African Journal of Agricultural Research Vol. 6(20), pp. 4746-4752, 26 September, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.845
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Antibacterial activity and ultraviolet (UV) protection property of some Egyptian cotton fabrics treated with aqeous extract from banana peel

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Accepted 26 November, 2010

The alkaline fractions of banana peel (*Musa,* cv. Cavendish) of fruits have been used as a natural dye for cotton fabrics. In the current study, banana peel was evaluated as a multi-functional antibacterial and UV protective agent on the cotton substrate. The extracted solution using 0.1% NaOH was analyzed by high performance thin layer chromatography (HPTLC) analysis technique. The extracted dye was applied to the premordated bleached and mercerized Egyptian cotton fabrics made from Giza 89 and Giza 80 cotton varieties. Ferric sulphate was used as mordent. Antibacterial activity was analyzed qualitatively in terms of zone of inhibition and quantitatively in terms of percentage reduction in bacteria. Dyeing performance in terms of color parameters K/S, L*, a*, b* and ΔE were studied. Effectiveness of banana peels against ultraviolet radiation was evaluated in terms of ultraviolet protection factor value (UPF). The data obtained showed that the mercerized fabrics have excellent antibacterial activity, high dye uptake with high UV protection properties among the control and the unmercerized cotton fabrics. The data obtained revealed that Giza 89 had the higher antibacterial activity, dye uptake with high ultraviolet (UV) protection properties than Giza 80. These results are very important for industrial application with the production of a natural dye, antibacterial, and UV protected as an inexpensive source from waste banana peel as a by product. The optimum treatment and dyeing conditions were applied on 620 g fabric (about 5 m) and matched results were obtained to the research samples.

Key words: Egyptian cotton, banana peel, antibacterial activity, ultraviolet protection factor (UPF), color parameters.

INTRODUCTION

According to the centers of disease control and prevention, Department of Health and Human Services, USA about two million people contact infections in hospitals each year. The infections are spread via person-to-person and also via surface contact with hands, clothes, and hospital devices such as surgeon gowns and bedclothes (Ayliff and Lowbury, 1982).

The degree of protection from the infection causing bacteria can be obtained by using appropriate protective clothes such as face masks and gloves but clothes itself has been found to be inadequate in preventing transmission of disease (Sun and Worley, 2005). In addition, bacteria can survive on textiles for many days and contribute in the transmission of disease (Neely and Maley, 2000). Examples of agents that have been successfully used as antibacterial agents on textile substrates include silver (Haug et al., 2006; shikonin et al., 2007) and quaternary ammonium chloride (Hamilon, 1968).

There has been increasing interest in building antibacterial properties into textiles. Consumers worldwide are looking for clothing which provide greater comfort and remains fresh and odor -free in use. Clothes and other textiles materials can act as carriers for microorganisms such as pathogenic or odor generating bacteria and moulds. Cotton textiles in contact with the human body offer an ideal environment for microbial growth. There is an increasing interest in adding value to textiles by the use of natural products. Many of he plants from which natural dyes are obtained are also known to have medicinal properties.

At present, many of the plants used for dye extraction are classified as medicinal, and some of these have been shown to possess significantly antimicrobial effect. The antimicrobial activities of some of these dyes are reported as potent owing to the existence of phenol, tannin and quinone in their extracts. The antimicrobial effects of some plants used in dye industries contribute to the longer life of the products they are used in (Hussein et al., 1997; Mehrabian et al., 2000).

The use of natural dye in textile application is growing in popularity because of the quality of the natural color obtained as well as the environmental computability of the dyes. Natural dyes can exhibit anti-microbial and deodorant properties. Natural dyes derived from plant sources have long been known to possess medicinal properties and consequently it seemed logical to explore the antibacterial activity of dyes. The application of dye extracted from banana peel on mordant cotton and silk was described by Yogesh and Patole (2005)

The antimicrobial properties of eleven natural dyes against three types of gram-negative bacteria were studied experimentally by Gupta et al. (2004). Antimicrobial activity of some natural dyes was mentioned by Rajni et al. (2005). The antibacterial functionality of natural colorant extracts, five kinds of natural dying aqueous solutions were obtained by extraction from peony, pomegranate, clove, Coptis chinensis and gallnut using water at 90°C for 90 min with a liquor ratio (solid natural colorant material/water, weight ratio) of 1:10. The colorimetric assay and antibacterial activity of cotton, silk, and wool fabrics dyed with these natural colorant extracts were examined, Young et al. (2009). Proper finishing treatments for sun-protective cotton-containing fabrics were described by Ibrahim et al. (2005).

