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RESEARCH ARTICLE

BIOPOLISHING TREATMENT OF CELLULOSIC FABRICS FOR HOTEL UNIFORMS INSPIRED FROM EGYPTIAN NUBA

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ABSTRACT

Environmental friendly treatment of textiles has become a preferred choice over chemical treatment because of it being less harmful to textiles as well as environment. Biopolishing treatments of cellulose-containing textile fabrics with cellulase enzyme are utilized for removing protruding fibers in order to achieve a smooth and polished surface. In this study, natural cellulosic fabrics (linen, gabardine and poplin fabrics) were biopolished using cellulase enzyme to improve their surface properties and quality (fuzzing and pilling). Physico-mechanical properties were measured and determined. Additionally, dyeing of finished fabrics was carried out using different classes of reactive dyes. Design and production of functional uniforms (coats, aprons, bows, trousers, etc.) were performed using the natural fabrics that available in Egyptian markets. That achieving the elements and requirements of hotel uniforms were inspired from the elements of Nubian art and folklore; such as design motifs, dye colors, printing, and fabrics types.

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INTRODUCTION

In the textile industry, finishing process is a stage where specific properties are imparted into fabrics; changing their appearance and improving their resistance to water, chemicals, biological, physical, mechanical and general wear, which is providing several features producing multifunctional textile. Enzymes are a sustainable alternative to the harsh toxic chemicals in the textile industry, which have a wide range of applications and a multitude of prospects for their use in textile processing, leading to a positive impact on the environment as they are readily biodegradable. Cellulase is the most popular and versatile enzyme used in textile wet processing for bio-preparation, biopolishing, and softening of cellulosic fabrics without using traditional, topically applied chemicals (Eladwi and kotb, 2015). The surface modification of these fabrics is performed using cellulase enzymes to improve their outlook by removing superficial fibrils and micro fibrils; conferring cooler and softer feel, brighter luminosity of colors, and more resistance to pilling propensity (Chinta *et al.,* 2012). In addition, this is a permanent process and it keeps the fabric in good condition after repeated washing; consequently, products become more attractive to the customer and fetch better prices. An important aspect of cellulase for textile application is their relatively slow kinetics which allows the modification of cellulosic fabrics in a controlled manner without excessive damage (Chinta *et al.*, 2012; Andreaus *et al.*, 2014; Noreen *et al.,* 2014).

The selection of the appropriate dyes and dyeing processes for cellulose is based on numerous factors depending on the application of the dyed fabric itself. For cellulosic fabrics dyeing, reactive dyes have been used very often and they are, by consumption, the most important textile dyes. High popularity of reactive dyes is based on producing brilliant and fast colors with a wide range of shades using various environmentally friendly procedures. They are divided, according to the structure of reactive group, in haloheterocycle and vinyl sulfone based dyes, which react with cellulose through nucleophilic substitution and addition mechanisms, respectively. Commercially, the widest used systems are: vinyl sulfone (VS), monochlorotriazine (MCT), bifunctional dyes, difluoro chloropyridine (DFCP), monofluorotriazine (MFT) and dichlorotriazine (DCT) (Ristić and Ristić, 2012; Khatri *et al.,* 2015).

Hotels are the backbone of tourism activity in any country of the civilized world and hotel uniforms are a must for any kind

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of hotel. Hotel staff is the appearance of every hotel, since people working in the hotel form the attitude and evaluation of the clients to the hotel. The range of hotel garments can be modified according to specific size, color, logo, fabric, and design specifications. The hotel staff must be readily identifiable via their work wear (Ting, 2010). Management and staff were to be involved at every stage to ensure garments were not only exquisitely designed but also fit-for-purpose, durable, comfortable and welcomed by staff. Depending on the type of hotel and the nature of work that the staff is involved in, uniforms could be simply utilitarian or highly attractive or a combination of both (Nelson and Bowen, 2000; Robinson, 2005).

Nuba is a region along the Nile River, which is located in southern Egypt and northern Sudan. Nubian architecture is characterized by the walls of the house especially the façade were decorated with ornaments and paintings of flags, flowers, birds and animals as shown in Figure (1) (Kennedy and Ferna, 2012). The exterior color scheme in the old Nubian houses reveals an earthy color scheme varying between yellow, brown, dark brown, white and yellow-grey, contrasts in saturation add interest without deformation of form; as shown in Figure (2) (Kamel and Abdel-Hadi, 2012).

