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Minimizing Pollution During Dyeing of Bio-Polished Cotton Fabric Using Eco-Friendly Microwave Technique

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MINIMIZING pollution in textile industry is gaining much attention nowadays. Microwave irradiation technique is one of the best techniques used recently to reduce environmental pollution via saving time, energy, as well as cost. The present work concerned with comparison between two dyeing techniques; conventional and microwave irradiation; of bio-polished cotton fabric with reactive dyeing process. The effect of dye concentration, temperature, liquor ratio, as well as auxiliaries added on the dyability of bio-polished cotton fabrics, was studied. The optimal irradiation parameters were chosen with respect to the colour strength and wash fastness. Physico-mechanical and fastness properties as well as durability of the two techniques were evaluated. Microwave techniques showed the best results as the fabric thickness, crease recovery angle, the warp set the weft sett and wettability increased after enzymatical treatment and microwave dyeing.

Keywords: Minimizing pollution, Microwave irradiation, Bio-polishing, Conventional dyeing, Cotton fabrics.

Introduction

Textile industries causes about 58% of environmental pollution impact.[1] Using enzymes in textile chemical processing is gaining global concern because of their eco-friendly characteristics.

Bio-polishing finishing is applied to cellulose textiles in order to remove protruding fibers from fabrics, significantly reduces pilling, softens fabric hand and provides a smooth fabric appearance [2, 3].

Enzymes are high molecular weight proteins produced by living organisms to catalyze the chemical reactions essential for the organism's survival. The enzyme and substrate together make a 'lock and key' complex that requires the enzyme to have a specific molecular alignment to act as a catalyst. Chemical reactions which catalyzed by enzymes can typically be carried out, under mild aqueous conditions without the need for high temperatures, extreme pH values or chemical solvents [2,4].

Cellulases are a hydrolase class of enzymes that cleave 1-4β glucosidic linkage of cellobiose chain or cellulose. The available cellulase enzymes are a mixture of Endogluconases, Exogluconases, and Cellobiases. Endogluconases are a subclass of cellulase enzymes which randomly attack the cellulose enzymes and cleavage 1-4 β glucosidic linkage of cellobiose chain. Exoglucanases of cellobiohydrolases hydrolyze 1-4 β glucosidic linkage of cellulose to release cellotiose from the cellulose chain. Cellobiases are enzymes which hydrolyze cellobiose into soluble glucose units. All these three enzymes act synergistically on cellulose to hydrolyze it. For textile and detergent applications, cellulase enzyme is characterized by their relatively slow kinetics, which allows the modification of cellulosic fibers in a controlled manner without excessive damage. However,

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high enzyme loads, and long treatment times may lead to severe fiber damage and strength loss [3, 5, 6].

Microwaves are electromagnetic irradiations in the frequency range 0.3–300GHz, between infrared radiation and radio frequencies. It was discovered as a heating method in 1946. Microwaves generate higher power densities. Microwave energy works selectively on the areas of greater moisture. This results in more uniform temperature and moisture profiles, improved yields and enhanced product performance [7, 8].

Microwave dielectric heating works on the activating the polar molecules in the treated medium (polarization phenomenon). In a microwave electromagnetic field oscillating occur at 2.5 GHz, which is considered as a preferred frequency for heating applications, the charge changes polarity nearly five billion times per second under the influence of a high frequency [9, 10].

Dyeing cotton fabrics with reactive dyes via microwave irradiation improved their dyeability and enhanced dye uptake when compared with conventional heating. The microwave heating shortens dye time and save energy greatly.

Cotton is one of the most widespread natural polymers; it has been widely used throughout the world and has a wide variety of applications in apparel, home furnishings, and industrial products [11, 12].

Microwave irradiation is a powerful technique of non-contact heating by causing vibration and rotation of permanent dipoles in the microwave field. Microwave dyeing is a possible alternative to conventional dyeing as it creates polarization in the dye bath to make it more interactive for fabrics. This uniform and leveled heating source help dye molecules to diffuse into fabrics more strongly. This energy easily penetrates all the particles of material by instantly and uniformly heating the fabrics [11,13].

Textile wet processing and dyeing is the leading consumer of water, time, energy, cost, pollutant chemicals as well as producers of wastewater. Therefore, herein, an attempt to solve this problem via using an ecofriendly enzyme treatment and microwave dyeing technique.

The aim of this research is to investigate and compare between two dyeing techniques the Conventional and microwave dyeing technique of bio-polished cotton fabric and choosing the most Eco- friendly technique.

Experimental

Materials

Woven cotton fabrics (100 %) were purchased from Misr Company for Spinning and Weaving, El-Mahalla, Egypt.

Cellulase enzyme was used under the commercial name (Texcell FML, Arslan Company) kindly supplied by El-Maestro Company, Egypt.

Hydrogen peroxide, sodium hydroxide, sodium sulphate, and sodium carbonate were kindly supplied by El-Maestro Company; Egypt were used.

