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Neoteric Approach To One-Step Bleaching And Antibacterial Finishing Of Cotton Fabric

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Abstract

The importance of antibacterial textiles was accelerated in the last years, especially in pharmaceutical and medical fields, as a result of the huge amount of the contamination in the world. Furthermore the need for conserving chemicals, time and energy in textile industry is consider an urgent requirement. So, In the present study via one step cotton fabric was acquired antibacterial as well as bleaching properties by treatment with hydrogen peroxide / zinc salts mixtures. The antibacterial properties were qualitatively evaluated against Gram-negative bacteria (*Escherichia coli*) and Gram-positive bacteria (*Staphylococcus aureus*). All treated cotton samples with different mixtures of zinc salts and hydrogen peroxide gave antibacterial properties against the two types of bacteria, but the mixture of zinc acetate showed the more durable properties than other zinc salts (chloride, sulphate and nitrate). Different treatment techniques have been done, and the pad-cure method achieved the higher antibacterial as well as whiteness properties than exhaustion method. In the durability test, the treated cotton fabrics showed a sustainable antibacterial activity against the two kinds of bacteria in addition to enhancement of whiteness properties even after 30 washing cycles. Nevertheless, the post dyeing of treated cotton fabrics with two types of reactive dyes decreased the antibacterial efficiency.

Keywords: antibacterial, zinc acetate, hydrogen peroxide, bleaching, cotton, textiles, dyeing

1-Introduction

Nowadays there is an urgent need to provide effective, and durable antimicrobial characteristics for textile items, particularly for apparel as a result of potential everyday exposure to the bacterial contamination hazards [1]. In addition, high numbers of microbes can easily contaminate the textile substrates, especially of natural origin, because they provide an ideal environment for their growth. This infection may be appeared in offensive odors, color degradation, cross-infection, or transmission of diseases, allergic responses and deterioration of textiles. So, in recent years, the antimicrobial textiles are rapidly advancing for use in various industries such as textile, pharmaceutical, and medical [2], consequently several classes of antimicrobial agents have been employed to impart antimicrobial activity to textile materials [3,4].

However, most of these agents have harmful effects on the wearer and/or on the environment, so there is a strong trend in searching and developing new non-toxic and eco-friendly agents [2]. Hydrogen peroxide is considered one of these non-toxic agents. The safety of hydrogen peroxide in addition to its broad spectrum antimicrobial activity against many species of bacteria, mold, fungi and viruses, make it favor in many application [1]. Hydrogen peroxide is a well-known antiseptic that has been extensively employed in aqueous solution for the treatment of infectious processes in both human and veterinary topical therapy and to clean wounds [1].

Other kinds of antibacterial agents which have numerous advantages are the inorganic biocides (metals) such as silver or copper and metal oxides, e.g. ZnO, CuO, MgO and TiO_2. These advantages include their mode of action is less specific which allows reducing a wide range of germs, The durability of metals or metal oxides is high compared with various organic alternatives and the harmful potential is often lower with metals or metal oxides [5]. Metal ions are toxic to microbes at very low concentration either in their free state or in compounds. They kill microbes by binding to intracellular proteins, DNA, and lipids damaging them [6].

Both of Gary [7] and William [1] are applied solutions containing Zinc salts and hydrogen peroxide (HP) to textiles, to obtain a complex of zinc salt and hydrogen peroxide in order to produce products with antimicrobial properties. Furthermore, the textiles treated with these antimicrobial treatment formulations have laundry-durable properties.

In addition to using hydrogen peroxide as antiseptic, it is a well known in textile industry as eco-friendly bleaching agent for cotton fabrics. However, bleaching of cotton based fabrics with hydrogen peroxide requires alkaline medium (normally NaOH), stabilizer and either high temperatures or long dwell times, as well as large amount of water for washing the residual of alkali [8]. So it is desirable to use alternative way for bleaching at lower temperature, shorter reaction times and/ or using lower chemical charges.