Figure 1 The decorative printed on wall and bawaba

Figure 2 Nubian house colors

The Nubians have unique handicrafts made of reeds and river palm leaves. These are often done in different colors and are very attractive and popular as shown in Figure (3). The Nubian woman dressing is unique especially among the women "*Gurbaba"* worn beneath the dress or "Kamis Toub" is to cover the shoulders and head. Other items of dressing are "Mendil", head scarf; "Ndala" is sandal for women and "Nila" for men. Women also wear "Bangil, Fidua, swar, suksuk" assessorries bangles; as shown in Figure (4).

Figure 3 Nubian handicraft

Figure 4 Nubian women dressing.

The Nubian man is normally dressed in "Kanzu" that means robe, tunic, or kaftan; it is a white or cream colored robe as shown in Figure (5). The wedding ceremonies and festivities connected with marriage were among the most important public events in the social life of Nubians. The Dukhan and Henna day before the official Henna day the groom's sisters and friends go to a henna designer to paint their hands. After drying, the henna is washed off, placed their hands and feet over a hole in the corner of a dark and smoky room the women call the "*dukhan*"; as shown in Figure (6) (Emberling, 2011).

Figure 5 Nubian man tunics

Figure 6 A girl exhibits her henna design.

The aim of this research is using natural textile fabrics produced in Egyptian environment and appropriate to the nature and atmosphere of Egypt; in environmentally friend biopolishing treatment with cellulase enzyme on industrial scale to enhance fabric physico-mechanical properties, reactive dyeing and color strength, fastness properties. As well as manipulate these biopolished fabrics in producing six functional designs of hotel staff uniforms, which suit their job nature and characteristics by using different techniques such as tie and dye, stencil printing, hand embroidery stitches, and patch work, which are inspired from Nuba, Egypt.

MATERIALS AND METHODS

Materials

100% woven cotton and linen fabrics were used; Poplin, Gabardine, and linen fabrics, their properties are shown in Table (1).

Table 1 Fabrics properties

Fabric types	**Weave Structure**	**Weight (g/m^2)**	Yarn count	**Density (ends/inch picks/inch)**	**Bleaching**
Blank gabardine	Twill 3/1	265	1.7 tex/ends 1.7 tex/picks	90 68	Half bleached
Blank poplin	Plain 1/1	120	4 tex/end 4 tex/picks	109 72	Half bleached
Blank linen	Plain 1/1	207	7 metric/ end 7metric/picks	125 125	Bleached

Chemicals

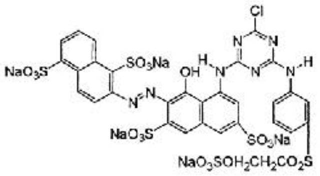
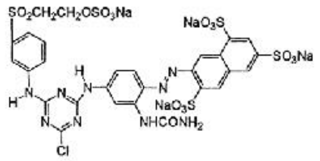
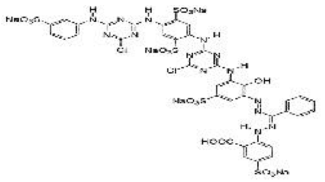
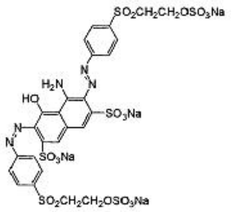
Cellulase Enzyme used under the commercial name of Dinamex®, hydrogen peroxide, sodium hydroxide, sodium sulphate, sodium carbonate, were used in bleaching process and kindly supplied by Misr Spinning and Weaving Company, Egypt. The other chemicals used were laboratory grade reagents.

Dyes

The dyes used are; ME® Red ME4BL (C.I Reactive Red 195), Jakofix® Yellow MERL (C.I. Reactive Yellow 145) are bifunctional groups dyes, Drimaren® Blue CLBR (C.I. Reactive

Blue 160), and Remazol® Black B (C.I Reactive black 5); were kindly supplied by Misr Spinning and Weaving Company, Egypt; and shown in Table (2).

Table 2 Reactive dyes structure

ME® Red ME4BL (C.I. Reactive Red 195)	
Jakofix® Yellow MERL (C.I. Reactive Yellow 145)	
Drimaren® Blue CLBR (C.I. Reactive Blue 160)	
Remazol® Black B (C.I. Reactive black 5)	

METHODS

Fabrics pretreatments

Cotton fabrics were desized and simultaneously scoured/half bleached with sodium hydroxide (3%) for 1 hour at 40 °C, followed by bleaching with hydrogen peroxide (35%) for 1 hour at 90°C, and finally rinsed several times.

