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Abstract:

In the recent years natural dyes are using in textile dyeing. The main advantage of using natural dyes rather than synthetic dyes is low toxicity, it is biodegradable and waste water doesn't cause environmental hazards. Aqueous extraction of hazelnut shell is used in dyeing for cotton fabrics. Two different salts are used as mordant (Aluminum Sulphate and Copper Sulphate,). The aqueous extraction of hazelnut shell is prepared with three different concentrations (100,150 and 200 ml/l) to dye cotton fabrics. Some Investigations such as fastness properties (wash, rubbing and perspiration were done for natural extract dyed cotton, *Scanning Electron Microscope* (SEM) and antimicrobial activity. The highest wash fastness is recorded by Copper mordant (5 g/l) for 20 ml/l dye concentration. Antibacterial activity was evaluated for dyed fabrics and compared with Ag NPs treated fabrics. Hazelnuts shells aqueous extract dyed fabrics achieved superior antibacterial effects against both *Staphylococcus aureus*, and *Escherichia coli*. In general, dyed cotton fabrics with hazelnut shell extract showed superior antibacterial effects against *S. Aureus.* The antibacterial activity of dyed fabrics showed superior antibacterial efficiency than Silver coated fabrics. SEM for both hazelnut shells dyed cotton and silver nanoparticles coated cotton fabrics are performed. By using virtual 3D fashion design program, nine proposed designs of active wear for physical exercises and hospital uniforms are executed.

Keyword: Hazelnut shell extract, AgNPs, cotton, dyeing, antimicrobial, hospital uniforms.

Introduction:

There is an intense research dedicated to the "greening" of textile polymeric supports through the utilization of various bioactive extracts, as well as establishment of antimicrobial potential, such as natural pigments or antimicrobial products, process referred as functionalization **[Carvalho C. and Santos G., 2015]**. The use of natural dyes in textile

application is growing and gaining popularity "because of their non-carcinogenic and non-hazardous nature **[Shahid A, 2013, Fazal-ur R. 2013 and Abdullahi U.I, 2013]**. Natural dyes repeatedly were used only for coloring of textiles from ancient times till the nineteenth century. Natural dyes repeatedly are eco-friendly due to its biodegradability, low toxicity, and UV absorbent than synthetic dyes **[Ghaheh F.S., *et al*, 2014 and Mirjalili, M. and Karimi, 2013]**. Hazelnut (Corylus avellana L.) is one of the most important tree nut crops in worldwide production. The world market for hazelnuts is divided into two groups: nuts with intact shells for direct consumption (10%) and shelled nuts transferred for further technological purposes (90%) **[Król K., 2019]**.

Hazelnut shells represent more than 50% of the total nut weight and they are the major byproduct in hazelnut industry production **[Caglar A., 2009]**.

(a) **(b)**

Fig. (1): Hazelnut kernels (a) and hazelnut shells (b)

Their disposal represents both an economic problem for the producers and a serious environmental problem due to the combustion of the crop residues **[Piccinelli, A.L, 2016, and Wijngaard, H, 2012]**.

Hazelnut shells are composed of about 30% hemicelluloses, 27% celluloses, and 43% lignin, so they are mainly utilized as a low-value heat source **[Demirbas A, 1999]**. Some efforts have been made to utilize hazelnut shells as a low-cost raw material for phenolic compound extraction **[Contini M., 2008, Shahidi F. 2007, and Xu Y., Sismour, 2012]**.

Arcan (2009) and Yemenicio˘glu (2019) indicated that walnuts exhibited the highest antioxidant activity, followed by pistachios and hazelnuts. Hazelnut shells are rich in phenolic compounds. Phenolic compounds are the primary bioactive components in plants. They have a wide range of health benefits, mainly due to their antioxidant properties, such as reactive oxygen species scavenging and inhibition, electrophile scavenging and metal chelation **[Randhir R., 2004]**. Phenolic compounds also exhibit pharmacological properties, such as anti-carcinogenic, anti-inflammatory, and anti-mutagenic effects, and anti-proliferative potential **[Kaliora, A. 2014]**.

In the last few years, the market for antimicrobial textiles has shown double-digit growth. This growth has been fueled by the increased need of consumers for fresh, clean and hygienic clothing. Extensive research is taking place to develop new antimicrobial finishes **[Mirjalili Mo., 2013]**.