Therefore, the goal of the present study is to conserve chemicals, energy, thus conserve the cost of finished products, through obtaining dual added value antibacterial properties additionally, bleaching of cotton fabric in one bath by using a mixture of hydrogen peroxide and zinc salts. As well as, study the effect of dyeing with reactive dyes on the antibacterial properties of the treated fabrics.

2-Experimental work

2.1. materials

2.1.1. fabrics

Loom state 100% cotton fabric (1/1 plain weave) was used in this study.

2.1.2. chemicals

Ammonium persulphate, sodium hydroxide, zinc acetate, zinc chloride, zinc sulphate, zinc nitrate, hydrogen peroxide, glacial acetic acid, sodium silicate, were purchased as a laboratory grade chemicals to use in this work. Also a non ionic detergent Hostpal® was used.

2.1.3. Microorganisms

Escherichia coli (E. coli) (Gram negative bacterium) and Staphylococcus aureus (S. aureus) (Gram positive bacterium), were used for estimation of antibacterial activities.

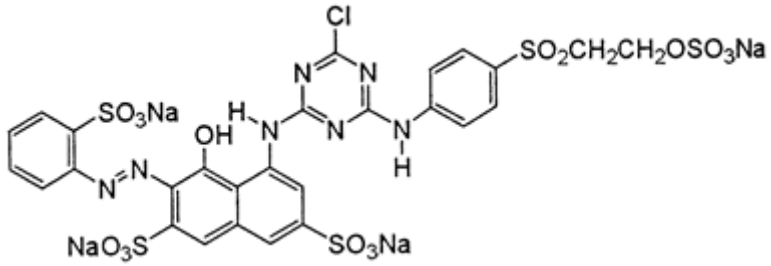
2.1.4. Media

Nutrient broth/ agar medium: contains beef extract (3 g/l), peptone (5 g/l). For solid medium (15 g/l) agar was added. This medium was sterilized for 20 min at 121°C under pressure.

2.1.5. Dyes

Two types of reactive dyes were used to dye cotton fabrics in this work :

1. Cibacron ® Red LS-B (C.I. Reactive Red 270), is a bichromophore-bireactive dyes contain fluorotriazine group and two chromophores are linked by aliphatic bridge. This dye was kindly supplied by Ciba-Geigy.
2. Remazol® Red 3BS (C.I. Reactive Red 239) with the following formula. This dye was kindly supplied by Dye Star.



2.2. methods

2.2.1. the desizing method

The gray cotton fabric was desized by using (1 g/l) amm.persulphate, (5g/l) sodium hydroxide, and (2g/l) nonionic detergent at 95 °C for 30 minutes with (1:50) M:LR.. After that, the fabric was washed with hot water, then with cold water and finally air-dried.

2.2.2. the scouring method

The desized fabric was scoured by using (30g/l) sodium hydroxide and (3g/l) nonionic

detergent at boiling temperature for 30 minutes with (1:50)M:LR. Then samples were washed by hot water several times, then with cold water.

2.2.3. the bleaching method

The Scoured fabrics were bleached by (15%) hydrogen peroxide, (0.1%) sodium silicate batched for 1 hr., then they were (dry-cure) one step at (140 °C) temperature for 3 minutes.

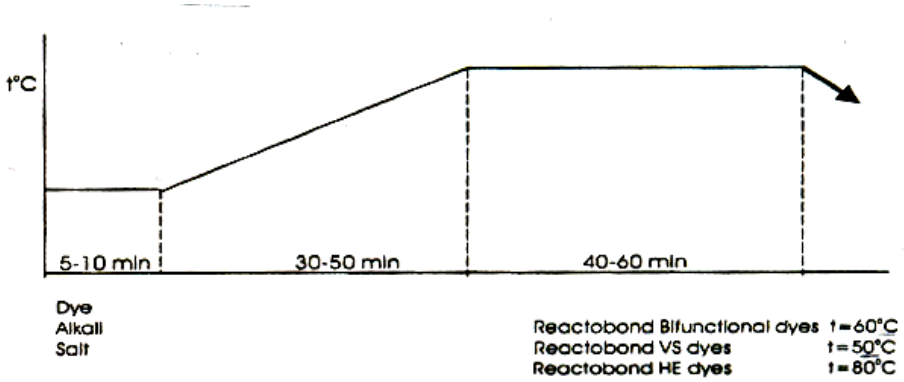
2.2.4. One bath bleaching and antibacterial treatment

