watts the increasing of the light reflection degree with the bleaching time increase and the best degree of bleaching in the group was at 20 minutes for the sample (4D).
- At the level 540 watts and 12 minutes ((the sample (4B)), it can be to obtaining a degree of bleaching higher than the conventional sample and thus saving time by 57.1% and the energy by 32.5%.
- By increasing the bleaching time in the microwave (the fifth group at 360 watts) the degree of optical reflection increases and the best result was at 24 minutes (sample 5B). The result at 20 minutes was

better than the conventional sample and thus, time saving by 28.6% and energy by 55%.
- The amount of chemicals listed in the table (4) can be saved by 16.7%, time saving by 14.3% and energy saving by 10% when the bleaching carried out in the microwave at 720 watt and 24 minutes (for sample (6A) in the group VI), and this sample is better than the conventional sample.
- The increase in the bleaching time in the microwave to 28 minutes (sample (6B) in the sixth group) was not affected significantly upon increasing the degree of the bleaching compared with the sample (6A) and therefore the time 24 minutes is the most appropriate in this group.

The table (9) shows the experimental data and results of the mercerizing process as follows:

Table (9): the experimental data for the mercerization and color strength of dyed samples (at 700nm).

number	group	Mercerizing method	Power Output (watt)	Time (sec)	the color strength k/s
0	--	non-mercerized	--	--	0.170
1	I	traditional	at cold	30	0.211
2				60	0.213
3				90	0.216
4	II	In the microwave	900	30	0.218
5				60	0.228
6				90	0.241
7	III	In the microwave	720	30	0.217
8				60	0.224
9				90	0.239
10	IV	In the microwave	540	30	0.215
11				60	0.222
12				90	0.235
13	V	In the microwave	360	30	0.214
14				60	0.221
15				90	0.229
16	VI	In the microwave	180	30	0.213
17				60	0.219
18				90	0.228

Figure (4) shows the effect of the energy levels on the color strength of the mercerized samples in the microwave and the conventional method as compared to the non-mercerized sample as follows:
- It is observed the low color strength of the dyed sample without mercerizing comparing with the mercerized samples.
- It was observed that the strength of the color increases with time increasing of mercerizing at each level of energy.
- It was observed the increasing in the color strength with increasing the energy level in the microwave and the best result was at the level 900 watts and 90 sec.

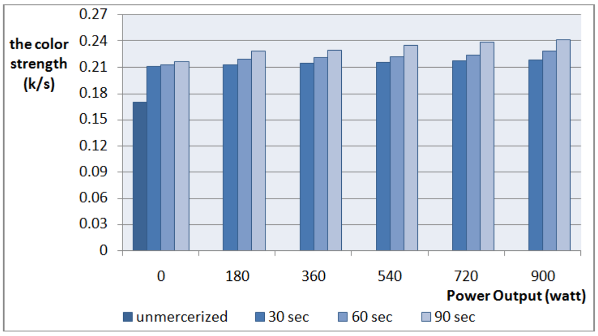

Figure (4): Effect of the energy levels on the color strength of the mercerized samples in the microwave and the traditional method by comparing with an non-mercerized sample.

4- Concluded remarks

1- The traditional method of pretreatment for dyeing and printing consumes large amounts of chemicals and energy and most of them need a long time to carry out.

2- Desizing in the microwave, which takes a relatively short time and requires less energy consumption, is better than the traditional method that takes a long time to get the desired result.

3- Scouring and bleaching in the microwave is better than the traditional method in terms of energy, time and chemicals saving.

4- Mercerizing in the microwave is better than the conventional method where the mercerized and dyed samples showed a higher color strength than the conventional samples with the same mercerizing time.