P. Lebaratoux *et al*, (2016]) study was undertaken to test almond, cashew, hazelnut and walnut extracts for the ability to inhibit microbial growth against a panel of pathogenic bacteria. They found that the bacterial growth inhibitory activities of the methanolic almond and walnut extracts, the anti-Giardial activity of the methanolic almond extract and their lack of toxicity indicates the potential of these extracts in the discovery and development of new natural antibiotic agents. **Coman *et al*, (2016)** study revealed that the natural polymeric supports functionalized by the addition of bioactive compounds extracted from plant sources, under the conditions of an ecologic dyeing methodology, and assistance of bio-mordant showed good antimicrobial activity with minimal chromatic changes of the textile support.

Most of the natural dyes have no substantively for the fibre and are required to be used in conjunction with mordants. A mordant, usually a metallic salt such as Alum, Copper and Chrome Mordant, is regarded as a chemical, which will be fixed on the fiber and which will attach the dyestuff. "A link is formed in this way between the fiber and the dye **[Vir S.S., 2012].**

Refers to the science and engineering concerning materials, structures and devices which at least one of the dimensions is 100 nanometers (0.1 μm) or less **[Ramakrishna S., 2005]**. Nanotechnology, deals with research and development at molecular and macromolecular scale, leading to the controlled manipulation and study of structure devices. Nanotechnology is one among the foremost important and active areas of research in modern science and technology which is concerned with the synthesis of nanomaterials using systems at nanoscale level **[Ashish K. S, 2015, and Sonal S. B, 2013]**.

Silver nanoparticles (AgNPs) show antibacterial activity **[Alivisatos A.P., 1996]**, owing to their unique physical, chemical and biological characteristics and high surface area, which increases their specific biological activity to volume ratio **[Hebeish, A.A, 2013, Montaser, A.S., 2016 and El-Rafie, M.H., 2011]**. It is stated that AgNPs show a bactericidal effect against several types of bacteria **[Antony J., 2013, Mahanty A., 2013, and Velmurugan P., 2014].**

The research undertaken a new way for treat cotton fabrics against microbes and apply this in the field of sportswear and medical textiles. Hazelnut shell aqueous extract is used as a natural dye for woven cotton fabrics. Three hazelnut shell extract concentrations are used (100, 150

and 200 ml/l), using two different mordants (Alum and Copper Sulphate). Finding optimum conditions of dyeing process are tested against microbes both gram positive and gram negative. The effect of dyeing process as antimicrobial treatment to cotton fabrics is compared with Ag NPs treatments. In final using virtual fashion design software in predicting proposed designs appearance.

Experiment:

Materials and Methods

Materials:

Cotton fabrics were studied with two different weave structures. The characteristics of the used fabrics are shown in Table 1.

Table (1): Used fabric characteristics

Fabric	Specification
Yarn type	**cotton**
Weave structure	**Plain (1/1)**
Mass per unit area	**173 (gm/m^2)**
Warp yarns/inch	**64**
Weft yarns/inch	**57**
Yarn count	**30/2**

Nano silver was kindly purchased from Sigma- Aldrich, particle size < 100 nm. Other used chemicals were of laboratory grade reagents.

Methods:

Scouring of cotton fabrics:

Cotton fabrics were scoured before treatment using 2 g/l sodium carbonate and 1 g/l non-ionic detergent at 80°C for 15 min followed by thorough rinsing with cold water and finally air dried at ambient temperature.

Preparation of Hazelnut shell Extract:

The natural dye (extract) of hazelnut shell residues are prepared by aqueous extraction process. At first dried pieces of hazelnut shell were soaked at 28°C for 24 hours, and boiled at 100°C for an hour. Continuous stirring when it was boiling. After the solution gets cold it was filtered and removed the residue. Three dye extract concentrations were prepared (100, 150 and 200 ml/l).

Dyeing process:

In the dyeing process the bath ratio was 1:20 and the dyeing process was applied by the exhaustion method at 90ºC for 60 min. Textile material is immersed in a dye bath solution containing different mordant [Aluminum Sulphate $Al_2(SO_4)_3$ and copper Sulphate $CuSO_4$] (5 g /l) and different concentrations dye extract (100, 150, 200 ml/l). Finally, the dyed samples are washed in presence of non-ionic detergent followed by

rinsed with running water to remove non absorbed dye, and were dried at ambient conditions.

Treatment with Silver Nano particles:

The treatment carried out by dip-pad-dry-cure technique. The cotton fabric was dipped in Silver colloidal solutions for 5 minutes at room temperature, and then padded using an automatic press at a nip pressure of 2.75 kg/cm^2 to obtain 80% wet pickup, dried in ambient air, and then cured at 140 ºC temperatures for 3 min. Then cotton fabric was air-dried at ambient temperature.

Finally, the impregnated fabric was rinsed with deionized water and non-ionic detergent {2 g/l at 40°C for 10 minutes}. During this step the unattached nano silver particles were removed out from the fiber surface.

