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Antimicrobial fabrication of cotton fabric and leather using green-synthesized nanosilver

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ABSTRACT

This study aims to investigate the green synthesis of silver nanoparticles (AgNPs) by *Erigeron annuus* (L.) pers flower extract as reducing and capping agent, and evaluation of their antibacterial activities for the first time. The obtained product was confirmed by UV–Vis spectrum, high resolution-transmission electron microscopy, energy-dispersive X-ray spectroscopy, Fourier transform infrared spectroscopy, and X-ray diffraction studies. The optimum AgNPs production was achieved at pH 7, metal silver (Ag^+ ion) concentration of 2.0 mM, flower extract concentration 4%, and time 335 min. In addition, the antibacterial activity of cotton fabrics and tanned leather loaded with AgNPs, commercial AgNPs, flower extract, Ag^+ ion and blend of flower extract with AgNPs were evaluated against Gram-positive odor causing bacteria *Brevibacterium linens* and *Staphylococcus epidermidis*. The results showed maximum zone of inhibition (ZOI) by the cotton fabrics embedded with blend of flower extract and AgNPs against *B. linens*. The structure and morphology of cotton fabric and leather samples embedded with AgNPs, Ag^+ ion and blend of flower extract with AgNPs were examined under field emission scanning electron microscope.

1. Introduction

Over the past few decades, substantial research attempt was made to fabricate antibacterial coatings on the surfaces of varied objects, such as garments, medical devices and food pack, to prevent infection and spoilage (Ravindra, Murali Mohan, Narayana Reddy, & Mohana Raju, 2010). Several attempts have been made to develop economical, non-toxic, and value effective antimicrobial finishing textiles for applications in medical, healthcare, pharmaceutical, hygienic products, and protective textile (Ul-Islam, Shahid, & Mohammad, 2013). Metal nanoparticles synthesized by physical, chemical and biological routes were extensively studied as a result of their wide applications (Mochochoko, Oluwafemi, Jumbam, & Songca, 2013; Isaacet al., 2013). Synthesis of various metal nanoparticles through chemical and physical routes is found to show certain toxicological effects in the medical research field (Kanmani & Lim, 2013); additionally it is quite expensive and as well unsafe. To overcome this limitation, we have fabricated AgNPsin an eco-friendly, inexpensive, easily available substrate, and safe method of synthesis from a phyto source (flower). The substrate originated from a natural source, particularly textile and leather, acts as an excellent harbor for microbes, as they will provide ideal conditions like moisture, temperature, oxygen, and nutrient required for its growth (Ul-Islam et al., 2013). Microbial pathogens have lethal effect on all forms of life. The odor in feet, shoes and/or socks is due to breakdown of amino acids present in our sweat and skin by *Brevibacterium linens* and *Staphylococcus epidermidis*. *B. linens* can breakdown an amino acid methionine present in sweat into methanethiol a gas. *S. epidermidis* creates body odor by breaking sweat into isovaleric acid (3-methyl butanoic acid) from the amino acid leucine (Ara et al., 2006; Kanlayavattanakul & Lourith, 2011), which causes unpleasant smell in feet, shoes and/or socks. To beat this difficulty, it is truly fascinating to possess antimicrobial properties in textile and leather product. Many chemicals and its strategies of imparting antimicrobial property into textile materials are of not eco-friendly, toxic to humans, and also bacteria will develop resistance over the chemical or/antibiotics (Rajendran, Radhai, Kotresh, & Csiszar, 2013; Ul-Islam et al., 2013). Thus, the people are now increasing awareness on antibiotic textile and leather finishing with eco-friendly and biodegradability. In view of these ecological and environmental concerns, green source (plants and its parts) become a key resources to obtain

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eco-friendly nanoparticles to fabricate bioactive fabric and leather products.