Cotton and wool substrates were treated with natural colorants from plants and their antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* were evaluated (Sakar and Renuka, 2009). Antimicrobial effect of natural dyes on some pathogenic bacteria was focused by Ayyfer et al. (2009).

Ultraviolet (UV) radiation is harmful to human health. Recently considerable attention has been aid to the barrier properties of textiles as a protection against UV radiation (Maged et al., 2009). The transmission of UV radiation through fabrics is greatly influenced by different parameters such as fiber type and chemical composition, fabric construction, additives, textile processing aids, color and fabric finish (Ghosh et al., 2003).

A UV absorber is a compound that can preferentially absorb high-energy ultraviolet radiation (280 to 320 nm), which is known to play a major role in the photo fading of dyes, and harmlessly dissipate the absorb energy as heat. The effect of natural dyes on the light fastness of natural dyes has been investigated by Lee et al. (2001).

The sun-blocking properties of a textile are enhanced when a dye, pigment, delustrant, or ultraviolet absorber finish is resent that absorbs ultraviolet radiation and blocks its transmission through a fabric to the skin. The naturally-pigment cottons exhibit significant higher UPF values than conventional cotton (Gweendolyn et al., 2005).

The annual cultivated area from banana plant in Egypt was about 62,000 feddans in 2009. It gave about 464,000 tons dry matter (about 1,116,000 tons fresh weight) of banana by products, (Ministry of Agriculture, Egypt 2009). These by products are collected from the field and burned after being sun dried, causing environmental pollution. Chemical treatment of banana peel and leaves may be suitable for natural dye extraction used from textile dyeing.

Banana should be considered to be a good source of natural antioxidant and antibacterial. The antioxidant and antibacterial power of banana peel was evaluated by Mokbel et al. (2005). The component isolated from banana peel was studied also and their activities were determined. Antibacterial activity and acute toxicity effect of flavonoids extracted from *Mentha longifolia* was described by Souad et al. (2009).

Our previous work, disclosed the extraction of dyes from banana peel as natural waste source to dye some Egyptian cotton fabrics. Alkaline extracted solution using 0.1% NaOH was analyzed by high performance thin layer chromatography (HPTLC), analysis technique (Saleh et al., 2009).

The main objective of the present study is to evaluate the antibacterial activity, dyeing performance in terms of color parameters K/S, L*, a*, b* and ΔE , and Effectiveness of banana peels extract against ultraviolet radiation in terms of ultraviolet protection factor value.

MATERIALS AND METHODS

Cotton fabric

Unbleached long stable Egyptian cotton fabrics made from Giza 80, and Giza 89 were purchased from Misr-El-Mehala Company for Spinning and Textile- Egypt. The fabrics have the following specification: plan weaved, wrap 36 yarn/cm, weft 30 yarn/cm and fabric 150 g/m.

Scouring, bleaching and mercerizing treatments

Scouring of the fabric samples was performed by the pad-steam technique by padding the fabric with 3% NaOH containing 1.5 to 2% of the wetting agent in a two-bowel padding mangle adjusting the squeeze pressure to enable 100% wet pick-up of the fabric and subsequently steamed in a laboratory steamer at 100°C for 10 min. The scoured fabric was washed with water, neutralized with dilute acetic acid, further washed with water, and finally dried in air.

The scoured fabrics were immersed in alkaline bleach liquor (180 ml H_2O), containing Na_2CO_3 (0.2 g/l), NaOH (1.5 g/l), SiO_2 (0.4 g/l), $MgSO_4$ (0.2 g/l), Triton 100 (0.5 g/l), and H_2O_2 (10 ml^{-1}) were added to the bleaching liquor. The samples were removed from the liquor and neutralized with aqueous solution containing 0.1% acetic acid followed by a through hot water (80 to 85°C) to ensure removal of residual chemicals. Samples were dried in an oven at 100°C for 60 min.

The bleached fabrics were treated with aqueous solution of NaOH (20%), at room temperature. The samples were then subjected to final treatment applying the same procedure for the scoured fabrics.