Testing and Analysis:

Fastness to washing:

The color fastness to washing was determined according to the AATCC Test method 61- 1975 using Launder-Ometer.

Fastness to rubbing:

The color fastness to rubbing (wet and dry) was determined according to the AATCC test method 8 – 1977 **[AATCC Test Method (8-2007)]**.

Fastness to perspiration:

The fastness to perspiration (alkaline and acidic) was determined according to the AATCC test method 8 - 1977 **[AATCC Test Method (15-2013)]**.

Scanning electron microscopy canning electron microscopy (SEM) with high magnification, large depth of field and strong spectroscopic effects was used to observe and display the surface morphology of cotton fabrics. Dyed samples were mounted on aluminum stubs and sputter coated with gold in an Edwards S150A sputter coater and examined by a Jeol (JXA-840A) electron probe microanalyser (Japan).

Bacterial resistance test:

The antimicrobial properties of un-mordant and mordant dyed fabrics and silver treated fabrics were quantitatively evaluated against *Staphylococcus aureus*, a Gram-positive bacterium, and *Escherichia coli*, which are Gram-negative bacteria, according to the AATCC 100- 1993 test method **[AATCC 100-1993]**.

Colour strength:

The colour strength (K / S) of the dyed fabrics was measured using Hunter Lab's Universal Software, Mini Scan XE: RSIN (USA), using the Kubelka–Munk equation **[Judd D., 1975]**:

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

Where “K, S and R” are absorption coefficient, scattering coefficient and reflectance coefficient respectively.

Fashion design application:

Nine proposed designs are executed by virtual 3D software, CLO version 5.1, 2019. Seven designs are proposed to serve in sportswear sector in usual physical exercises. Another two proposed designs are suggested to using antibacterial treated cotton fabrics in medical textiles as hospitals nursing uniforms.

Results and discussion:

Effect of extract concentration on color strength:

Three different concentrations of hazelnut shell extract are used to dye cotton fabrics.

Table (2): Color strength of cotton fabrics dyed with different concentrations of hazelnut shell extract

[Extract] (ml/l)	Mordant Type	[Mordant] g/l	K/S
100	without	0	2.7
	Alum	5	3.4
	Copper Sulphate	5	4.2
150	without	0	3.7
	Alum	5	5.2
	Copper Sulphate	5	5.7
200	without	0	4.2
	Alum	5	6.23
	Copper Sulphate	5	7.2

Dyeing conditions: 90ºC for 60 min.

The data in this table reveals that the K/S value of the dyed cotton is increase d by increasing extract concentration. Mordants in general showed better strength in dyeing than in un-mordanted cotton. Copper Sulphate mordant gives better color strength to hazelnut dye extract. It can be concluded that the color of the dyed fabrics was significantly affected by both the concentration of natural colorant and mordant type.

Effect of extract concentration and mordant type on fastness properties:

Dyeing cotton fabric with aqueous extract of hazelnut shells are carried out with three concentration (100, 150, and 200 ml/l) as shown in figure 2. Two different salts are used as mordants $Al_2(SO_4)_3$ and $CuSO_4$. The textile material is immersed in a dye bath solution containing both mordant and dye. A mordant, usually a metallic salt, is regarded as a chemical substance, which will be fixed on the cotton fibers and which will attach the dyestuff. Wash fastness are examined to dyed fabrics, perspiration and rubbing fastness are also tested.

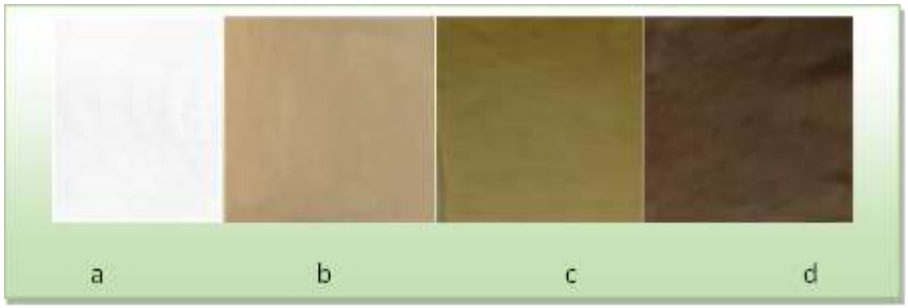


Fig. (2. a) Blank woven cotton fabric, (b , c and d) hazelnut shell extract dyed cotton fabric concentation 100, 150, and 200 ml/ lrespectively

Dyed fabrics are subjected to different factors affecting their fastness as frequent washing, light, rubbing and prespiration. Hence the durability of dye under there conditions are important to assessed.