Instruments:

SHARO microwave oven, model (R-210B), power 700 watts (made in Thailand) was used.

Hunter lab Mini Scan XE serial NO.3620, model NO. D/8/s (made in the U.S.A.), Hunter associates laboratory Inc., Reston, VA. was used.

Dyes:

The dye was supplied by Dystar Company, Egypt. The color index and the chemical structure are shown in table (1).

Methods:

Fabric Pretreatment:

Desizing: Cellulosic fabrics were desized for 1 hour at 60 °C using desizing agent (size – L) provided from El-Maestro, Cairo, Egypt.

Bleaching: Half bleaching was carried out using the H_2O_2 (35%) and NaOH (0.5%) at 70°C for 10 minutes followed by rinsing and air drying.

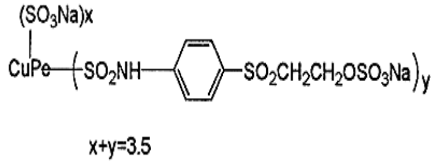
Bio-polishing: Bio-polishing process was conducted using a cellulase enzyme (1 g/l) at 60°C, pH 5 for 10 min followed by rinsing and finally drying.

Dyeing: Reactive dyeing at fabrics was carried out using a 3% shade of Remazol® Turquoise Blue G-133.

Dyeing techniques:

Conventional exhaustion method using technical data sheet recommended by Dystar company, Egypt. The material liquor ratio was (1:50), the dye concentration (3%), sodium chloride (60 g/l), and sodium carbonate (15 g/l) as shown in the following figure.

TABLE 1.The chemical structure of dye and its color index:

Dyes	Color index	Chemical structures
Remazol® Turquoise Blue G-133	Reactive Blue21	

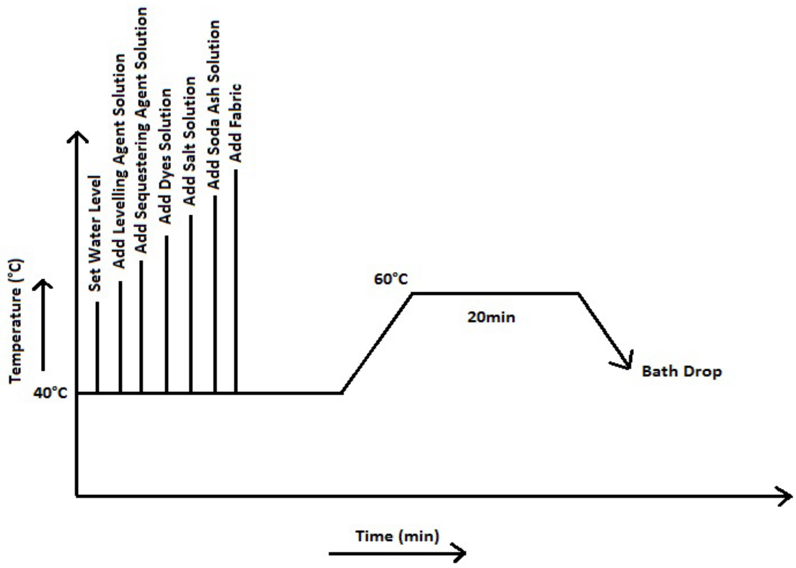


Fig.1.Technical data sheet recommended by Dystar Company

Dyeing of cotton fabric with reactive dyes using microwave technique:

Bio polished cotton fabrics were dyed using Remazol® Turquoise Blue G-133. at different dye concentrations (1, 2, 3, 4 and 5%); time(10, 20,30,40 and 50 min.); microwave power (140, 280, 420, 560 and 700 watt); sodium sulphate(2, 3, 4, 5 and 6%) and sodium carbonate (0 .5, 1, 1.5, 2 and 2.5%).

Testing and analysis:

The warp and weft sett:

The warp and weft threads of fabric were measured according to ASTM D 3775-98 [14].

The fabric weight:

The weight of the fabric was determined according to ASTM D3776-09a [15].

Color strength(K/S)

Color strength (K/S) of the dyed samples was measured using Mini Scan XE spectrophotometer using Hunter lab universal software, which based on Kubelka-Munk equation:

$$K/S=(1-R)^2/2R \qquad \text{Eqn. (1)}$$

where: K, S, and R are the absorption coefficient, scattering coefficient and reflectance, respectively.

Physico- mechanical measurements:

Stiffness of fabric:

The stiffness of the fabrics was measured according to ASTM D1388-18 [16].

Tearing strength:

Tearing resistance of woven fabrics was determined according to ASTMD1424 [17].

The tensile strength and elongation:

The tensile strength and elongation of woven fabric were determined according to ASTMD5035[18].

Wrinkle recovery:

The Wrinkle crease recovery of woven fabric in the warp and weft direction was measured according to **AATCC 66-2008** test method [19].

The wettability:

Wettability of fabric before and after treatment was measured according to ISO 4920 [20].