Banana peel pigments extraction

About 100 g of the banana peel that contains the dye component was cut to small pieces and boiled in one liter in a solution of 0.1% NaOH and concentrated to 500cc. The slurry was left to react for a period of time wherein a yellow supernatant forms at the top. This yellow supernatant changes to amber and then to an opaque black as the reaction proceeds. The entire slurry was then filtered and any solid material discarded. The extracted liquor was used as the foundation of the dye.

Dye material

The cotton fabrics pre-mordanted with ferric sulfate ($FeSO_4$). The banana peel extraction liquor was used in the dyeing bath at 80° for 90 min under continuous stirring. The pH of the dye was adjusted to 9. After completion of dyeing, the fabrics were thoroughly rinsed and washed with water and air dried.

Chemicals

All chemicals used were of analytical grade using doubly distilled water (18.5 MΩ.cm^{-1}). NaOH was analytical grade (Koch-Light Co.), Hydrogen peroxide (30% LR grade) from Aldrich. Sodium carbonate (LR grade), sodium silicate (136°Tw, 27% SiO_2), the wetting agent was the commercially Triton 100 supplied by Merck. Acetontrile, formic acid was of HPLC grade.

Antimicrobial assay

The antibacterial activity of both Giza 89, and Giza 80 cotton fabrics dyed with The alkaline soluble fractions of banana peel has been used as a natural dye against *S. aureus* ATCC 6538 (gram positive) and *Klebsiella pneumoniae* ATCC 4352 (gram-negative) according to modified KSK 0693-2006 (Assessment of antibacterial activity). The concentrations of the cultures were adjusted using spectrophotometer (λ660 nm) to 1.3 × 105 colony forming unit (CFU) per ml. The bacteriostatic reduction rate was estimated by the standard equation:

Reduction (%) = [(A-B) / A] × 100

Where A and B is the bacteria colonies of untreated and treated fabrics, respectively.

Color strength

The color strength expressed as (K/S) was measured using Perkin-Elmer double beam spectrophotometer of model Lambda 35 that is equipped with integrating sphere. The diffuse transmittance was detected at the wavelength 307.02 nm. This wavelength fall in the spectral range of 305 to 315 nm which is of greatest importance in the various daylight phases (EN13758-1:2001) according to the Kubelka-Munk that is given by:

$$K/S = (1-R)^2/2R - (1-R0)^2/2R0$$

Where R is the reflectance of the colored fabric, R0 is the reflectance of the uncolored fabric, and K/S is the ratio of the absorption coefficient (K) to scattering coefficient (S): the higher the value, the greater the color strength.

The color parameters L*(lightness-darkness), a*(red-green), b*(blue-yellow component), R % (reflectance), and ΔE were measured by using the Win lab software delta-E 1976 using the following equation.

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

UPF (Ultra violet protection factor) value

UPF is the scientific term used to indicate the amount of UV protection provided to skin by fabric. UPF is defined as the ratio of the average effective irradiance calculated for skin to the average UV irradiance calculated for skin protected by the test fabric. UVA and UVB transmission were measured and the UPF calculated according to ATTCC Test method 183: Transmission or Blocking of erythermally weighted UV radiation through Fabrics (ATTCC, 2002). Measurements were performed using a Perkin -Elmer double beam spectrophotometer of model Lambda 35 with an integrated sphere attachment and a Schott glass UG-11 filter. UPF was calculated using mean percentage transmission in the UVA region (320 to 400) and mean percentage transmission in the UVB region (280 to 320) according to the following equation:

$$UPF = \frac{\sum_{\lambda=280}^{400} E_\lambda * S_\lambda * \Delta_\lambda}{\sum_{\lambda=280}^{400} E_\lambda * S_\lambda * T_\lambda * \Delta_\lambda}$$

where: E_λ = erythermal spectral effectiveness, S_λ = solar spectral irradiancies Wm^{-2}nm^{-1}, T_λ = spectral transmittance of the fabric, Δ_λ = the bandwidth in nm, λ = the wavelength in nm.

Ultraviolet radiation up to 60 times as strong as the sun's rays was directed through the fabric and onto the skin for varying lengths of time. The resulting degree of sunburn to the exposed skin determined the fabric's protection factor.

Fastness to washing

Colour fastness of dyed samples to laundering was tested at 5, 10 and 60 cycles. This accelerated test was carried out in accordance to the AATCC test method 61-1996. Putting into consideration that one commercial laundering at 40°C for 45 min is equivalent to 5 home washing cycle

Toxicity

Acute toxicity test was carried out in the Department of Molecular and Cellular Biology, Faculty of Agriculture, Cairo University according to Lorke (1983).