The scoured samples were treated by (15%) hydrogen peroxide, (0.1%) sodium silicate, (16%) zinc salts, and (5%) glacial acetic acid either by padding technique [two dip and nip for 15 minutes at 100% wet pick up, after that the fabrics were batched for 1 hr., then they were (dry-cure) one step at (140 °C) temperature for 3 minutes] or exhaustion technique (at 50 °C for 1 hr. and the M:LR was 1: 50),after that the samples were washed using (2g/l) nonionic detergent at 40 °C for 20 min. At the end, the samples were rinsed several times with hot water then with cold water and dried at ambient conditions.

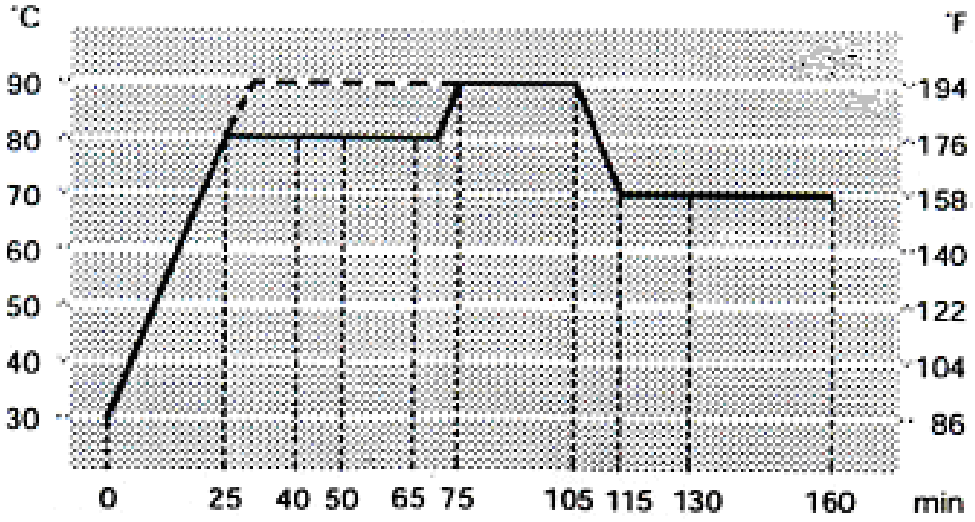
2.2.5. the dyeing with reactive dyes

The scoured, bleached and treated cotton fabrics were dyed according to the manufacturer manual by Remazol Red 3BS (C.I. Reactive Red 239) and Cibacron ® Red LS-B (C.I. Reactive Red 270) reactive dyes as follow:

Remazol dye: (1%) dye, (35) g/l sodium sulphate, (13)g/l sodium carbonate, M:LR 1:50. The dyeing process was carried out according to the following chart:



Cibacron® Red L-S dye: (1%) dye, (15) g/l sodium sulphate, (10)g/l sodium carbonate, M:LR 1:50. The dyeing process was carried out according to the following chart:



3. Testing and analysis

3.2. Antibacterial properties

The antibacterial properties were qualitatively evaluated against Gram-negative bacteria (*Escherichia coli*), Gram-positive bacteria (*Staphylococcus aureus*), according to agar diffusion test according to AATCC Test Method 147-1988.

3.3. whiteness properties

The whiteness index (WI) of the treated samples was assessed by Mini Scan^{TM} XE Hunter-lab Universal Software.

3.4. Durability test

The durability of the treated fabrics to repeated laundering was evaluated according to AATCC test method (124-2006).