Durability test:

The durability of the treated fabric against repeated laundering was evaluated according to **the AATCC 124-1992** test method subjected to the 5-25 washing cycle in the presence of the nonionic detergent [21].

Fastness Properties:

Light fastness

The light fastness of dyed fabric was determined according to ISO **105-BO2** test method color fastness to artificial light Xenon arc fading lamp test [22].

2.6.5.2. Wash fastness:

The wash fastness of dyed fabrics was determined according to **ISO105-C06** [23].

Perspiration fastness:

Perspiration fastness was determined according to AATCC15-2002 [24].

Result and Discussion

Dyeing bio-polished cotton fabrics with reactive dyes via the conventional technique:

Dyeing conditions: Remazol® Turquoise Blue G-133. Concentration 3% (o.w.f), salt 6% (o.w.f), liquor ratio 1:50 (o.w.f), soda ash 1.5 % (o.w.f).

It was observed from Table (2) that the K/S of the treated fabric (bio-polished fabric) enhanced by 10% using Remazol® Turquoise Blue G-133. The improvement may be due to the removal of the protruded fuzz fibers from the surface of the fabric leading to enhance wettability and absorbency [3, 5].

The wettability of the fabrics facilitates the penetration of the dye from the surface through the open fine micropores structure of the bio polished fabric, leading to enhance the K/S and fastness properties of the dye [25, 26].

Dyeing cotton fabrics with reactive dyes via microwave technique:

To investigate the effect of microwave irradiation on dyeing of bio-polished cotton fabric, a variety of conditions are investigated.

Effect of dyeing time on the treated cotton fabrics using microwave techniques:

Dyeing conditions: Remazol® Turquoise Blue G-133.concentration 3% (o.w.f), Na_2SO_4 5%(o.w.f), soda ash 1.5% (o.w.f), liquor ratio 1:50 (o.w.f) and microwave power 140 watt, time (10:50 min.)

Tables (3) shows the results of color strength (K/S) and wash fastness properties of the untreated and bio- polished cotton fabric dyed with reactive dye using microwave irradiation technique at different treatment time. The improvement percentage on the K/S of the bio-polished fabric dyed via microwave and bio-polished conventional method was calculated according to the following equation:

$$\frac{K/S_1 - K/S_2}{K/S_1} * 100 \qquad \text{Eqn. (2)}$$

Where K/S_1 is the color strength of the bio polished microwave dyeing sample and K/S_2 is the color strength of bio-polished conventional dyeing sample.

The color strength of the bio-polished microwave dyeing fabrics was improved by 24% than the conventional technique. This may be due to the mode of action of microwave irradiation. The microwave ovens heat materials by passing microwave radiation through it. Microwaves are form of non-ionizing electromagnetic radiations with a frequency higher than ordinary radio waves but lower than infrared radiation [27, 28].

Many molecules are electric dipoles; for example, water has a partial positive charge at one end and a partial negative charge at the other end when subjected to alternating electric fields of the

TABLE 2. Shows the results of dyeing of untreated and bio-polished cotton fabrics with Remazol® Turquoise Blue G-133 via the conventional method and their wash fastness property using a grayscale.

Cotton fabric	Color strength (k/s)	Wash fastness
Untreated	**1.5804**	**5**
Bio-polished	**1.7453**	**5**

Dyeing conditions: Remazol® Turquoise Blue G-133. Concentration 3% (o.w.f), salt 6% (o.w.f), liquor ratio 1:50 (o.w.f), soda ash 1.5 % (o.w.f).

microwaves they rotate and tries to align themselves. This rotation leads to hitting other molecules and putting them into motion thus dispersing energy. This dispersed energy of a molecular (rotations, vibrations and/or translations) raises the temperature of the solids and liquids. Microwave irradiation creates polarity and volumetric heating inside the solution bonding with cotton fabric [13, 29].

Increasing the time of the reaction accelerates the migration rate of the dye in the direction of fabric rather than the other direction (the formation of the hydrolyzed dye) which leads to increase in the color strength, the time saved by the microwave dyeing technique (58%) and calculated according to the following equation:

$$(T_1-T_2/T_1) * 100 \qquad \text{Eqn. (3)}$$

Where T1 is the time consumed in the conventional dyeing process (120 min) according to the technical data sheet recommended by Dystar Company in Fig.1 and T2 is the time consumed in the microwave dyeing technique (50 min) from the Table (3).

3.2.2 Effect of dye concentration on K/S and wash fastness of cotton fabrics using microwave techniques:

Dyeing condition: Remazol® Turquoise Blue G-133.concentration (1: 5 % (o.w.f)), time 50 min, Na2SO4 5% (o.w.f), soda ash 1.5% (o.w.f), Liquor ratio 1:50 (o.w.f) , and microwave power 140 Watt.

Table (4) shows an increase in the K/S by increasing the dye concentration in both untreated and bio- polished samples. The extent of this increase upon using microwave irradiation is higher than the conventional method. The enzyme treatment improved the fabric wettability by removing the fuzz fibers and improving the K/S [13, 29].