Biopolishing

Biopolishing process was conducted using cellulase enzyme (2 g/l) of the enzyme solution at a buffered pH of 4.5–5 and at a temperature in the range of 45–60°C for 45 min, finally tumble to dry.

Reactive dyeing

Reactive dyeing of fabrics were carried out using ME® Red ME4BL, Drimaren® Blue CLBR, Jakofix® Yellow MERL were 6% shade, and Remazol® Black B 10% shade. As well as, their mixtures according to the manufacture instructions as shown in Figure (7).

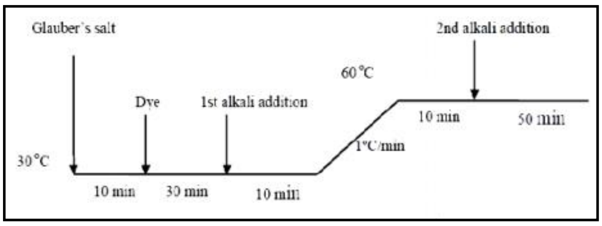


Figure 7 Reactive dyeing procedure.

Test Methods

Physico-mechanical properties

Different physico-mechanical properties that may be affected by the treatment such as; the fabrics warp and weft sett (ASTM D3775 – 98 by pic glass), fabric weight (ASTM D3776-96), fabric stiffness (ASTM D1388-96), fabric wettability (AATCC D39-1980), the resistance to tearing (ASTM D1424-63-1970), crease recovery angle of the fabrics (AATCC D67-1957), tensile strength and elongation at break in woven fabrics (ASTM D1682-64-1975); were measured and determined according to standard test methods.

Color strength

The color strength (K/S) of dyed fabrics was measured in Misr Spinning and Weaving Company by Datacolor Spectrophotometers international v2.3 on hunter lab universal software. The color strength (K/S) values were assessed using the Kubelka- Munk equation: (Ristić and Ristić, 2012).
K/S= (1-R) 2/2R

Where K is the sorption coefficient, R is the reflectance of the dyed fabric and S is the scattering coefficient. The CIE Lab values were determined for all the investigated samples.

Wash fastness

Color fastness to wash of dyed samples was measured by ISO 105-C06-1994.

Perspiration fastness

Color fastness to perspiration was determined according to AATCC Test Method 15-2002.

Light fastness

Colorfastness to light was determined according to AATCC Test Method 16-2004.

RESULTS AND DISCUSSIONS

Effect of biopolishing treatment on physico-mechanical properties

The effect of biopolishing on some physico-properties (fabrics warp and weft sett, weight, stiffness, wettability, tear resistance, crease recovery angles, tensile strength, elongation) were evaluated. As a general observation, it can be seen that there were differences in the obtained results of evaluated properties with respect to different cotton and linen fabrics. Which generally may be attributed surface morphology, fabric construction, weight, as well as inherent strength properties. Since, the mechanical properties of fibers depend on their molecular structure, where macromolecules can be arranged in crystalline (unique arrangements of molecules) or amorphous (coincidental arrangements of molecules) structure (Eladwi and kotb, 2015).

Effect on fabric warp and weft sett:

It was observed from the results shown in Figure (8) that, the biopolishing treatment enhanced the fabric set in both directions. There is a significant improvement in gabardine more than poplin and linen, which may be that due to cellulase enzymatic treatment improves surface morphology, appearance and handle values. Which indicate that cellulase enzyme plays a dominating role in altering surface morphology of the fibers and alters the dimensional stability of the fabrics. Additionally, the obtained results can also be attributed to the high hydrophilicity gained to fabrics upon biopolishing (Saravanan *et al.*, 2013).

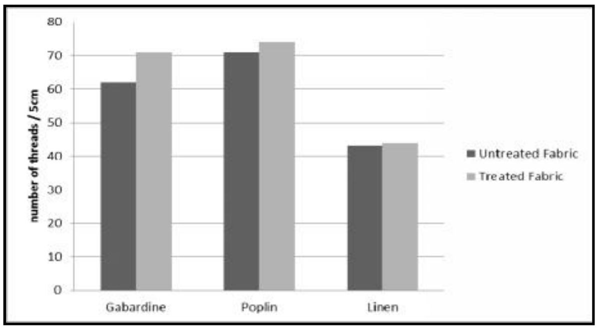


Figure 8 Effect of biofinishing on warp and weft sett of cotton and linen fabrics

Effect on Fabrics Weight (g/m²)

It should be noted that the fabrics tested in the lab scale after the treatment in the industrial scale. Figure (9) shows the effect of biopolishing treatment on cotton and linen fabrics weight. It was slightly observed that, the weight of the biopolished samples increased than untreated samples. Which depended on that shrinkage increased and the process conditions employed during the treatment i.e. concentration of cellulase and treatment temperature to a large extent (Saravanan *et al.*, 2009).