3.4. Color strength (K/S)

Color strength (K/S) of the dyed samples was measured on Mini Scan XE Spectrophotometer using Hunter lab Universal Software, which based on Kubelka-Munk equation. [9]

$$K/S= (1-R)^2/2R$$

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

4. Results and discussion

4.1. the effect of zinc salts on the antibacterial properties of cotton fabrics

In order to investigate the higher effect of zinc salts on antibacterial activity, the first experiment was carried out. Table(1) expresses the antibacterial efficiency of blank cotton fabric (sized and scouring) and cotton fabrics treated with hydrogen peroxide and different zinc salts (acetate, chloride, sulphate and nitrate) against Gram-negative

bacteria (*Escherichia coli*) and Gram-positive bacteria (*Staphylococcus aureus*) before and after washing. From table (1) and figure (1), it is clear that, the complex obtained by the reaction of all zinc salts and hydrogen peroxide gives antibacterial properties against both bacteria. Although, the zinc chloride gave the higher antibacterial efficiency than other zinc salts, but this efficiency was sharply decreased after washing, on the contrary, zinc acetate gave nearly constant antibacterial efficiency before and after washing more than other zinc salts. The obtained results indicate the durability of the complex composed by reaction of zinc acetate and hydrogen peroxide. These results resemble those obtained by [1]. Consequently, zinc acetate was chosen for the next experiments. It could be noted that, zinc acetate reacts with hydrogen peroxide in aqueous media to form solid, colorless, water-insoluble complexes whose elemental analyses correspond to the following. structure.

$$CH_3COO(ZnO\text{-}O)_x(ZnO)_yZnOOCCH_3$$

Where, *x* has values in the range of 9-16, and *y* has values in the range of 1-7. The value of *x* and y vary with the proportions of zinc acetate and hydrogen peroxide used in carrying out the reaction. The analyses indicate that these water-insoluble products are polymeric complexes derived from three simple compounds; namely, zinc peroxide, zinc oxide and zinc acetate [7]. So, any zinc ions gradually released from this complex will have an antibacterial effect supplementing the effect of hydrogen peroxide released as the complex slowly interacts with regain moisture in the cotton substrate [10].

Table (1): The effect of zinc salts on the antibacterial efficiency against E.coli. and S.aureus of cotton fabric

The sample	Zone of inhibition (mm.)	
	E.coli.	S.aureus
Blank*	0	0
Zinc acetate (un washed)	22	16
Zinc acetate	18	16
Zinc chloride (un washed)	50	40
Zinc chloride	16	15
Zinc sulphate (unwashed)	17	36
Zinc sulphate	20	12
Zinc nitrate (unwashed)	19	30
Zinc nitrate	20	7

Blank: desized and scoured*

Treatment conditions: (15%) hydrogen peroxide, (16%) zinc salt, and (5%) glacial acetic acid, two dip and nip for 15 minutes at 100% wet pick up, after that the fabrics were batched for 1 hr., then they were (dry-cure) one step at (140 °C) temperature for 3 minutes).