The table also shows the results of the wash fastness property of the treated and untreated samples which range from 4 to 5 with both samples. This may be due to the linkage between primary hydroxyl group of cellulosic cotton fabric and reactive group of reactive dye is strong and doesn't allow the dye molecule to detach from the fabric surface [30].

The wash fastness decreased at concentrations 4 and 5 due to competition reaction between the dye and the hydroxide anions present in the aqueous alkaline dyebath, so the equilibrium state is not reached.

Effect of microwave power on K/S and wash fastness of cotton fabrics using microwave techniques

Dyeing condition: Remazol® Turquoise Blue G-133 concentration 3 % (o.w.f), time 50 min., Na2So4 5%(o.w.f), Soda ash 1.5%(o.w.f), Liquor ratio 1:50(o.w.f), and Microwave power (140, 280, 420, 560 and 700).

Table (5) shows that increasing the power of microwave led to a decrease in the color strength of both bio-polished and untreated dyed cotton fabric. The low microwave irradiation temperature is considered enough to raise the energy of the colorants, whereas, at high microwave heating level a dyebath shift occurs to dye bath equilibrium from fabric to solution (hydrolyzed dye i.e. disaggregation occurs as

TABLE 3.The effect of different dyeing time on the color strength and wash fastness of untreated and bio- polished cotton fabrics:

Samples									
Untreated					Bio-polished				
Time (min.)									
10	20	30	40	50	10	20	30	40	**50**
K/S									
0.7076	1.1082	1.215	1.5801	1.9022	1.1149	1.301	1.423	1.617	**2.2943**
Wash fastness									
4	5	5	5	5	4	4	5	5	**5**

Dyeing conditions: Remazol® Turquoise Blue G-133.concentration 3% (o.w.f), Na2SO4 5%(o.w.f), soda ash 1.5% (o.w.f), liquor ratio 1:50 (o.w.f) and microwave power 140 watt, time (10:50 min.)

shown in fig. 2.) which in turns gives low color strength. The dyeing equilibrium shifts the dyeing process in the endothermic direction i.e. heat-absorbing, dye desorbing from the fibers so that the final exhaustion is less color strength than at higher microwave power [31].

The effect of the temperature on the reactive dye is considered to be one of the important parameters in reactive dyeing. In the conventional

TABLE 4. The effect of different concentrations of Remazol® Turquoise Blue G-133 dye on the color strength and wash fastness of the cotton fabric.

Samples									
Untreated					Bio polished				
Dye concentration% (o.w.f)									
1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
K/S									
1.418	1.656	1.902	1.987	2.011	1.528	1.881	2.294	2.350	2.502
Wash fastness									
5	5	5	4	4	4	4	5	4	4

Dyeing condition: Remazol® Turquoise Blue G-133.concentration (1: 5 % (o.w.f)), time 50 min, Na2SO4 5% (o.w.f), soda ash 1.5% (o.w.f), Liquor ratio 1:50 (o.w.f) , and microwave power 140 Watt.

TABLE 5.The effect of different microwave power on the color strength (K/S) and wash fastness of the bio-polished and untreated cotton fabric

Samples									
Untreated					**Bio polished**				
Microwave power (watt)									
140	280	420	560	700	140	280	420	560	**700**
K/S									
1.9022	1.844	1.721	1.654	1.588	2.2943	2.156	2.01	1.945	**1.865**
Wash fastness									
5	5	4	4	4	5	4	4	4	**4**

Dyeing condition: Remazol® Turquoise Blue G-133 concentration 3 % (o.w.f), time 50 min., Na2So4 5%(o.w.f), Soda ash 1.5%(o.w.f), Liquor ratio 1:50(o.w.f), and Microwave power (140, 280, 420, 560 and 700).

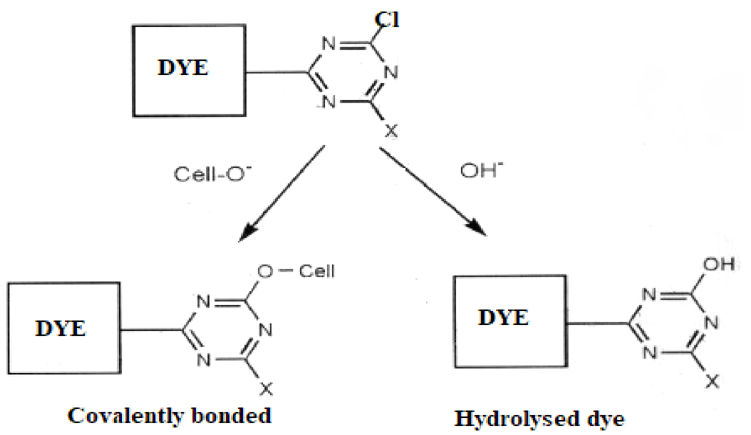


Fig.2. The schematic of the competition reaction of reactive dyeing [37]

dyeing techniques, the gradual rise of temperature, the kinetic energy of colorant is raised, and its sorption ability is enhanced, thereby giving excellent color strength on to fabrics. On the other hand, in microwave techniques the dyeing process is carried out at low power (140 Watt) to avoid the dyeing shifting [31]. Moreover, high dyeing temperature causes degradation of the colorant and by-product formed after degradation get significant chance to sorb onto fabric [30], which in turn gives low K/S value. Hence microwave irradiation at high power to both dye solution and cotton fabric is not recommended.