Statistical analysis

The obtained results subjected to statistical analysis according to

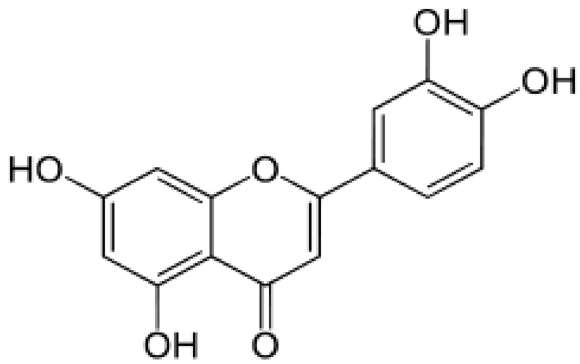

Figure 1. Structure of the banana peel crude alkaline extracted compound.

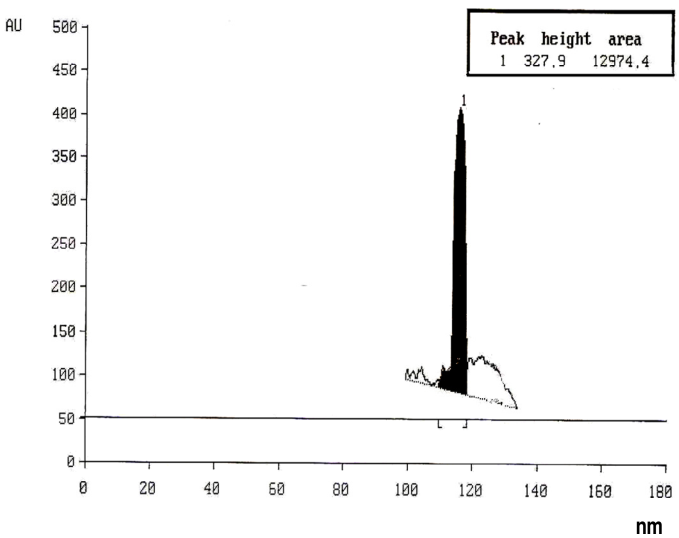

Figure 2. HPTLC chromatogram of the banana peel crude extracted.

Sendcor and Cochran (1982). The experiments were in randomized complete design (RCD) with three replicates. Means were compared using the significant difference (LSD) at 5% level probability.

Industrial application

The optimum conditions of dyeing with respect to the highest colour strength, UPF and antimicrobial activity were applied on a pilot scale using rotadyer machine SDL-UK, to treat and dye 5 m fabric of weight 620 g.

RESULTS AND DISCUSSION

HPTLC analysis of the banana peel extracts

A CAMAG TLC system comprising of a Linomat-5 applicator, CAMAG TLC scanner and single pan balance of Shimadzu model was used according to Saleh et al. (2009). Stationary phase used was silica gel $G60F_{254}$, 20×10 cm TLC plate activated at 75°C for 20 min, the mobile phase used was forestal solvent conc. HCl – HOAc –H_2O (3:30:10). The plates were developed by ascending method in a CAMAG twin trough glass chamber (20 × 10 cm) saturated with filter paper for 10 min. Distance of solvent front 80 mm, band length 8 mm, slit dimension 6.00 × 0.30 mm, detection wavelength 254 nm, temperature of 26.4°C and humidity 61%.

Banana peel crude extract was used as stock solution spotted on precoated TLC plates using Linomat 5 applicator; plates were developed and scanned using CAMAG TLC scanner 3. The plate was developed and the spots were scanned, peak, height, areas and R_f values were measured.

The HPTLC analysis of the banana peel extracts characterize the pigment compound Luteolin, which exists in the banana peel crude alkaline extract. The structure of this compound is shown in Figure 1.

The spectral data presented in Figure 2 show the maximum absorption for the chromatographic peak as luteolin, peak height as 327.9, and peak area as 12974.4 and Rf as 66.