To combat these adversities, we have been made to fabricate AgNPs using *Erigeron annuus* (L.) pers flower extract as a reducing and capping agent for fabric and leather finishing. To brief, genus *E. annuus* belonging to the family Asteraceae (tribe Astereae), involves about 150 species occurring within the hemisphere zone, mainly in North America. Some of them were introduced to Europe. *E. annuus* (daisy fleabane) is an annual plant and reaches a height of up to 150 cm posses erect, branched stem completing inflorescences. The central disk florets are numerous, very small, and yellow; they are surrounded by 50–120 white ray florets. Both kinds of florets can be self-fertile. They often settle on same places like roadsides and wastelands. Various parts of *E. annuus* have been employed in Chinese folk drugs for the treatment of dyspepsia, enteritis, epidemic hepatitis, and haematuria. As the constituents of the aerial part of *E. annuus* contain γ-pyranone derivatives, flavonoids, and phenolic acids and their derivatives, sesquiterpenoids and cyclopentenone derivatives have been reported (Nazaruk & Kalemba, 2009). Human beings are often infected by microorganisms such as bacterium, mold, yeast, and virus in living environment. In this study, the synthesis and application of AgNPs were systematically optimized, characterized and their antibacterial properties of cotton fabric and tanned leather samples loaded with various obtained materials also evaluated against the bacteria responsible for causing odor in sweat, shoe and shocks.

2. Experimental

2.1. Flower material

The *E. annuus* flowers were collected from the road side of Chonbuk National University, Iksan, South Korea and washed thoroughly with copious amount of RO in nanopure purified water (conductivity = 18 μΩ/m, TOC < 3 ppb, Barnstead, Waltham, MA, USA). Such flowers (100 g) were added to 250 ml distilled water and crushed by a juicer. The extract was filtered through a Whatman filter paper and stored at 4 °C for further experiments.

2.2. Chemicals and media

Silver nitrate ($AgNO_3$) (99.9%) acquired from DaeJung chemicals, South Korea, and commercial silver nano powder (99.5%, <100 nm) purchased from Sigma–Aldrich (St. Louis, MO), were used for the synthesis of AgNPs, and Brain Heart Infusion broth (BHI) and Mueller-Hinton agar (MHA) were purchased from MB Cell, South Korea for antibacterial study. All chemicals were used as supplied. Nanopure purified water was used throughout this investigation.

2.3. Microorganisms

The antimicrobial activity of cotton fabric and leather samples loaded with various materials was evaluated against two stains *B. linens* (KACC-14346) and *S. epidermidis* (KACC-13234) purchased from KACC (Korean Agricultural Culture Collection). The microbial cultures were maintained in nutrient agar media and stored in 4 °C for further use.

2.4. Synthesis and optimization of silver nanoparticles

For the entire study, silver nitrate ($AgNO_3$) was used as a source for silver in nanopure water. For the AgNPs synthesis, 5 ml of *E. annuus* flower extract was added to 45 ml of 1 mM aqueous $AgNO_3$ solution in a 250 ml Erlenmeyer flask. To obtain optimum AgNPs production, various parameters like pH (4, 5, 6, 7, 8, 9, and 10), flower extract (1, 2, 3, 4, 5, 6, 7, 8, 9 and 10%), Ag^+ ion concentrations (0.25, 0.5, 1.0, 2.0, 3.0,4.0 and 5.0 mM), and time (15, 30, 45, 60, 95, 110, 125, 140, 175 and 190 min), were studied. The reaction mixtures were filtered through 0.22 μm Steritop Millipore filters and centrifuged at 12,000 rpm for 15 min for AgNPs isolation. The resulting pellets were redispersed in nanopure water to eliminate any uncoordinated molecules. The process was repeated several times in order to ensure better separation of free entities from the metal NPs. The obtained NPs were stored freeze-dried to obtain a powder. To check the stability of synthesized AgNPs, it was exposed to ambient condition for several months and scanned for the wavelength. Furthermore, the overall study and production was carried out in the optimized parameters. All experiments were carried out in triplicates.

2.5. Preparation of leather and fabrics samples

The leather sample was purchased from the local market in South Korea. The obtained leather was punched with help of 13 mm cork borer in order to get spherical shape and slice to reduce the thickness by removing the smooth surface, using a sharp knife with care. To remove the impurities, the leather was immersed in boiling water (50 ml) with 2 ml/l of non-ionic detergent for 1 h, followed by hot and cold water washing (to avoid break down of the emulsion and precipitation of the impurities onto the leather), and air dried at room temperature. Cotton fabric was obtained from the local market in Iksan, South Korea. To remove the impurities, 3 g of cotton fabric treated in the same condition was used for leather. Later the dried cotton fabrics were punched to get spherical holes. These samples were used for further study. Before embedding the particles, we ensured that the fabric and leather samples were free from any chemicals obtained by EDX spectra.