The table also shows the results of wash fastness of the samples which also decreased upon increasing the temperature. This may be due to the washing off the unbounded and desorbed dyes.

Effect of dying liquor ratio on K/S and wash fastness of cotton fabrics using microwave techniques

Dyeing condition: Remazol® Turquoise Blue G-133. Concentration 3 % (o.w.f), time 50 min., Na_2So_4 5% (o.w.f), Soda ash 1.5% (o.w.f), Liquor ratio (1:20 to 1:60), and Microwave power 140 watt.

Table (6) shows the results of different dyeing liquor ratio effect on the color strength and wash fastness of the cotton fabric. The role of dye bath volume is very important in reactive dyeing, it is found that low dye bath volume gives less color strength, while high dye bath volume causes over sorption of dye molecules in the irradiated cotton fabric [31].

Using a high liquor ratio (1:50) of dye solution with microwave technique causes even sorption onto irradiated fabric results in a maximum color strength (K/S). The wash fastness shows gradually increase by increasing the Liquor ratio. it reached grad 5 at liquor ratio1:50and at low liquor ratio at 1:20 and 1: 30 recorded grade 3 and 4 this may be due to the uneven dyeing. The dyeing Liquor ratio for the dyeing of treated and untreated cotton fabric with Remazol® Turquoise Blue G-133. dye is 1:50 (o.w.f.)

Effect of Sodium Sulfate (Na_2SO_4) concentration on dyeing cotton fabrics using reactive dye

The following table shows the results of the effect of different sodium sulfate concentration on the color strength and wash fastness of the cotton fabric

Dyeing condition: Remazol® Turquoise Blue G-133 concentration 3 % (o.w.f), time 50 min., Na_2S_4 (2: 6% (o.w.f), Soda ash 1.5% (o.w.f), Liquor ratio 1:50, and Microwave power 140 watt**.**

From table (7), it was observed that increasing of Na_2SO_4 concentration the K/S increased. This can be explained in terms of the action of the salt which creates an electrically positive double layer, which hides the negative electrostatic charge of the cotton surface (- OH^-). This leads to a significant attraction of the dye to the surface of the fabric and an increase of K/S (the small size of the salt particles compared to dye molecule, the salt occupies first the (–OH^-) negative site. [32, 33].

The wash fastness properties showed also good results even at low concentrations. This result agreed with the previous studies [32, 33].

Effect of Soda ash concentration on dyeing cotton fabrics using reactive dye

TABLE 6. The effect of different dyeing liquor ratio on the color strength and wash fastness of the cotton fabric using Remazol® Turquoise Blue G-133 .

Samples	**Untreated**					**Bio polished**				
Liquor ratio	**1:20**	**1:30**	**1:40**	**1:50**	**1:60**	**1:20**	**1:30**	**1:40**	**1:50**	**1:60**
K/S	**1.65**	**1.78**	**1.85**	**1.90**	**1.90**	**1.87**	**2.11**	**2.17**	**2.29**	**2.29**
Wash fastness	**3**	**4**	**5**	**5**	**5**	**4**	**4**	**5**	**5**	**5**

Dyeing condition: Remazol® Turquoise Blue G-133. Concentration 3 % (o.w.f), time 50 min., Na2So4 5% (o.w.f), Soda ash 1.5% (o.w.f), Liquor ratio (1:20 to 1:60), and Microwave power 140 watt.

The following table shows the results of using different dyeing soda ash concentration on the color strength and wash fastness of the cotton fabric.

Dyeing condition: Remazol® Turquoise Blue G-133 .concentration 3 % (o.w.f), time 50 min., Na_2So_4 (6%)(o.w.f), Soda ash (0.5 - 2.5%(o.w.f), Liquor ratio 1:50, and Microwave power 140 watt.

Table (8) shows the result of using different dyeing soda ash concentration on the color strength and wash fastness of the cotton fabric, the color strength depend so great on the concentration of soda ash as an increasing the concentration of soda ash lead to an increase on the color strength and the best soda ash concentration at 2.5% with color strength 2.25 and 2.760 with the untreated and bio polished samples respectively, also the wash fastness recorded an excellent results as it recorded 5 with all the soda ash concentrations.