Table (3): Effect of extract concentration and mordant type on wash fastness properties of cotton fabrics

Mordant type	Wash fastness	Hazelnut shell extract concentration (ml/l)		
		100	150	200
alum	Wet	3-4	3-4	4
	Dry	3-4	4	4
Copper Sulphate	Wet	4-5	4-5	5
	dry	4-5	4	4

Dyeing conditions: 90ºC for 60 min, 5gm/l mordant

As is evident from Table 3, the washing fastness of all dyed samples was high, regardless of the types of mordant. It is clear from Table (3) that the copper sulfate mordant recorded the highest degree of fastness for all dye concentrations. This may be due to complex formation between the dye molecules and copper metal ions in the cotton fiber, and that the concentration of 200 ml/l gave the highest degree of wash fastness. Based on the previous results, highest degree of wash fastness are those samples that were mordanted with Copper Sulfate and at extract concentration 200 ml/l.

Fig. (3): wash fastness properties for dyed woven cotton fabric (200 ml/l)

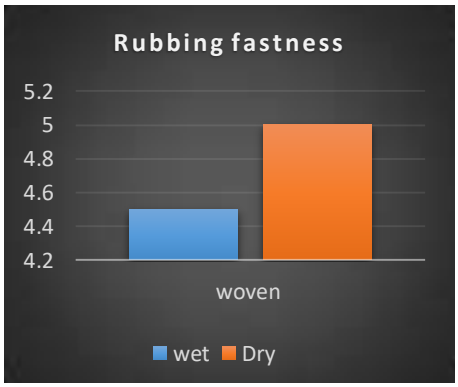


Fig. (4): rubbing fastness for woven cotton fabric (200 ml/l)

It is clear from figure (3) that wash fastness in wet conditions are superior to in dry conditions.

Figure (4) revealed that rub fastness test is designated for determining the degree of color, which may be transferred from the surface of the colored fabric to other surfaces by rubbing. As shown in figure 4, dyed woven cotton fabric achieved the highest degree of rubbing fastness in dry conditions than wet rub fastness values. This indicates strong dye-fiber bond which gives high fixation with aid of Copper mordant.

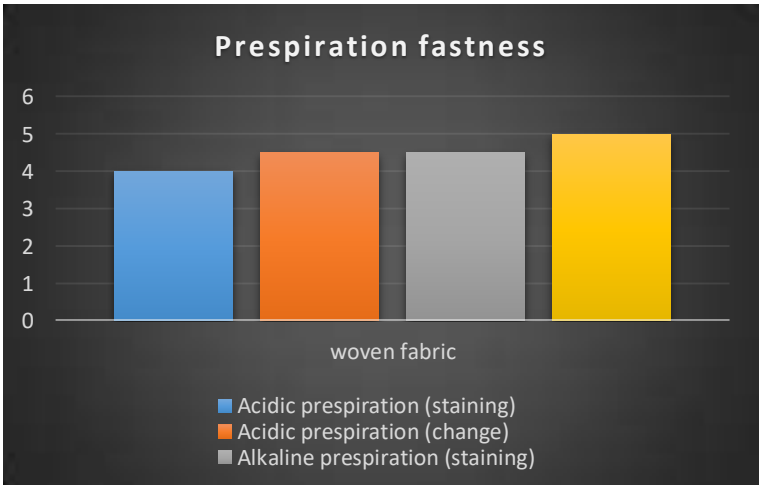


Fig. (5): Perspiration fastness for woven cotton fabric

It is clear from figure (5), that the hazelnut shell extracted dyed cotton achieved the highest degree of alkaline perspiration fastness (change) in cotton fabrics. And the woven dyed cotton achieved the very good acidic perspiration fastness for both change and staining condition.

Effect of Antimicrobial activity:

Antibacterial activities of pristine and dyed cotton fabrics against both *Escherichia coli* and *Staphylococcus aureus* bacteria were examined. *S. aureus* bacterium is a pathogenic microorganism causing many illnesses such as purulence, toxic shock, fibrin coagulation, endocarditic, and abscess. Furthermore, it is resistant to common antibacterial agents **[Montazer M., 2011]**. Moreover, E. coli bacterium is causes wound infections and urinary tract diseases **[McDonnell G., 1999]**.

Table (4) shows the antibacterial activities (inhabitation zone) of cotton fabrics dyed with the hazelnut shell extract in different concentrations with Copper Sulphate mordant against *E. coli* and *S. aureus* and comparing the resulting antibacterial effect with cotton samples treated with Silver nanoparticle. Antibacterial activity of dyed fabrics showed superior antibacterial inhibition than AgNPs treated fabrics.