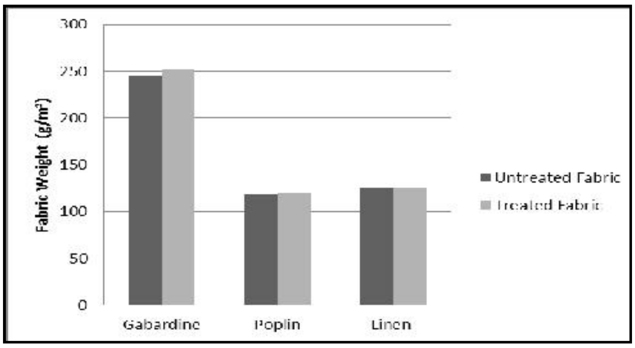


Figure 9 Effect of biopolishing on weight of cotton and Linen fabrics.

Effect on Fabrics stiffness

The results shown in Figure (10) shows the effect of biopolishing on cotton and linen fabric stiffness. It was observed that the stiffness decreased in all types of examined fabrics. These results can be regarded to the action of cellulase enzyme which prevent the fuzz and pills of fabrics, leading to an increasing and enhancement in the smoothness and softness. (Raje *et al.*, 2001; Saravanan *et al.*, 2013).

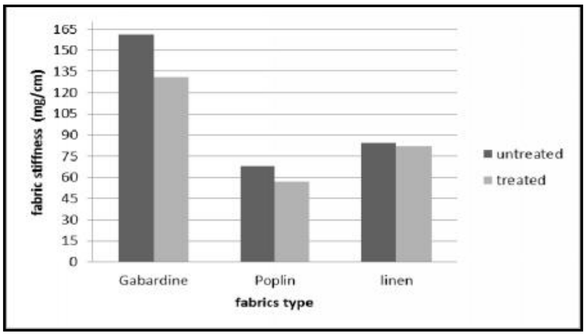


Figure 10 Effect of biopolishing on cotton and linen fabrics stiffness.

Effect on fabrics wettability

Figure (11) shows the effect of enzymatic treatment on cotton and linen fabrics wettability. It is clearly noticed from the obtained results that, the wettability of fabrics after biopolishing is highly improved depending upon construction of the fabrics, which furtherly increased by the softening effect of biopolishing treatment applied to the fabrics. (Raje *et al.*, 2001; Saravanan *et al.*, 2013)

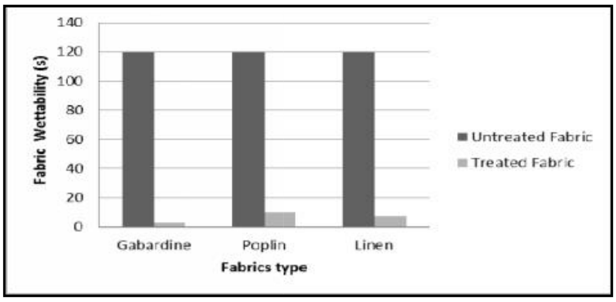


Figure 11 Effect of biopolishing on cotton and linen fabrics wettability.

Effect on fabrics tear resistance

It can be seen from the results obtained and shown in Figure (12) that tear resistance of cotton and linen fabrics values increased after biopolishing treatment. Biopolishing improved tear resistance of all types of biopolished fabrics, these results may be due to cellulase enzymatic treatment decreases the tensile and compressional energy. Where, biopolishing cause the fabrics handle to enhance, decrease bending and shear rigidity, additionally enhance the softness. (Eladwi and kotb, 2015).