The aqueous solution on the dyeing consists of two components which are polar, in the high-frequency microwave field oscillating at 2450MHz [7], which influences the water and the dye molecules vibrational energy. The heating mechanism via ionic conduction, which is a type of resistance heating. Depending on the acceleration of the ions through the dye solution, it results in a collision of dye molecules with the molecules of the fiber. this makes microwave superior to dyeing techniques [7, 34].

Physico mechanical measurement:

The following table shows the results of physico mechanical properties of treated and untreated cotton fabric using microwave and the conventional dyeing techniques for dyeing with Remazol® Turquoise Blue G-133.

Table (9) shows the breaking force of both warp and weft direction affected by the enzymatical treatment and microwave irradiation

TABLE 7.The effect of different sodium sulfate concentration on the color strength and wash fastness of the cotton fabric:

Samples									
Untreated					Bio polished				
Na_2So_4 concentration (%)									
2	3	4	5	6	2	3	4	5	6
K/S									
1.601	1.654	1.744	1.9022	2.13	1.985	2.098	2.142	2.29	2.42
Wash fastness									
5	5	5	5	5	5	5	5	5	5

Dyeing condition: Remazol® Turquoise Blue G-133 concentration 3 % (o.w.f), time 50 min., Na2S4 (2: 6% (o.w.f), Soda ash 1.5% (o.w.f), Liquor ratio 1:50, and Microwave power 140 watt.

TABLE 8. The effect of different soda ash concentration on the color strength and wash fastness of the treated and untreated cotton fabric:

Samples									
Untreated					Bio polished				
Soda ash concentration (%)									
0.5	1	1.5	2	2.5	0.5	1	1.5	2	2.5
K/S									
1.98	2.10	2.13	2.33	2.25	2.38	2.40	2.42	2.65	2.760
Wash fastness									
5	5	5	5	5	5	5	5	5	5

Dyeing condition: Remazol® Turquoise Blue G-133 .concentration 3 % (o.w.f), time 50 min., Na_2So_4 (6%) (o.w.f), Soda ash (0.5 - 2.5%(o.w.f), Liquor ratio 1:50, and Microwave power 140 watt.

energy. The cellulase enzyme removes the fuzz fibers which lead to weaken the cotton fabric. On the other hand, the microwave irradiation energy affects the tenacity especially with prolonged time (50 min.) so the breaking force decreased in both treated and untreated cotton fabric [35].

Cotton fabric shrinks due to the tension that is applied to its yarn during the construction the tension is released by the enzyme treatment and the microwave heat which causes the fabrics to be reduced to its natural size, the weight and tear resistance of the fabric increased. Wettability also enhanced due to the ability of the cellulase enzyme to degrade the short and protruded cellulose chains in the primary wall and so it improves the fabric hydrophilicity and wettability.

The elongation of microwave dyed cotton fabrics slightly decreased after the enzymatical treatment due to the effect of the enzyme action which causes shrinking of the cotton fabric and hence decreases the elongation. Fabric stiffness of the cotton fabric enzymatically treated with microwave shows decrease, this may be related to the fabric longer exposure to the microwave and the cellulase enzyme which endow fabric with smooth appearance, better hand feeling and improve the fabric drapability by removing fuzz fibers from the fabric surface. Fabric thickness increased after the enzyme treatment due to the shrinkage of the cotton fabric [35-36].

The crease recovery angle shows an increase of both techniques after the cellulase enzyme treatment due to the action of the cellulase enzyme, so the fabric softness increases. The warp sett and the weft sett slightly increased on both techniques after dying due to the fabric shrinkage acted by the enzyme.

The Fastness properties:

The following table shows the effect of bio-polished and microwave irradiation technique on the fastness properties of cotton fabrics.

All the fastness tests show an excellent to good grades (4-5, 5). This may be due to the strong covalent bonding between the dye molecules and the cotton fabric; the covalent bond cleavage energy is more than the microwave irradiation energy, so the fastness properties mainly good.

Fabric durability results:

The following table shows the results of the color strength and durability of untreated and enzyme-treated cotton fabrics dyed via two dyeing techniques (microwave and the conventional)

TABLE 9. The physico mechanical properties results of the undyed and dyed (microwave and conventional techniques)

Properties	Fabrics					
	untreated	Bio polished	untreated		Bio polished	
	Undyed		Dyed			
			Conventional	Microwave	Conventional	Microwave
Tensile strength (force per unit area)	19	17.5	15	17.5	15	12
Elongation (%)	10	16	13.5	10	13.5	9.5
Tear resistance (kN/m)	2116	2667	2167	2367	2167	2234
Fabric stiffness (mg/cm^2)	682	291	255	282	255	332
Fabric thickness (mm)	0.28	0.38	0.35	0.33	0.39	0.35
Crease recovery angle (^{o})	170	168	168	160	170	166
The warp sett (mm)	26	26	26	24	27	26
The weft sett (mm)	20	21	20	22	21	24
Wettability(sec.)	120	0	120	120	10	0
Fabric Weight(g/m^2)	0.75	0.80	0.81	0.80	0.84	0.86