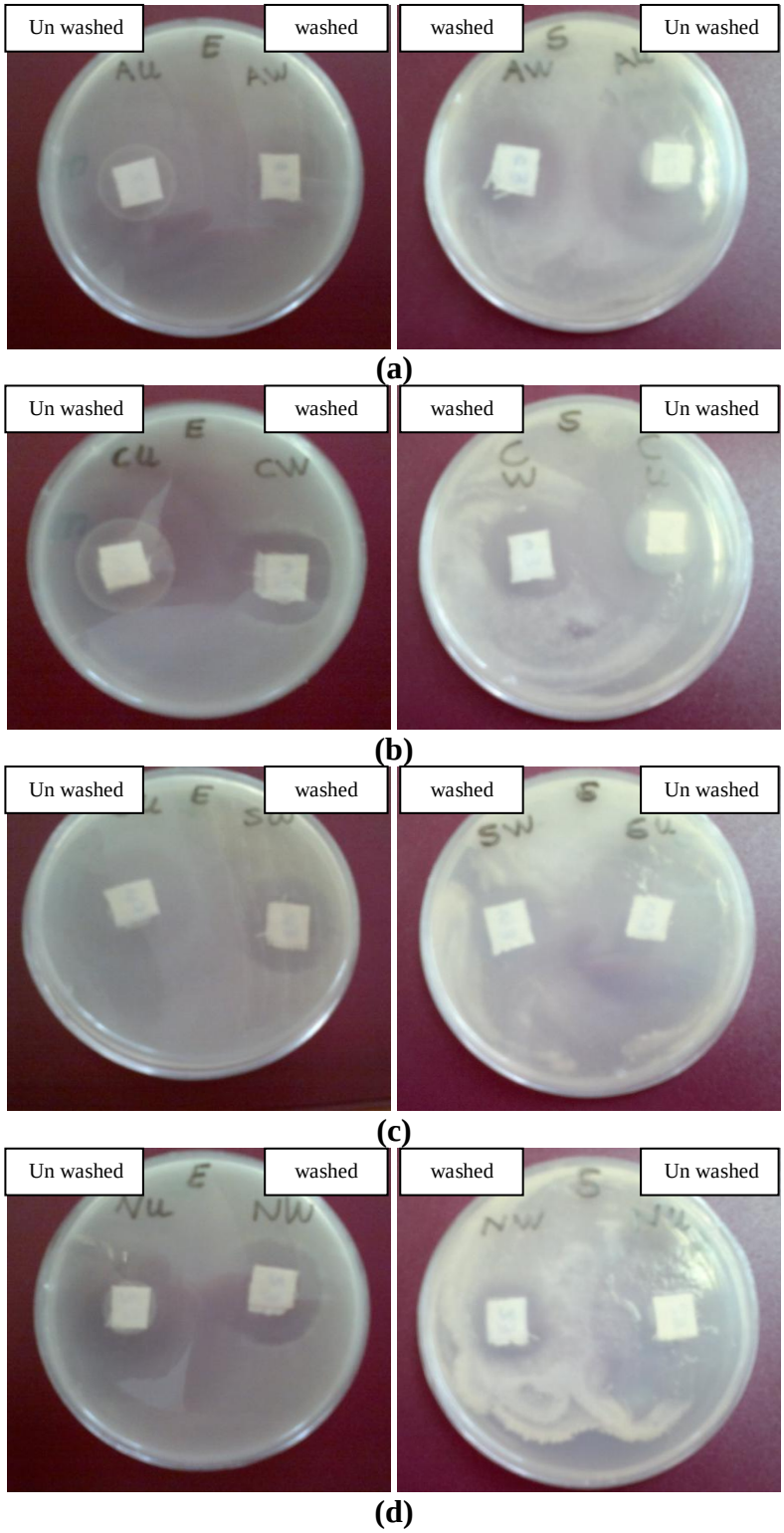


Figure (1): the inhibition zone of *Escherichia coli* (E) and *Staphylococcus aureus* (S) for different zinc salts before and after washing Where: (a) zinc acetate, (b) zinc chloride, (c) zinc sulphate, (d) zinc nitrate

4.2. the effect of treatment technique

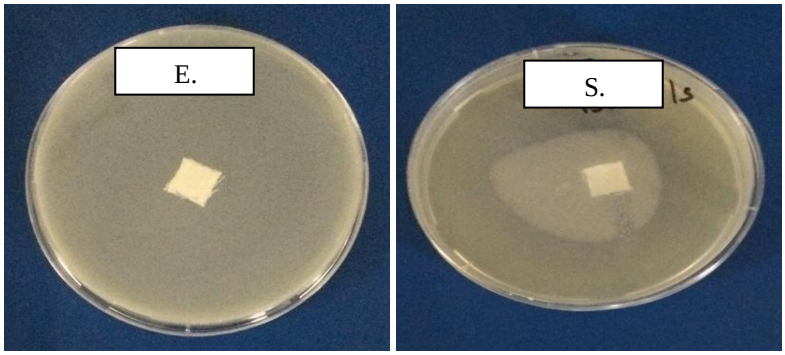
The effect of treatment technique on the antibacterial as well as the whiteness properties of cotton fabric was investigated by carried out the treatment with hydrogen peroxide and zinc acetate via exhaustion and pad-cure methods before and after washing. The data in table (2) and fig. (2) shows that, antibacterial and whiteness properties of cotton fabrics which were treated by pad-cure method were higher than that by exhaustion method.