Antibacterial activity of banana peel extracts dyed fabrics against *S. aureus* and *K. pneumonia*

The antibacterial activity (the bacteriostatic reduction rates in percentage) of control and dyed fabrics against *S. aureus* and *K. pneumonia* is illustrated in Table 1. All the fabrics dyed with the soluble fractions of banana peel extracts displayed outstanding antibacterial activities against *S. aureus* in the range 95.7, and 92.1 for unmercerized Giza 89 and Giza 80 to 99.9 and 98.32 for mercerized samples and *K. pneumonia* in the range 93.8, and 90.31 for unmercerized Giza 89 and Giza 80 to 98.9 and 97.77 for mercerized samples respectively.

The antibacterial activity might be attributable to the Luteolin which is one of the more common flavones a known antibacterial and antioxidant. Natural colorant extracts are composed of main component and many unknown components. Therefore, it is very difficult to identify the exact components that have antibacterial activity against microorganisms. More detailed studies should be made. On the other hand, the mercerized samples show a high antibacterial activity than the unmercerized samples. The antibacterial activity might be attributable to the swollen effect.

Colorimetric data of Giza 89 and 80 fabrics dyed with banana peel extracts

As shown in Table 2, It has been noted that mordanting with iron gave a maximum ΔE, which is mainly attributed to the lower values of L*, due to the high stability

Table 1. The bacteriostatic reduction rates (%) of Giza 89 and 80 control and fabrics dyed with banana peel extracts against *S. aureus* and *K. pneumonia*.

Fabric variety	Sample	*S. aureus*	*K. pneumonia*
	Control	0.65	0.32
Giza 89	Unmercerized	95.7	92.10
	Mercerized	99.9	98.32
	Control	0.50	0.12
Giza 80	Unmercerized	93.8	90.31
	Mercerized	98.9	97.77

*Dyed fabric without Fe as mordant after scoured and bleached treatment used as control. **Unmercerized and mercerized dyed cotton fabric treated with Fe as a premordant.

Table 2. Colorimetric data of Giza 89 and 80 fabrics dyed with banana peel extracts.

Fabric variety	Sample	K/S	L*	a*	b*	∆E
	Control	0.13	83.45	0.13	01.69	16.65
Giza 89	Unmercerized	1.90	77.01	3.60	19.43	36.24
	Mercerized	3.99	69.54	4.81	21.67	41.71
	Control	0.10	85.70	0.17	01.21	14.36
Giza 80	Unmercerized	1.71	62.43	6.92	25.35	45.79
	Mercerized	2.96	60.30	2.90	18.20	26.82
	L.S.D	0.11	0.40	0.15	0.13	0.15

*Dyed fabric without Fe as mordant after scoured and bleached treatment used as control. **Unmercerized and mercerized dyed cotton fabric treated with Fe as a premordant.

formation of the complex between the Fe and luteoline as a phenolic compound. Fe metal is well known for its ability to form coordination complexes, and readily chelated with the dye. Since the coordination numbers of Fe is 6, some coordination sites are unoccupied when they interact with the fiber. These unoccupied sites are accessible to functional groups on the fiber. Thus Fe metals can form a ternary complex on one site with the fiber and on the other site with the dye. Such a strong coordination tendency enhances the interaction between the fiber and the dye, resulting in high dye uptake. The mercerization process involves partial destruction of inter molecular bonds.

The fibrous transformation from cellulose I to cellulose II occurs during mercerization, which consists of a swelling of the initial fibers in alkali, followed by recrystallization during subsequent washing. In cellulose I, the chains within the unit cell are in parallel conformation. Penetration of the dye in the swollen amorphous region of the cellulose where they are held by hydrogen bonding increase the dye uptake more than the unmercerized samples. The presence of Fe which forms a chelate with the sodium cellulose and sodium alcoholates formed during mercerization increase the uptake of dyes also.

The results obtained revealed that the values of L*, a*, and b* have been changed by the addition of the Fe metal which shift the color of the dye due to the reaction between the metal ion and luteoline.

UPF values, percentage UV transmission and percentage UV absorbance

It has been noted that the UPF is strongly dependent on the chemical structure and other additives present in the fiber. A high correlation exists between the UPF and the fabric porosity but it is also influenced by the type of the fibers. Table 3 indicates the effect of light exposure on UPF values, percentage UV transmission and percentage UV absorbance for control, unmercerized, and mercerized Giza 89, and 80. The mercerized cotton fabrics had a mean UPF of 64, and 59.8 for Giza 89, and 80, respectively, whereas the control and unmercerized had a mean UPF of only 19, 8 and 48.9 for Giza 89, and 17.99 and 44.3 for Giza 80. The increase in UPF and decrease in the percentage of UVA, and UVB transmission values can be attributed to shrinkage, which reduces fabric porosity. This might be due to ternary complex of Fe on one site with the fiber and on the other site with the dye. Another approach is the coordination sites of Fe metal which are unoccupied can absorb UV

Table 3. Effect of light exposure on UPF values, percentage UV transmission, and percentage UV absorbance.