TABLE 10. The effect of bio-polished and microwave irradiation technique on the fastness properties of cotton fabrics

Properties	Fabrics			
	Untreated		Bio-polished	
	Dyed			
	Conventional	Microwave	Conventional	Microwave
	Grade scale			
Fastness to perspiration (Acid)	4-5	4-5	4-5	4-5
Fastness to perspiration (Alkali)	4-5	4-5	4-5	4-5
Fastness to light	5	5	5	5
Fastness to wash	5	5	5	5

TABLE 11.The effect of the durability on K/S of untreated and bio polished and microwave dyed cotton fabric

No. of wash cycle	Fabrics			
	Untreated		Bio-polished	
	Dyed			
	Conventional	Microwave	Conventional	Microwave
	K/S			
5	1.40	1.93	1.48	2.10
10	1.31	1.68	1.40	1.94
15	1.26	1.63	1.22	1.82
20	1.21	1.62	1.89	1.94
25	1.18	1.60	1.07	2.04

after (5, 10, 15, 20 and 25 wash cycles).

Increasing the numbers of the wash cycle resulted in a decrease the color strength except for the cotton fabric dyed with microwave and enzyme treatment after 20 and 25 wash cycle. The color strength of the reactive dye is increased due to the removal of the unbounded dyes and shifting the light to longer wavelength of the spectrum so darker shades and hence increasing the light reflecting rays and increasing the color strength [34,37].

Conclusion

Cotton fabric was treated with cellulase enzyme to increase the fabric wettability. Two dyeing techniques were used the conventional and microwave irradiation. Different microwave dyeing factors were studied as time, temperature, concentration of chemicals and liquor ratio. The dyeing process showed the best results using the microwave technique compared with the known conventional one. The microwave dyeing technique saves the dyeing time and the dyeing temperature and hence saves cost. Bio-polishing plays a role in enhancement the wettability, hand, and softness, Green finishing is recommended to save the environment.

References

1. Aravin P. P., Samson R. and Yan Z., Environmental Friendly Textile Processing, *Handbook of Ecomaterials, Springer Nature Switzerland,* 1521-1558 (2019).

2. Aly A.S., Moustafa A.B. and Hebeish A., Biotechnological treatment of cellulosic textiles, *Journal of Cleaner Production,* 12, 697-705(2004).

3. Hong Y., Ding Y., Cui L., Wang P., Yuan J. and Wang Q., Enzymatic Polishing and Reactive Dyeing of Cotton Fabric in One Bath, *Fibers and Textiles in Eastern Europe*, 23, 109-113(2015).

4. Esfandiari A., PouyaeiE. F. and Meibodi P. A. Effect of enzymatic and mechanical treatment on combined desizing and bio-polishing of cotton fabrics, *The Journal of The Textile Institute,* 105,

1193-1202(2014).

5. Hebeish A., Hashem M., Shaker N., Ramadan M., El-Sadek B., and Abdel Hady M., Cellulase Enzyme in Bio-finishing of Cotton-Based Fabrics Effects of Process Parameters, *Research Journal of Textile and Apparel,* 16, 57-65(2012).

6. Rafsan Md., Bioprocessing of textiles Bio-polishing & Enzyme washing, the bachelor's degree in Textile Engineering, *Southeast University, (2011*).

7. Haggag K., Ragheb A., Nassar S. H., Hashem M., El Sayed H. and Abd El-Thalouth I. Microwave Irradiation and its Application in Textile Industries, Science Publishing Group (2014).

8. Montazer M. and Ali B. F. Microwave-Assisted Dyeing of Cellulose with Direct Dyes, *9th Asian Textile Conference*, Taiwan,28-30(2007).

9. Suresh P., Vijaya J.J., and Kennedy L.I. Photocatalytic degradation of textile dyeing wastewater through microwave synthesized Zr−AC, Ni−AC, and Zn−AC, *Transactions of Nonferrous Metals Society of China,* 25, 4216-4225(2015).

10. Xue Z. Effect of Microwave Irradiation on the Physical Properties and Structures of Cotton Fabric. *Journal of Engineered Fibers and Fabrics*,13, 1-6(2018)

11. Katovic D., Bischof S., Hrabar S., and Bartoli J., Microwaves in chemical finishing of textiles, 18th International Conference on Applied Electromagnetics and Communications, 2005.

12. Sun J., Wang W., and Yue Q. Review on Microwave-Matter Interaction Fundamentals and Efficient Microwave-Associated Heating Strategies, *Materials*, 9, 2-25(2016).

13. Ning L. N., Li G. D., Rui L.X. and Dong S.Y., Researches on microwave dyeing cotton fabrics, *Advanced Materials Research,* 627,343-347 (2013).