2.6. Embedding silver nanoparticles onto cotton fabrics and tanned leather

Different materials are used for embedding onto cotton fabric and tanned leather like synthesized AgNPs (0.01 g/10 ml), commercial AgNPs (0.01 g/10 ml), Ag^+ ion (0.01 g/10 ml), flower extract (5 ml), and flower extract with AgNPs (5 ml: 0.01 g/5 ml). The commercial grade AgNPs were kept in glassware cleaning ultra sonicator water bath with maintained agitation for 20 min at 100 Hz (Elmasonic S30H. Ultrasonic bath, Germany). For the successive embedding of each materials on to cotton fabric and leather samples, the samples were immersed in separate 50 ml screw cap tubes with the above said materials and kept in a ultrasonicator with manual agitation for 20 min at 70 °C at 100 Hz, respectively. The samples were then pressed with tissue paper. The same conditions were followed for control samples without the implant material. To remove excess particles or materials, the dried samples were subjected to several washing with detergent water and the same drying conditions were repeated. The cotton fabric samples were dried at 120 °C for 2 min, and leather samples were dried at 80 °C for 15 min (in order to avoid damage occur faster at higher temperatures) for curing, respectively. Later, the antibacterial efficacy was evaluated in triplicates for each prepared fabric and leather samples and average values were presented.

2.7. Characterization of AgNPs and coated cotton fabric and leather samples

The optical absorption spectra of the AgNPs were observed by UV-1800, UV–Vis (Shimadzu, Japan) spectrophotometer. The morphology of AgNPs were observed using HR-TEM (JeolJEM100SX). The elemental composition of the AgNPs was analyzed using energy dispersive spectroscopy (EDX) (SEM–EDX; JEOL-6 4000, Japan).

FT-IR spectra of AgNPs were obtained with a PerkinElmer FTIR spectrophotometer (Norwalk, USA) in the diffuse reflectance mode at a resolution of 4 particles cm^{-1} in KBr pellets. X-ray powder diffraction was used to determine the crystalline nature of the AgNPs by Rigaku X-ray diffractometer (XRD; Rigaku, Japan). The morphology of embedded silver nanoparticles onto control, cotton fabric and leather samples were studied using FE-SEM (AURIGA Laser - Carl Zeiss Microscopy) after gold coating. Electro kinetic measurement (zeta potential) of AgNPs was evaluated at different pH, ranging from 5 to 10, and was analyzed using Zetasizer, Malvern, respectively.

2.8. Bactericidal activity – zone of inhibition (ZOI) and minimum bactericidal concentrations (MBC)

The bactericidal activity of cotton fabric and leather samples loaded with various materials was tested by ZOI and MBC. To enrich the culture, the cultures were aseptically inoculated into BHI and incubated at 30 °C (*B. linens*) and 37 °C (*S. epidermidis*), respectively. Each strain was tested by spreading on MHA plates with 50 μl each of an overnight culture grown in BHI. The treated cotton fabric and leather samples (discs) were placed on agar plates and incubated at suitable temperatures. The plates were examined for possible clear zone formation after incubation. The presence of clear zone around the samples was recorded as an inhibition against the bacterial strains. The diameter of such ZOI was measured using a meter ruler, and the mean value for each organism was recorded and expressed in millimeters. To determine the MBC, each treated cotton fabric, leather samples (disc) and its controls were placed in a separate falcon tube containing 5 ml of Luria-Bertani broth (LB). A 0.1 ml of each bacterial culture was then inoculated into LB broth and incubated on a reciprocating shaker for 24 h. Then, 10 μl of culture was spread over the LB agar with suitable dilution, and colonies of viable cells were counted. Antibacterial activity was defined as the percentage of microbe reduction (Lic et al., 2009; Dastjerdi, Mojtahedi, Shoshtari, & Khosroshahi, 2010; Lee et al., 2013) and was calculated according to AATCC 100 and calculated by Eq. (1).

$$R(\%) = \frac{A - B}{A} \times 100 \quad (1)$$

where A is the number of bacteria recovered from the inoculated test specimen and B is the number of bacteria according to "A" conditions with antibacterial modified sample. Consequently, R(%) is the percentage of reduction ratio which indicates biostatic efficiency. Each experiment was performed in triplicates and the final values were presented as the mean ± standard deviation (SD).