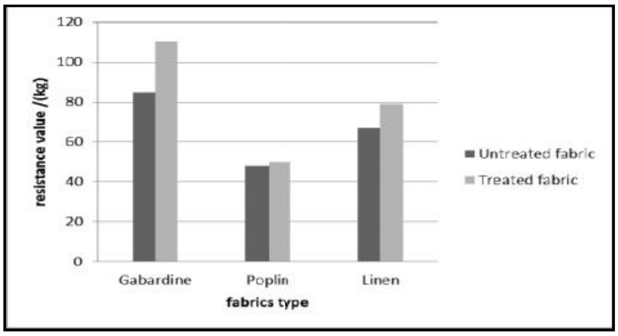


Figure 12 Effect of biopolishing of tear resistance on cotton and linen Fabrics.

Effect on Fabrics crease recovery angle:

Figure (13) shows the effect of crease recovery angle which expressed as fabric resiliency. It is observed that from the data obtained that, the crease recovery angles values of biopolished fabric samples had increased than the untreated ones. That indicated that the fabrics become less rigid and stiff, easier to stretch and looser in structure. This may be regarded to cellulase enzyme treatment optimize the surface properties (Andreaus, 2014; Eladwi and kotb, 2015).

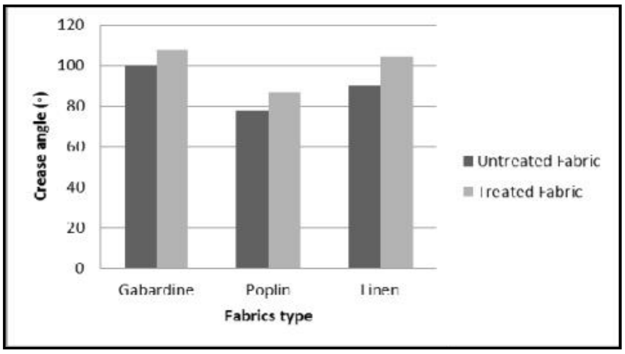


Figure 13 Effect of biopolishing of crease recovery on cotton and linen fabrics.

Effect on fabrics tensile strength and elongation

It can be noticed from the results shown in Figure (14) that biopolishing treatment decreased tensile strength in warp and weft of all treated fabrics. It was observed that biopolished gabardine fabrics have more decreasing values than biopolished linen and poplin fabrics. It can be claimed that cellulase treatment lowers the tensile and compressional energy, which in turn improving handle that confirmed by decreasing bending and shear rigidity, i.e. enhancement softness.

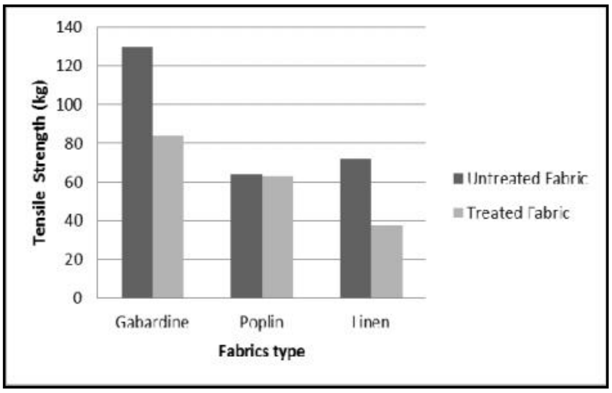


Figure 14 Effect of biopolishing on tensile strength in warp and weft of cotton and linen fabrics.

On the other hand, it can be observed from Figure (15) that the elongation values of biopolished fabrics were increased. That may be due to enzymatic treatment enhance elongation properties. Biopolishing treatment can be applied to cellulosic fabrics to remove the pills and fuzz from their surface. Hence, reducing the tendency of pilling as well as improving the smoothness, drape, flexibility and luster (Saravanan *et al.*, 2013).

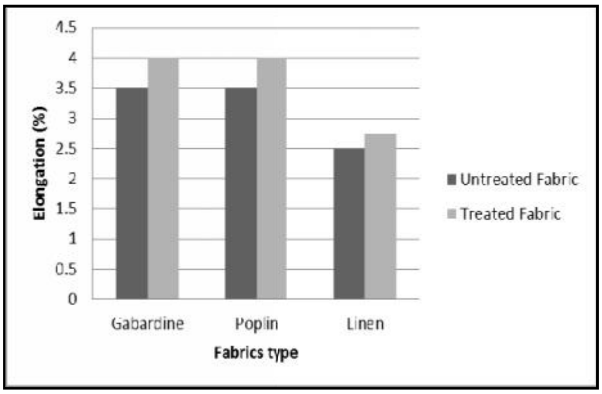


Figure 15 Effect of biopolishing on elongation of cotton and linen fabrics.