14. ASTM D 3775, Standard Test Method for Fabric Count of Woven Fabric (1998).

15. ASTM D 3776/D3776M09a, Standard Test Methods for Mass Per Unit Area (Weight) of Fabric, (2013).

16. ASTM D1388, Standard Test Method for Stiffness of Fabrics, (2018).

17. ASTM D 1424, Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum (Elmendorf-Type) Apparatus, (2019).

18. ASTM D 5035, Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method), (2019).

19. AATCC 66, Wrinkle Recovery of woven Fabrics, (2008).

20. ISO 4920, Textile fabrics -Determination of resistance to surface wetting (spray test), (2012).

21. AATCC 124, Appearance of Fabrics after Repeated Home laundering, (1996).

22. ISO 105 BO2, Colour fastness to artificial light: Xenon arc fading lamp test, (1994).

23. ISO105 C06, Colour fastness to domestic and commercial laundering, (2010).

24. AATCC 15, Colorfastness to Perspiration, (2002).

25. Khatri A., White M. and Padhye R., Effect of Dye Solution Ionic Strength on Dyeing of Cotton with Reactive Dyes, *Fibers, and Polymers,* 19, 1266-1270(2017).

26. Nallathambi, Arivithamani, Rengaswami V. Dev G., Salt-free reactive dyeing of cotton hosiery fabrics by exhaust application of cationic agent, *Carbohydrate Polymers,* 152,1-11 (2016).

27. Ahmed S. A. E. and Fadel M.T., Some Applications of Electromagnetic Theory, *International Journal of Innovative Science, Engineering & Technology,* 5, 1- 20 (2018).

28. Ghaffar A., Adeel S., Habib N., Jalal F., Haq A., Munir B., Ahmad A., Jahangeer M. and Jamil Q., Effects of Microwave Radiation on Cotton Dyeing with Reactive Blue 21 Dye, *Polish Journal of Environmental Studies,* 28,1687-169 (2019).

29. Elshemy N. and Haggag K. New Trend in Textile Coloration Using Microwave Irradiation, *Journal of Textiles, Coloration, and Polymer Science,* 16, 53-68(2019).

30. Kiran S., Adeel S., Rehman F. U., Gulzar T., Jannat M., and Zuber M., Eco-friendly dyeing of microwave treated cotton fabric using reactive violet H3R, *Global NEST Journal,* 21, 43-47(2018).

31. Paul D., Das S. C., Islam T., Siddiquee M.A., and Al Mamun M.A., Effect of Temperature on Dyeing Cotton Knitted Fabrics with Reactive Dyes," *Journal of Scientific and Engineering Research,*

vol. 4, pp. 388-393, (2017).

32. Kabir, Mamun S. M., Koh, Momotaz J., and Farhana, Analyzing the suitable electrolyte for reactive dyeing process in cotton goods, *Journal of Engineering Science,* vol. 5, pp. 75- 80, (2014).

33. Kabir S. M. M., Karim R., and Islam K., A Comparative Study on Dyeing Properties of Hemp and Cotton Fiber, *European Scientific Journal, vol.*13, (2017).

34. Abdul Ghaffar, Shahaid A, Noman H., Fatima J., Effects of Microwave Radiation on Cotton Dyeing with Reactive Blue 21 Dye," *polish journal of environmental studies,* vol. 28, pp. 1-5, (2019).

35. Petra F. T., Effects of Cellulase Enzyme Treatment on the Properties of Cotton Terry Fabrics, *FIBRES & TEXTILES in Eastern Europe,* pp. 100-106 (2013).

36. Matilda M., Menaka, Subramaniam V., Kothandaraman B., Effect of Cellulase Enzyme on the Mechanical and Surface Properties of Regular and Compact Yarns, *Journal of Engineered Fibers and Fabrics*, Vol 9, Issue 4, (2014).

37. Christie R. M., Mather R. R., Wardman R. H., *The Chemistry of Colour Application*. Blackwell Publishing Limited, (2000).

تقليل التلوث البيئي للقطن المعالج حيويا باستخدام تقنيه الميكرويف الصديقه للبيئه

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ان تقليل التلوث في صناعة النسيج نال الكثيرمن الاهتمام في الوقت الحاضر.وتعتبر تقنية استخدام الميكروويف هي واحدة من أفضل التقنيات المستخدمة في الآونة الأخيرة وذلك للتقليل من التلوث البيئي عن طريق توفير الوقت والطاقة ، فضلا عن التكلفة. ويهدف العمل الحالي المقارنة بين تقنيتين لطرق الصباغة وهما الصباغه التقليديه والصباغه باستخدام الميكروويف وذلك للقطن المعالج حيويا باستخدام الصبغات النشطه كيميائيا. تمت دراسة تركيز الصبغة ودرجة حرارة الصباغة و حجم حمام الصباغة، بالإضافة إلى المواد المساعده المضافة للحمام. تم دراسة الظروف المثلى للوصول الى التقنية الافضل من حيث قوة اللون وثبات اللون للغسيل. وكذا تقييم الخواص الفيزيائيه الميكانيكية وقوة التحمل لعدد مرات الغسيل. وأظهرت النتائج ان تقنيه الميكروويف هى الافضل.