Table 4. Inhibitation zone diameter of treated and untreated cotton fabrics

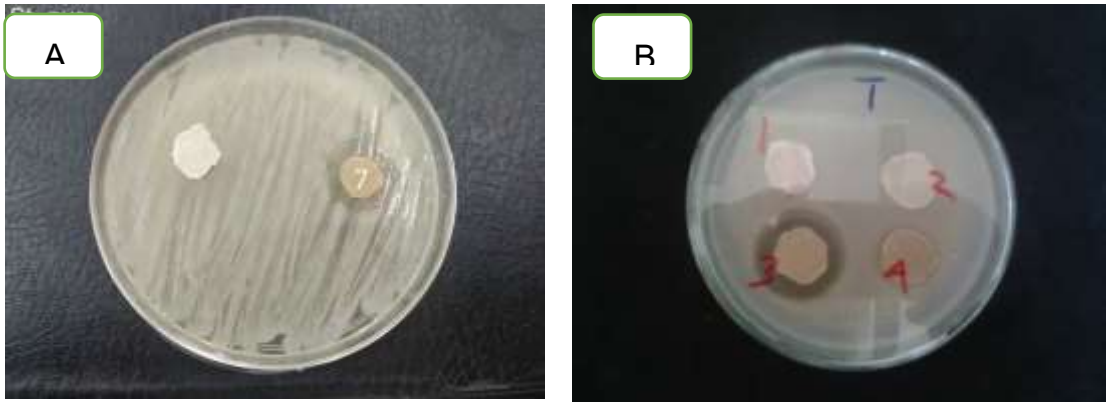
Treatment	Inhabitation zone (mm)	
	E-Coli	*S. Aureus*
Untreated	**-**	**-**
Hazelnut shell dye 200 ml- un-mordanted	**11**	**18**
Hazelnut shell dye 10o ml- $CuSO_4$	**6**	**9**
Hazelnut shell dye 150 ml- $CuSO_4$	**13**	**19**
Hazelnut shell dye 200 ml - $CuSO_4$	**25**	**28**
AgNPs 1g/l	**6**	**7**
AgNPs 3g/l	**8**	**10**
AgNPs 5g/l	**11**	**12**

Dyeing conditions: 90°C for 60 min, 5% mordant. AgNPs treatment: dip-pad-dry-cure technique for 5 minutes at room temperature, 80% wet pickup, cured at 140 ºC temperatures for 3 min.

Based on the obtained results in table 4, hazelnut dyed cotton showed superior inhibition efficiency against *Staphylococcus aureus* than *Escherichia coli*., also it showed that using mordant (Copper Sulphate) in dyeing gives better antibacterial activity than without mordant. It is well known that the metallic salts used as mordants exhibit toxic effects against the pathogens **[Delgado, T.; 2010]**.

The results acquired indicate that the increase in dye concentration had a tangible effect on antibacterial activity of dyed fabrics. Also, by increasing silver concentration the inhabitation is increased against both bacteria. Silver nanoparticles have been demonstrated to exhibit antimicrobial properties against bacteria. Silver kills bacteria by strangling them in a warm and moist environment. Highly bioactive silver ions bind with proteins inside and outside bacterial cell membranes thus inhibiting cell respiration and reproduction **[Montazer M., 2011]**.

From the previous results, it was proven that hazelnut shell aqueous extract can be used for dyeing cotton fabrics - with high fastness properties- as an alternative to the very expensive, synthetic, and toxic dyes. And that the extracted natural dye gives superior antibacterial properties for cotton fabrics than using synthetic Silver nanoparticles.



a **b**

Fig. (6 a, b): Antibacterial activity of treated cotton fabrics against Staphylococcus aureus

Figure. (6a) dyed sample with hazelnut shell extract 200 ml/l without mordant and in fig. (6 b) sample No. 1 is for cotton fabric treated with 3g/l AgNPs and sample No. 2 is for 5g/l AgNPs, sample 3 and 4 are for hazelnut shell dye 150 ml/l and 200ml/l respectively with Copper Sulphate.

Figure 6 (a, b) shows example of agar diffusion for *Staph* bacteria only, which achieved superior effects. It reveals the higher antibacterial properties of the hazelnut shell dyed fabrics in comparison with Silver nano particles coated samples. It was observed that the dyed fabric with the hazelnut extract had a higher antibacterial activity.