Reactive dyeing of biopolished fabrics

After the application of different classes of reactive dyes, the results of the color strength (K/S) values of fabrics dyed after cellulase treatment are represented in Figures (16,17,18,19) and clearly showed the positive effect of biopolishing treatment on K/S values, which improved for all dye classes. This may be due to the removal of protruding fibers and decreasing the scattering coefficient, which depends on degree of polymerization, ratio of amorphous to crystalline regions, swell-ability, accessibility, chemical reactivity, surface morphology and affinity for dyes (Kan and Law, 2012; Saravanan *et al.*, 2013).

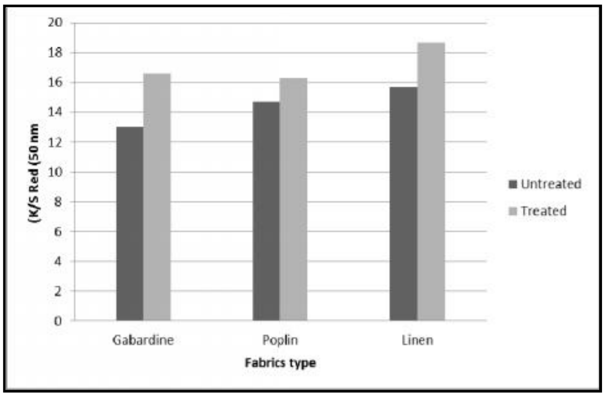


Figure 16 Effect of biopolishing on color strength (K/S) using ME® Red ME4BL.

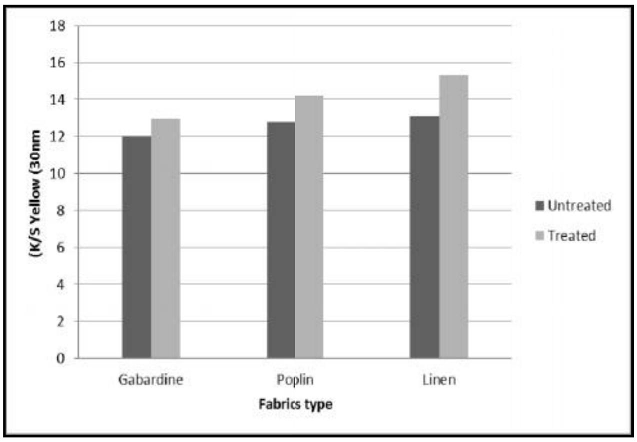


Figure 17 Effect of biopolishing on color strength (K/S) using Jakofix® Yellow MERL.

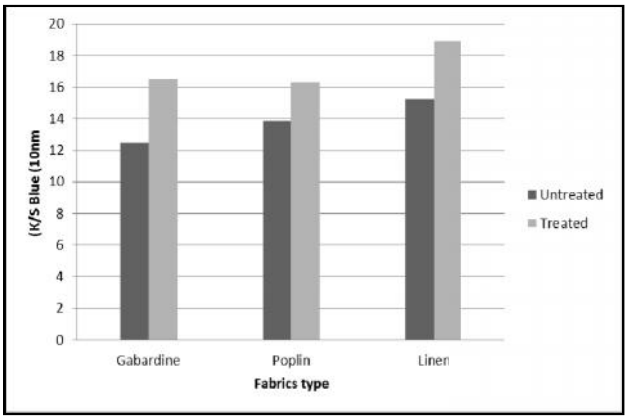


Figure 18 Effect of biopolishing on color strength (K/S) using Drimaren® Blue CLBR.

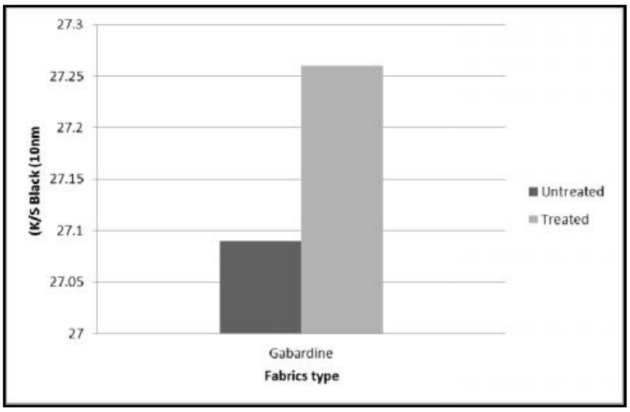


Figure 19 Effect of biopolishing on color strength (K/S) using Remazol® Black B.