Table (2): The effect of treatment technique of zinc acetate and hydrogen peroxide on the antibacterial efficiency and the whiteness properties of cotton fabric

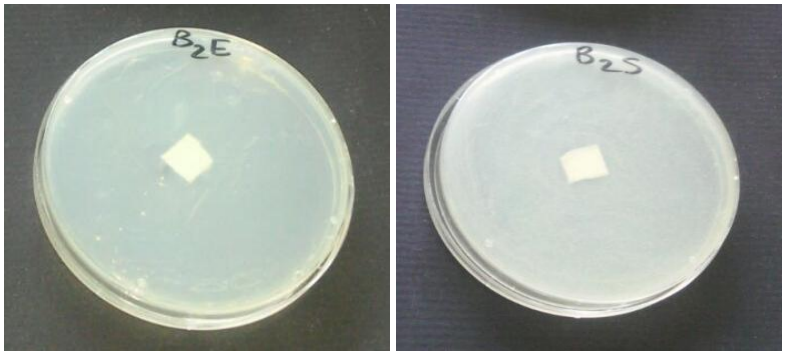
Treatment technique	Zone of inhibition (mm.)		W.I
	E. coli	Staph	
Blank	0	0	24.3
Bleached (padding)	0	0	46.3
Treatment only (padding)	18	16	36.7
Exhaustion, Simultaneous (treatment + bleaching), unwashed	8	11	41.2
Exhaustion, Simultaneous (treatment + bleaching), washed	10	17	45.7
Simultaneous (treatment + bleaching), unwashed and padding	20	30	35.5
Simultaneous (treatment + bleaching) washed and padding	17.5	16	55.5

Blank: desized and scoured

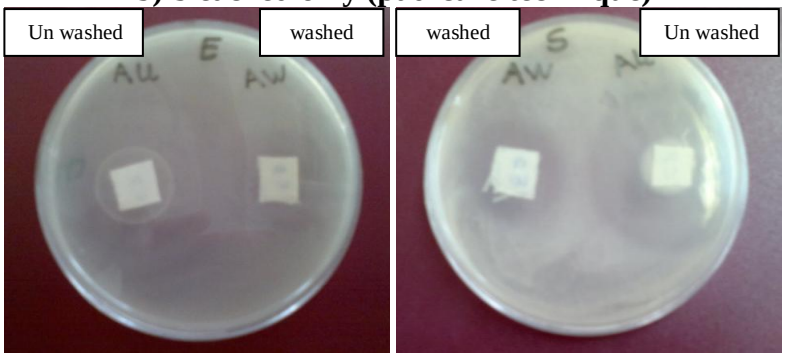
Bleached: (15%) H_2O_2 and (0.1%) sodium silicate. **Treatment only:** (15%) H_2O_2, (16%) zinc acetate, and (5%) glacial acetic acid. **Simultaneous:** (15%) hydrogen peroxide, (0.1%) sodium silicate, (16%) zinc acetate, and (5%) glacial acetic acid. **Padding technique:** two dip and nip for 15 minutes at 100% wet pick up, after that the fabrics were batched for 1 hr., then they were (dry-cure) one step at (140 °C) temperature for 3 minutes). **Exhaustion technique**: (at 50 °C for 1 hr. and the M:LR was 1: 50) **washing:** (2g/l) nonionic detergent at 40 °C for 20 min.