Fabric variety	Sample	UPF	UVA	UVB	UV (%)	P.C
Giza 89	Control	19.80	0.75	0.25	94.80	Good
	Unmercerized	48.9	1.83	0.61	97.92	Excellent
	Mercerized	64.0	2.40	0.80	98.60	Excellent
Giza 80	Control	17.99	0.67	0.22	83.4	Good
	Unmercerized	44.30	1.70	0.59	97.12	Excellent
	Mercerized	59.80	2.24	0.74	98.10	Excellent
	L.S.D	0.15	0.018	0.018	0.11	

The term UPF represents Ultraviolet protection value. The term UVA represents the region 320-400 nm. The term UVA represents the region 290-320 nm. The term UV (%) represents the percentage UV radiation absorbance. The term P.C represents the protection category according to the cancer council (ACT) recommendation www.actcancer.org.

Table 4. Colourfastness to laundering.

Cotton variety	Fabric	Washing cycle					
		5		10		60	
		St*	Alt**	St*	Alt**	St*	Alt**
Giza 89	Mercerized	4	4	3 /4	4/5	3/4	5
	Un-Mercerized	4	3/4	4	3/4	4	4
Giza 80	Mercerized	4	4	3/4	4	4/5	4/5
	Un-Mercerized	4	4	3	4/5	4	5

*Staining on white cotton fabric, ** colour change of the tested sample. Theses two parameters were graded via standard grey scale (5 is very fast while 1 is not fast), either for test the staining or alteration.

incorporated into the fibers convert electronic excitation energy into thermal energy. Another reason is that the presence of luteolin as antioxidant can yield synergistic effect (Abrahart et al., 1977).

In the case of mercerization treatment, the influence largely depends on the hygroscopicity of fibers, as well as concentration of NaOH, which result in fiber swelling. The mercerization treatment affects the UPF value of cotton fabrics in two ways, namely the swelling of fibers that gave high dye absorption and reduces the interstices, and consequently the UV transmittance. On the other hand the presence of water reduces scattering effects, as the refractive index of water is closer to that of the textile polymer, and hence there is a greater UV transmission and lower UPF.

For the acute toxicity effect, it was observed that luteolin had the lowest values with activity and acute toxicity effect which encouraged an LD of 2 mg/g, and it had no impact in the acute toxicity effect.

Table 4 shows the fastness to washing from 5 to 60 washing cycle. The samples fast to washing for both staining on white cotton fabric and colour alteration of the original color of the samples. By studying economical feasibility we find out that the use of waste banana peel increase the value of this waste in addition to the good eco-image of the natural dye in addition to health, antibacterial and environmental protection issues added to the dyed samples. The optimum conditions of dyeing with respect to the highest colour strength, UPF and antimicrobial activity were applied on a pilot scale using rotadyer machine to treat and dye 5 m fabric of weight 620 g. Matched results to the research samples were obtained . This proves the applicability on the industrial scale and a further communication will be done for application on the large scale.

Conclusion

In the current study, the alkaline fractions of peel were evaluated as a dye, multi-functional antibacterial and UV protective agent on the cotton substrate. The data obtained showed that the mercerized fabrics have excellent antibacterial activity, high dye uptake with high UV protection properties among the control and the unmercerized cotton fabrics due to the swelling of fibers which resulted in higher dye absorption which reduces the interstices, and consequently the UV transmittance. The data obtained revealed that Giza 89 had the higher antibacterial activity, dye uptake with high UV protection properties than Giza 80.

The addition of Fe as a mordant increase all the above mentioned parameters due to ternary complex of Fe on one site with the fiber and on the other site with the dye, and also the coordination sites of Fe metal which are unoccupied can absorb UV incorporated into the fibers convert electronic excitation energy into thermal energy. These results are very important for industrial application with the production of a natural dye, antibacterial, and UV protected as an inexpensive source from waste banana peel as a by product.

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