Fastness properties

The data represented in Table (3) shows the values of light, wash, and perspiration fastness properties of pre- biopolished post dyed gabardine, poplin, and linen fabric samples. It can be seen from the obtained results that, all biopolished fabrics acquired better fastness properties regardless dye class and fastness type. it can claimed that biopolishing treatment applied to cellulosic fabrics prior to dyeing process could remove the pills and fuzz from fabric surface that means reducing tendency to pilling, improve the smoothness, drape, flexibility, luster, and fastness properties. Biopolishing using cellulase enzyme give a partial hydrolysis of cellulosic fibers; allowing more available dye sites and penetration that produces more leveling properties. Additionally, the short fiber ends are hydrolyzed, leaving the surface free and providing more even look (Lenting and Warmoeserken, 2001; Kan and Law, 2012).

Application of biopolished and dyed fabrics in hotel uniforms Designs

Requirements and considerations for hotel uniform design and production

Depending on the type of hotel and the nature of work that the staff is involved in, uniforms could be simply utilitarian or highly attractive or a combination of the following:

1. Ornamentation: The design of the garment based on functionality, visual and tactile impact to what extent does it serve an aesthetic purpose.
2. Practicality/Necessity: The protective or strictly is utilitarian qualities of a garment.
3. Communication/Identification: Uniforms indicate membership in a group or team.
4. Mutability / Reconfigure-ability: This element refers to how much the wearer can transform or customize a garment.
5. Off Body: the free movements of the staff throughout a hotel and work area with fitting design.
6. Light/Luminosity: This element refers to the modulation of light by or on a garment. Black clothing absorbs light. Hotel uniform should be: comprehensive hotel uniform set, fashionable design, comfortable, elegant, customers' design is welcomed and size specifications as per buyer's requirement (Emberling, 2011).

Nubian clothing elements using in structure and decorative design

1. Inspiration from Nubian color in all designs while maintaining the form of the uniform.
2. Decoration of designs inspired from Nubian Architecture such as the walls of the house were decorated with ornaments and paintings of flags, triangles, flowers, birds and animals as shown in applied uniforms (1,3,5) with modern motifs add pretty to design.
3. Inspiration from Nubian Henna in Embroidery as shown in applied uniforms (2) showed the spirit of Nubian art.

Table 3 Fastness properties of gabardine, poplin, and linen fabrics dyed with different used reactive dyes.

Dyed Fabrics	Gabardine				Poplin				linen			
	wash	light	Perspiration		wash	light	Perspiration		wash	light	Perspiration	
			alkaline	acidic			alkaline	acidic			alkaline	acidic
Untreated/ yellow dye	3.5	3.5	4	4	3.5	3.5	3.5	4	3.5	3.5	4	4
Treated/ yellow/dye	3.5	4	4.5	4.5	3.5	4	4.5	4.5	3.5	3.5	4.5	4.5
Untreated/ red dye	3.5	3.5	2.5	2.5	3.5	3.5	4	4	3	3.5	3.5	3.5
Treated/ red dye	3.5	4	4.5	4.5	3.5	4	4.5	4.5	3.5	4	4.5	4.5
Untreated/ blue dye	3.5	4	3.5	3.5	3	4	4	4	3.5	4	4	5
Treated/ blue dye	3.5	4	4.5	4.5	3.5	4	4.5	4.5	3.5	4	4.5	4.5
Untreated/ black dye	3	3	3.5	3.5	3	3	3.5	3.5	3	3	3	3.5
Treated/ black dye	3.5	4	4	4	3.5	3.5	4	4	3.5	3.5	4	4

4. Inspiration from Nubian fascinated patterns on handicrafts (A rhythm wide colored zigzag lines, Diagonal colored lines, Nubian dashed triangle design) as shown in products (3,4,5) with new fashion artistic touch.
5. Unconventional design and attractive asymmetry lines inspired from the walls of the house ornaments and flowers, henna and handicrafts with modern motifs as shown in applied uniforms (5,6).

Proposed designs and applied functional hotel staff uniforms

Figure 20: Proposed Design (1) This design is suitable for hotel reception. Longitudinal lines with under chest cut added femininity to Model. The contrast in colors is appropriate fashion renewable. It printed with decorative triangles inspired from Nubian walls of the house with modern motifs.

Figure 21: Applied uniform (1) **Fabrics:** Linen for blouse and gabardine for skirt. **Techniques:** Stencil printing triangles with foam printing in skirt. Embroidery stitches (Chain Stitches) on front, collar and cuffs. **Dyes:** Reactive black 5.