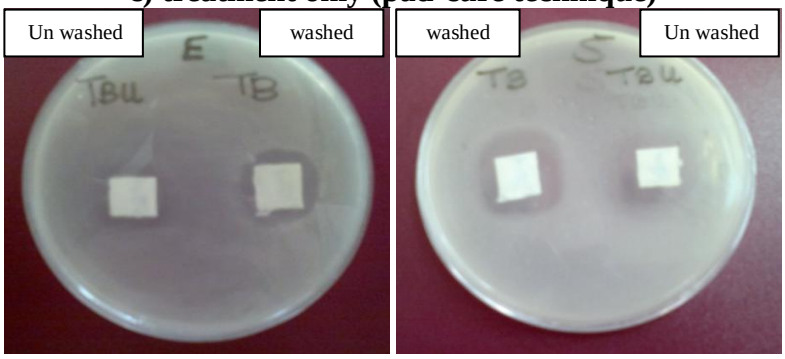
a) blank



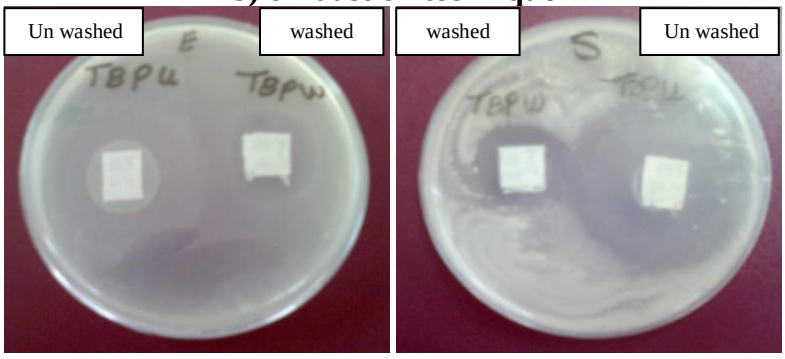
b) bleached only (pad-cure technique)



c) treatment only (pad-cure technique)



b) exhaustion technique



c) pad-cure technique

Figure (2): The inhibition zone of *Escherichia coli* (E) and *Staphylococcus aureus* (S) for different technique methods before and after washing

4.3. Evaluation of treatment durability

Table (3) shows the effect of washing cycles on the antibacterial properties and whiteness index of cotton fabrics. From the following data, it is clear that the antibacterial properties was decreased after repeated washing cycles. This may be related to the removal of un-reacted complex (zinc acetate and hydrogen peroxide) particles. However, the increase in washing cycles did not show a significant decrease in the antibacterial properties for both bacteria. Also, from the same table; the whiteness index of cotton fabric was increased after washing and continues to be enhanced by washing cycles. This sustainable activity against bacteria is probably due to the controlled release of the peroxide during laundering [10], as well as the results of whiteness index are matched with this explanation.

Table (3): The durability properties and whiteness of zinc acetate and hydrogen peroxide treatment

The no. of wash cycles	Zone of inhibition (mm.)		W.I
	E. coli	Staph	
Bleached	0	0	46.3
0 washes	20	30	35.5
10 washes	17.5	16	55.5
20 washes	17	15	58.3
30 washes	16	15	59.3

4.4. the effect of post dyeing with reactive dyes

The following table (4), present the effect of post dyeing with two types of reactive dyes (Remazol Red 3BS-C.I. Reactive Red 239 and Cibacron ® Red LS-B-C.I. Reactive Red 270) on the antibacterial efficiency of cotton fabrics in addition to the color strength. The obtained results demonstrate that, the post dyeing of treated cotton fabrics led to the decrease of the antibacterial efficiency for both types of reactive dyes, this may be related to disrupt the reactive dyes for cotton fabrics to release the active components of zinc acetate and hydrogen peroxide complex, which contribute in the decrease of antibacterial efficiency. On the other hand, there is not a significant difference in the color strength before and after treated with hydrogen peroxide / zinc acetate.

Table (4): The effect of dyeing with Remazol Red 3BS (C.I. Reactive Red 239) and Cibacron ® Red LS-B (C.I. Reactive Red 270) reactive dyes on the antibacterial efficiency and the color strength of cotton fabric

The sample	Zone of inhibition (mm.)				K/S	
	E. coli		Staph			
	Remazol dye	Cibacron dye	Remazol dye	Cibacron dye	Remazol dye	Cibacron dye
Blank	0	0	0	0	1.92	6.72
Bleached, post-dyed	0	0	0	0	2.12	3.3
Treatment only post-dyed	11	9	13	13	2.86	6.21
Simultaneous (bleaching+ treatment), post-dyed	10	8	14	13	2.26	6.38

Blank: desized and scoured

Bleached: (15%) H_2O_2 and (0.1%) sodium silicate. **Treatment only:** (15%) H_2O_2, (16%) zinc acetate, and (5%) glacial acetic acid. **Simultaneous:** (15%) hydrogen peroxide, (0.1%) sodium silicate, (16%) zinc acetate, and (5%) glacial acetic acid. **Padding technique:** two dip and nip for 15 minutes at 100% wet pick up, after that the fabrics were batched for 1 hr., then they were (dry-cure) one step at (140 °C).