The antimicrobial effect of hazelnut shell aqueous extract is due to the presence of natural phenolic antioxidants as represented in **[Judd D., 1975]**. The reported antioxidant potential of both hazelnut kernel and shell extract might be related to the presence of phenolic acids and tannins (fig. 7) **[Kammerer D. R.; 2014 and Ghaheh F. S., 2012]**.

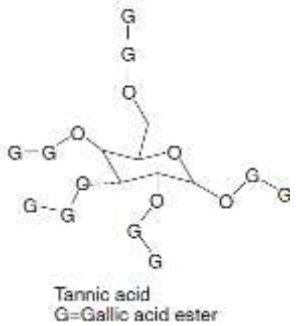


Fig. (7): The structures of the main components of natural colorants hazelnut shell

Results demonstrated in fig. 8 shows that hazelnut shell dyed cotton sample gives inhabitation zone increases by increasing extract concentration. Optimum inhabitation zone (25mm "*E-coli*" and 28 mm "*S. Aureus*") is achieved with extract concentration. 200ml/l with using Copper Sulphate mordant.

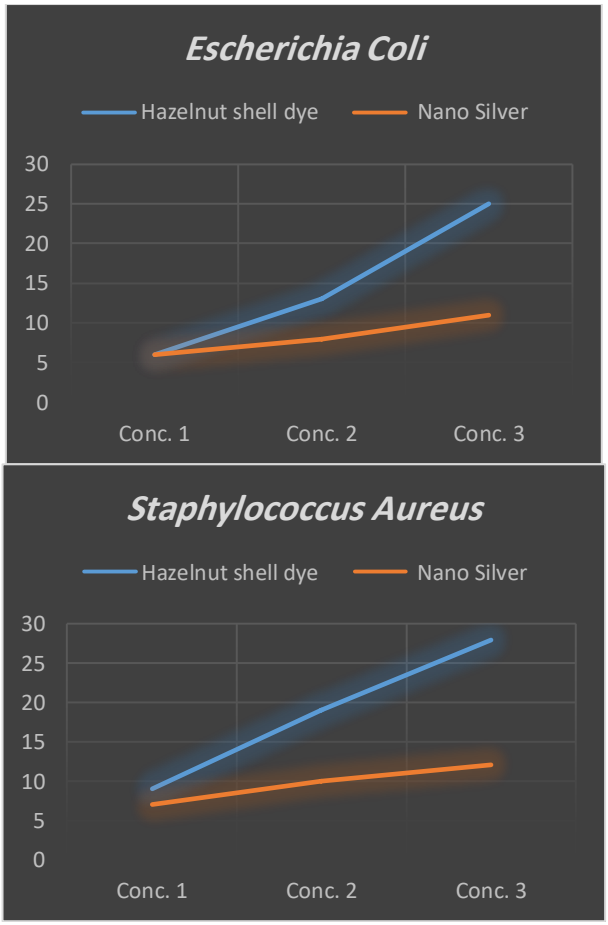


Fig. (8): ffect of Hazelnut shell dye (100, 150, and 200 ml/l) and Ag NPs (1, 3, and 5gm/l) against both *Escherichia Coli* and *Staphylococcus Aureus*

Also, by increasing Silver NPs concentration from 1, 3, reach to 5% the inhibition zone increases. It reaches to (11mm "*E-coli*" and 12 mm "*S. Aureus*") by using 5g/l Ag NPs. In general hazelnut shell extract shows excellent antibacterial activity both against *Escherichia coli* and *Staphylococcus aureus*.

Scanning Electron Microscope of treated cotton fabrics:

A scanning electron microscope (SEM) was used to characterize the surface morphology of cotton fabrics (Fig.9 a-d). The surface of the dyed cotton fiber (Fig.9 b) is smooth and undamaged. There are mineral deposits on the surface of the cotton fiber (Fig. 9b) it is a copper sulphate mordant. 800 x magnification of nano silver treated cotton fabric (Fig.9c), and 12000 x magnification of Silver nano particles coated cotton fabric (Figure 9d) shows deposited silver particles on cotton fibers.