Figure 22: Proposed Design (2) This design is suitable for hotel Human resource. It has asymmetry curve lines inspired from the Nubian henna with beautiful creative reliefs. It embroidered in decorative design inspired from Nubian Henna which showed the spirit of Nubian art.

Figure 23: Applied uniform (2) **Fabrics:** Linen for blouse, and gabardine for skirt. **Techniques:** Embroidery stitches: (Chain Stitches – Stem Stitches – Zigzag Stitches – Satin stitches – Chained Feather Stitches – Bullion stitches) on jacket and trousers inspired from Nubian Henna design. **Dyes:** Jakofix® Yellow MERL, and Drimaren® Blue CLBR.

Figure 24: Proposed Design (3) This design is suitable for front office. A rhythm wide zigzag lines with different light colors make smoothness of eye movements. This design inspired from fascinated patterns on handicrafts in colored zigzag with new fashion artistic touch, it embroidered in decorative line.

Figure 25: Applied uniform (3) **Fabrics:** Poplin for blouse, and gabardine for jacket and skirt. **Techniques:** Stencil printing zigzag on jacket and skirt. Embroidery stitches (Chain Stitches) on sleeve and skirt. **Dyes:** Drimaren® Blue CLBR, Jakofix® Yellow MERL, and ME® Red ME4BL.

Figure 26: Proposed Design (4) This design is suitable for Housekeeper, diagonal colored lines used inspired from Nubian handicrafts art. It printed with decorative triangles inspired from Nubian art on with modern motifs. It embroidered on apron with simple stitches.

Figure 27 Applied uniform (4) **Fabrics:** Gabardine for all dress parts and apron. **Techniques:** Stencil printing triangles on cuff, front neck and apron. Embroidery stitches (Chevron Stitches) on apron. **Dyes:** Drimaren® Blue CLBR, Jakofix® Yellow MERL, and ME® Red ME4BL.

	
Figure 28: Proposed Design (5) This design is suitable for chef it has attractive diagonal closet lines making eye moving around. It printed with decorative Nubian dashed triangle design on jacket, trouser and cap. It inspired from Nubian handicrafts art with modern motifs.	**Figure 29: Applied uniform (5)** **Fabrics:** Gabardine for jacket, trousers and bonnet. **Techniques:** Stencil printing Nubian dashed triangles. **Dyes:** Drimaren® Blue CLBR.
	
Figure 30: Proposed Design (6) This design is suitable for restaurant, its unconventional design it has more attractive asymmetry lines. It printed with decorative design inspired from the walls of the house were decorated with ornaments and flowers, henna and handicrafts with modern motifs, It embroidered with simple and pretty stitches	**Figure 31: Applied uniform (6)** **Fabrics:** Remaining parts of fabrics linen, poplin and gabardine. **Techniques:** Stencil printing from different used designs. Embroidery stitches (Stem Stitches) on upper part of dress. Tie and dye on lower part of dress. **Dyes:** Drimaren® Blue CLBR, Jakofix® Yellow MERL, ME® Red ME4BL, and Remazol® Black B.

CONCLUSION

Keeping in view the increasing environmental concerns and constraints being imposed on textile industry, cellulase treatment of cellulosic fabrics is an environmental friendly way of improving different properties of cellulosic fabrics. In this research, different cellulosic material (gabardine, poplin, and linen) available in Egyptian markets. These fabrics were subjected to biopolishing treatment using cellulase enzyme to improve fabric surface properties. Physico-mechanical properties were measured and evaluated and the obtained results indicated that biopolishing treatment significantly enhanced fabric hydrophilicity, swelling, and wettability; increased crease recovery, tear strength and elongation; reducing stiffness, fuzzing and pilling properties leading to improvement the smoothness and softness. As well as, biopolishing treatment significantly had a positive impact on color strength values and fastness properties to wash, light, and perspiration. Inspiration from Nubian civilization art to make a hotel uniforms which is one of the oldest methods and have more beauty and culture. Six functional hotel uniforms (coats, aprons, bows, trousers, etc.) were inspired from Nubian folklore and produced by the examined fabrics using tie and dye, stencil printing with the used reactive dyes. The final produced hotel uniforms are environmental friendly finished, as well as have added value and functionally suit the nature of hotel uniform in terms of comfort, movement, working and the weather to satisfy the wearer and the intended purpose.

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