5- Conclusion:

The use of microwave energy in the dyeing and printing pretreatment of cotton fabrics is one of the most promising and important methods to improve these processes. Desizing by using the microwave energy showed increasing in process efficiency as well as saving of energy and time compared with the traditional method which required longer processing time and gave unacceptable results where it required an increasing in the process time. The scoured and bleached samples in the microwave are better than the traditional samples and have shown savings in energy, time and the used chemicals by remarkable rates. The higher color strength was obtained from the mercerized and dyed samples in the microwave compared with the traditional samples at the same time, and the increasing in the energy level in the microwave increased the color strength.

6- References:

[1] Haggag K. Microwave Irradiatiion and its Application in Textile Industries. Science Publishing Group, First Edition, Cairo, Egypt, 86, 2014.
[2] Hoa A, Wang X, Lianghua Wu. Effect of microwave irradiation on the physical properties and morphological structures of cotton cellulose. Journal Carbohydrate Polymers 74,934-937, 2008.
[3] Murugan. R, Senthilkumar, Ramachandran. T. Study on the possibility of reducation in dyeing time using microwave oven dyeing technique, IE(I) Journal – TX, Vol 87,23-27, 2007.

[4] KoÇak D, Akalin M, Merdan B. Effect of microwave energy on disperse dyeability of polypropylene fibres. Marmara Journal of Pure and Applied Sciences, Special Issue-1: 27-31, 2015.
[5] Katovic D, Bischof Vukusic, Flincec Grgac. Aplication of microwaves in textile finishing processes. Faculty of Textile Technology, University of Zagreb, Department of textile Chemistry and Ecology, Croatia, 2005.
[6] Haggag K, Hanna H.L., Youssef B.M., El-Shimy N.S. dyeing polyester with microwave heating using disperse dyestuffs. Textile Research Division, Nat'l Res.Centre, Dokki, Cairo, Egypt, 1995.
[7] Bellini P. Finishing (reference books of textile technologies), the ACIMIT Foundation, Italy, 202, 2001.
[8] Rachana S. Sustainable processes for pre-treatment of cotton fabric. Springer, 9, 2016.
[9] Al-Mousawi S. Microwave assisted dyeing of polyester fabrics with disperse dyes. Molecules, 11, 2013.
[10] C. Karaboğa, A. E. Körlü, K. Duran, M. İ. Bahtiyari. Use of ultrasonic technology in enzymatic pretreatment processes of cotton fabrics. FIBRES & TEXTILES in Eastern Europe, Vol. 15, No. 4 (63), 97-100, 2007.
[11] Banu Yeşim Büyükakinci. Usage of microwave energy in turkish textile production sector. Energy procedia 14, 424- 431, 2012.
[12] Weilin Xu, Chaoli Yang. Hydrolysis and dyeing of polyester fabric using microwave irradiation, Coloration Technology,118, 211-214, 2002.
[13] Kiran S. Ecofriendly dyeing of microwave treated cotton fabric using reactive violet H3R, Global NEST Journal, Vol 20, 2018.
[14] Shahid Adeel. Sustainable dyeing of microwave treated polyester fabric using disperse yellow 211 Dye, J. *Mex. Chem. Soc.*, *61*(*1*), 2018.
[15] T. Abou Elmaaty. Microwave and nanotechnology advanced solutions to improve Eco-friendly cotton's coloration and performance properties. Egypt.J.Chem. 61, No.3, 2018.
[16] Xue Zhao. Research on microwave pad dyeing process for wool fabric, Research Journal of Textile and Apparel, Vol. 21 Issue: 4, pp.263-275, 2017.
[17] Xue Z. Effect of microwave pretreatment on dyeing performance of wool fabric. Journal of Textile Engineering & Fashion Technology;1(6):217–222, 2017.
[18] Morsy A. El-Apasery. Microwave, ultrasound assisted dyeing- part I: Dyeing characteristics of C.I. Disperse Red 60 on polyester fabric. Egypt. J. Chem. 143 – 151, 2017.
[19] Brochure of LG Society, Korea, The owner`s Manuel for Microwave/Grill/Convection, Model MC-9287BR.