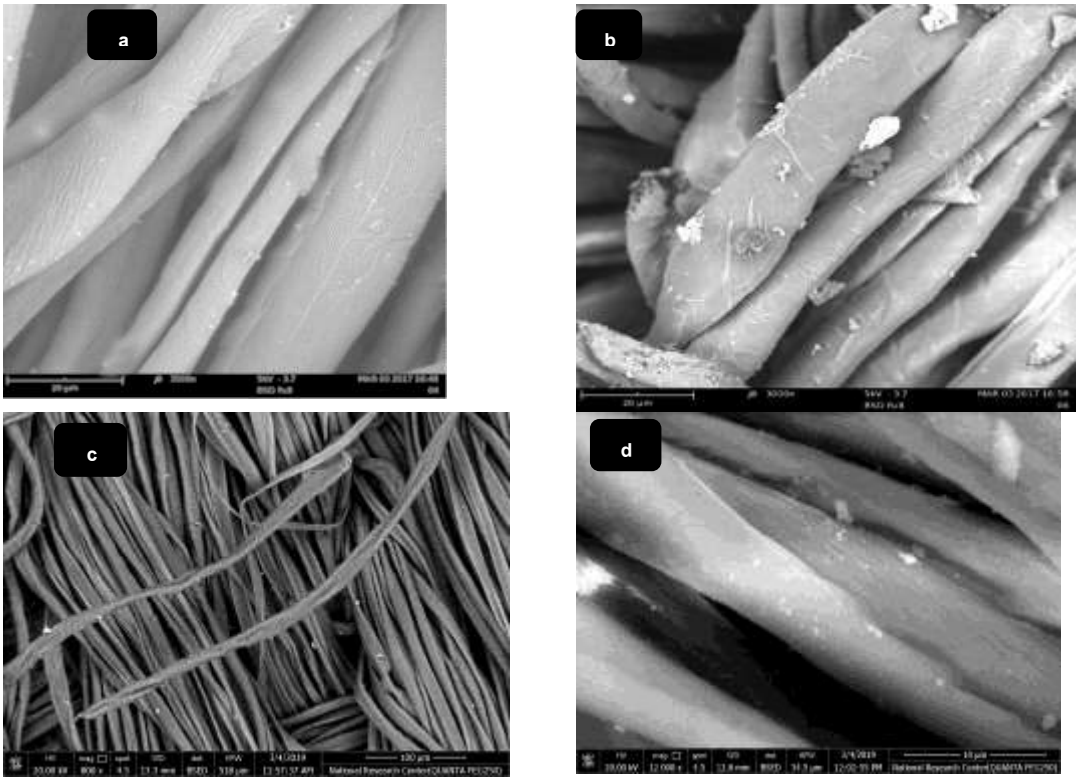


Fig. (9): EM of woven cotton fabric. a- pristine cotton fabric, b- hazelnut extract (200ml/l) with copper mordant, c- 800 x magnification of nano silver treated cotton fabric, d- 12000 x magnification of Ag NPs (5g/l) treated cotton fabric

Proposed design:

By using virtual 3D fashion design program, seven proposed designs of active wear for physical exercises are executed. Practical, comfort or aesthetic factors are considered in designs beside antimicrobial functional treatments. Another two proposed designs are suggested to using antibacterial treated cotton fabrics in medical textiles sector as hospitals nursing uniforms.

Design (1)

Design color: -tan brown color (150 ml/l extract concentration)-Navy to Cerulean blue grades with oranges printed fabric.
Design proposed fabric: 100% cotton fabric.
Design description: Sleeveless blouse, A-line skirt (knee length)

Design (2)


Design color: -corn silk brown color (100 ml/l concentration), metallic orange.
Design proposed fabric: 100% cotton fabric- spandex polyester.
Design description: Sleeveless blouse, Legging (under-knee length)

Design (3)


Design color: -wheat brown color (150 ml/l concentration) -Navy to Cerulean blue grades with pink printed fabric.
Design proposed fabric: 100% cotton fabric.
Design description: Sleeveless blouse, A-line skirt (knee length) with buttons in center front

Design (4):


Design color: -tan brown color (200 ml/l concentration) -purple color. **Design proposed fabric:** 100% cotton fabric. **Design description:** Sleeveless blouse with bust cuts, Circular knee length skirt

Design (5)


Design color: wheat brown color (150 ml/l concentration) -white and dark blue colors.**Design proposed fabric:** 100% cotton fabric- spandex polyester. **Design description:** Shirt with squares cuts, Legging (hem length)

Design (6)

Design color: - brown color (200 ml/l concentration) -Gold yellow color. **Design proposed fabric:** 100% cotton fabric. **Design description:** A-line - midi length dress

Design (7)

Design color: - corn silk brown color (100 ml/l concentration), dark red.
Design proposed fabric: 100% cotton fabric- satin fabric.
Design description: Fitted blouse waist length, Pleated mini length skirt.