Remazol dye: (1%) dye, (35) g/l sodium sulphate, (13)g/l sodium carbonate, M:LR 1:50. **Cibacron dye:** (1%) dye, (15) g/l sodium sulphate, (10)g/l sodium carbonate, M:LR 1:50.

Conclusion

In order to donate antibacterial properties to cotton fabrics as well as enhance their whiteness properties i.e., bleaching at the same time, treatment with zinc salts/hydrogen peroxide was applied. From the obtained results, zinc acetate achieved the best results among other zinc salts, which gave sustainable antibacterial efficiency against Gram-negative bacteria (*Escherichia coli*) and Gram-positive bacteria (*Staphylococcus aureus*). The treatment of zinc acetate/ hydrogen peroxide was carried out by two techniques, pad-cure and exhaustion. The higher antibacterial efficiency in addition to the whiteness properties were obtained by pad-cure technique. The durability of antibacterial efficiency was examined by accomplished 10, 20, and 30 repeated washing cycles. It could be concluded from the results that, the complex composed by the reaction of zinc salt/hydrogen peroxide gave durable antibacterial activity, which withstand and maintained for 30 washing cycles. Furthermore, the whiteness properties were enhanced through increasing the washing cycles. Additionally, the effect of post dyeing on the antibacterial activity was investigated by dyeing the cotton fabrics with two types of reactive dyes. The dyeing process slightly affected the antibacterial efficiency of cotton fabrics against both kinds of bacteria. Thus, it is very important to investigate novel approaches to conserve chemicals, energy, and time in textile industry which, subsequently effect on the environment and the price of end product.

References

1. William, T., Albina, M., Susan, L., Bernd, L., and Gerald M. Olderman, 2013, "Antimicrobial textiles comprising peroxide", U.S. Patent N0. US 2013/0011491 A1.
2. Ul-Islam, Sh., Shahid, M., and Mohammad, F., 2013, " Green Chemistry Approaches to Develop Antimicrobial Textiles Based on Sustainable Biopolymers", A Review, Ind. Eng. Chem. Res., 52, pp. 5245−5260.
3. Gao, Y., and Cranston, R., 2008, " Recent Advances in Antimicrobial Treatments of Textiles", Text. Res. J, 78, (1), PP. 60-72.
4. Goh, Ch., H., Heng, P., W., and Chan, L., W., 2012, "Cross-linker and non-gelling Na+ effects on multi-functional alginate dressings", Carbohydr. Polym., 87, (2), pp. 1796-1802.
5. Farouk, A., Moussa, Sh., Ulbrich, M., Schollmeyer, E., and Textor, T., 2014,"ZnO-modified hybrid polymers as an antibacterial finish for textiles", Text. Res. J, 84, (1), pp. 40-50.
6. Kotb, R., M., Elsayed N., A., A., and Salama, A., A., 2014, "Promising modification of cotton fabric for multifunctional applications", J. chem. pharm. res., 6, (11), pp. 900-912.
7. Gary, D., F., Vigo, T., L., and Welch, C., M., 1979, "antibacterial textile finishes utilizing zinc acetate and hydrogen peroxide", U.S. Patent N0. 4,172,841.
8. Hashem, M., El-Bisi, M., Sharaf, S., and Refaie, R., 2010, " Pre-cationization of cotton fabrics: An effective alternative tool for activation of hydrogen peroxide bleaching process", Carbohydr. Polym., 79, pp. 533-540.
9. Kannan, M., S., S., and Nithyanandan, R., 2005, " Salt & alkali-free reactive dyeing on cotton", I T J, 115, (8), pp. 18-20.
10. Gary, D., F., Vigo, T., L., and Welch, C., M., 1978, "permox-A hydrogen peroxide-zinc acetate antibacterial finish for cotton", Text. Res. J, 48, pp. 173-177.