Design (8,9)

Two proposed designs are suggested to using antibacterial treated cotton fabrics in medical textiles as hospitals nursing uniforms

Conclusion:

- Hazelnut shell aqueous extract is used as a natural dye for woven cotton fabrics. Three dye concentrations are used (100, 150 and 200ml/l), using two different mordants (Alum and Copper Sulphate). Finding optimum conditions of dyeing process are tested against microbes both Gram positive and Gram negative. The effect of dyeing process as antimicrobial treatment to cotton fabrics is compared with Ag NPs treatments.
- The copper sulfate mordant recorded the highest degree of fastness for all dye concentrations. This may be due to complex formation between the dye molecules and copper metal ions in the cotton fiber, and that the concentration of 20٠ gave the highest degree of wash fastness.
- Fastness to washing showed very good results indicating that there was a good fixation of the dye in the fabric. Therefore, it was concluded that the cotton fabric is easily dyed with extract of hazelnut outer shell providing different brown shades color.
- Hazelnut shell extracted dyed cotton achieved excellent degree of alkaline perspiration fastness (change) in woven cotton fabrics. And dyed cotton achieved very good degree of acidic perspiration fastness for both change and staining condition.

- The antibacterial activity of dyed fabrics (Hazelnut) showed superior antibacterial inhibition than silver treated fabrics.
- Based on the obtained results, specimens showed better efficiency against *Staphylococcus Aureus* in comparison with *Escherichia Coli*.
- From the previous results, it was proven that hazelnut shell aqueous extract can be used for dyeing cotton fabrics - with high fastness properties- as an alternative to the very expensive, synthetic, and toxic dyes. And that the extracted natural dye gives superior antibacterial properties for cotton fabrics. The antimicrobial effect of hazelnut shell aqueous extract is due to the presence of natural phenolic antioxidants. The reported antioxidant potential of both hazelnut kernel and shell extract might be related to the presence of phenolic acids and tannins.
- In general dyed cotton fabrics with hazelnut shell showed superior antibacterial effects against Staphylococcus aureus. Certain groups of people are at greater risk, cluding newborn infants, breastfeeding women, and people with chronic conditions such as diabetes, cancer, vascular disease, and lung disease. Injecting drug users, those with skin injuries or disorders, intravenous catheters, surgical incisions, and those with a weakened immune system due either to disease or a result of immune suppressing medications all have an increased risk of developing staph infections so dyed fabrics will give wide range of protection against pathogens.
- By using virtual 3D fashion design program, seven proposed designs of active wear for both medical sector and physical exercises are executed. Practical, comfort and aesthetic factors are considered in designs beside antimicrobial functional treatments.

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استخدام مستخلص قشر البندق كمضادات للبكتيريا فى صباغة الاقمشة القطنية وتطبيقاتها الوظيفية

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الملخص:

يعتبر اعادة استخدام قشور البندقالصلبة طريقة مبتكرة لاعادة تدوير نفايات صناعة البندق. فى هذه الدراسة تم استخلاص صبغات طبيعية من قشور البندق الصلبة واستخدامها فى صباغة اقمشة قطنية (منسوجة)، حيث ان استخدام الصبغات الطبيعية متعارف عليه منذ العصور القديمة فى صباغة المنسوجات. تتميز استخدام الصبغات الطبيعية عن الصبغات الصناعية بأنها مواد طبيعية غير سامة وغير مسرطنة وبها يمكن تلافى المشاكل البيئية الناجمة عن مياه الصرف الخاصة بالصبغات الصناعية. تم استخدام مثبتات للصبغة الطبيعية (كبريتات الامونيوم –كبريتات النحاس) واستخدام ثلاث تركيزات مختلفة للصبغة المستخلصة. مثبت كبريتات النحاس سجل أعلى درجة ثبات للغسيل لجميع تركيزات الصبغة محل الدراسة كما أن تركيز ٢٠٠ مل/ لتر أعطى أعلى درجة ثبات. تم ايضا قياس ثبات اللون للغسيل والعرق والاحتكاك.

لذا تتناول الدراسة الحالية اقتراح بديل طبيعى فعال مقاوم للبكتريا و قليل التكلفة لخدمة صناعة الملابس والنسيج وتنميتها خاصة مجال الملابس الرياضية والاقمشة التى تخدم القطاع الطبي سواء ملابس او رداء مضاد للبكتيريا او اغطية واقية لاسرة المستشفيات , وهو استخدام مستخلص قشر البندق فى صباغة الاقمشة القطنية و دراسة فاعليته فى مقاومة البكتريا موجبة الجرام(*Staphylococcus aureus*) وسالبة الجرام (*Escherichia coli*) ومقارنتها بفاعلية نانو الفضة كمثبط للبكتيريا.اثبتت الدراسة فعالية المستخلص المائى لقشر البندق كصبغة مقاومة للبكتيريا تتفوق على المعالجة بجزيئات الفضة النانومترية الحجم.