3. Results and discussion

The simple and viable technique in phytosynthetic method became an alternative to chemical and physical methods. Such consistent and environmental friendly technologies help to boost the synthesis and application of nanoparticles which are good for mankind (Amarnath et al., 2012). In green synthesis, it is believed that the plant extract acts as reducing and stabilizing agent for the production of metal nanoparticles. The reaction media (Ag^+ ion with *E. annuus* flowers extract) was transformed from light yellow to striking colors, brown with yellow shade (Fig. 1a and inset) in room temperature due to the excitation of surface plasmon vibrations in the formed nanoparticles. (For interpretation of the references to color in the text, the reader is referred to the web version of the article.) This distinct color change itself indicates a visual evidence for nanoparticle formation. In the present study, *E. annuus* flowers extract acts as a reducing and capping agent for synthesis AgNPs. Previously, it was reported that *Lonicera japonica* flower extract acts as a reducing and a capping agent for synthesis of Ag nanoparticle (Nagajyothi, Lee, An, & Lee, 2012), so UV–Vis absorption spectroscopy was performed to identify the formation of silver nanoparticle. The sharp band of AgNPs was observed at 434 nm.

3.1. Study of various process parameters to obtain optimum AgNPs production

To obtain maximum nanoparticles production, we have studied various process parameters such as the effect of pH; flowers extract concentration, Ag^+ ion concentrations, and contact time. All reactions were carried out at room temperature. Hence, the maximum production was achieved at room temperature. The *E. annuus* flower extract mediated synthesized AgNPs' stability was estimated with zeta potentiometer (data not shown) with varied pH ranges and their corresponding SPR from pH 5 to 10 as shown in Fig. 1a and inset, and high absorbance peak was observed at pH 7. It is observed from Fig. 1a, in the higher pH range the zeta potential shows slight variation based on UV–Vis spectra as well. A similar result was already reported in the past (Dwivedi & Gopal, 2010). Production of AgNPs in various percentages of flower extract concentrations is shown in Fig. 1b and inset, consequent color changes were observed from light yellow to brown with yellow shade with increasing percentage of *E. annuus* flowers extract, respectively. Notably, the lowest amount of 4% flower extract is effective to induce the generation of AgNPs. Based on the visible spectrum, a fixed flowers extract concentration is reliable for the production; the lower and higher concentrations have not supported the fine production (Fig. 1b). To study various Ag^+ ion concentrations for the synthesis of AgNPs, the Ag^+ ion concentrations were varied from 0.01 to 4 mM. The sharp peak absorbance was observed at 1.5 mM Ag^+ ion concentration for AgNPs (Fig. 1c and inset). Increased Ag^+ ion concentration increased nanoparticles' size (Dubey, Lahtinen, & Sillanpaa, 2010; Dwivedi & Gopal, 2010). The synthesis of AgNPs was found slow at lowest Ag^+ ion concentration, and hence, absorbance is also weaker. To evaluate the effect of contact time for the AgNPs synthesis the absorbance was evaluated in UV–Vis spectroscopy from 0 to 335 min. It was noted that, with increase in contact time, the peak becomes sharper (Fig. 1d). Formation of AgNPs started within 15 min and increased up to 3 h. Hence, our research shows a significant step in the development of green processes for the synthesis of AgNPs. Further experiments were conducted using the obtained optimal parameters.

3.2. Morphological and structural characterization of E. annuus flowers extract mediated synthesized AgNPs

Fig. 2 shows the EDX spectrum of the *E. annuus* flowers extract mediated synthesized AgNPs. The strongest peak was revealed at ~3 keV, which confirmed the presence of elemental silver in pure form. Furthermore, the EDX pattern of AgNPs consists of Ag, O and C with percentages of 48.24%, 10.44%, and 41.32%. Fig. 3a–c shows the TEM image with an average particle size ranging from 10 to 20 nm along with SAED pattern, respectively. The size, shape, morphology, and distribution of the synthesized AgNPs were confirmed with help of HR-TEM. Fig. 3a–c shows AgNPs with spherical and hexagonal shaped structures in which individual spherical shaped AgNPs with an average diameter of 10–20 nm were capped by *E. annuus* flower extract. The possible phytoconstituents responsible for the reduction and the stabilization of synthesized metallic nanoparticles can be achieved by the FTIR studies, which can help in further functionalization with other molecules for various applications (Dubey et al., 2010). Fig. 4 shows the FTIR spectra of AgNPs and flower extract. The AgNPs show prominent

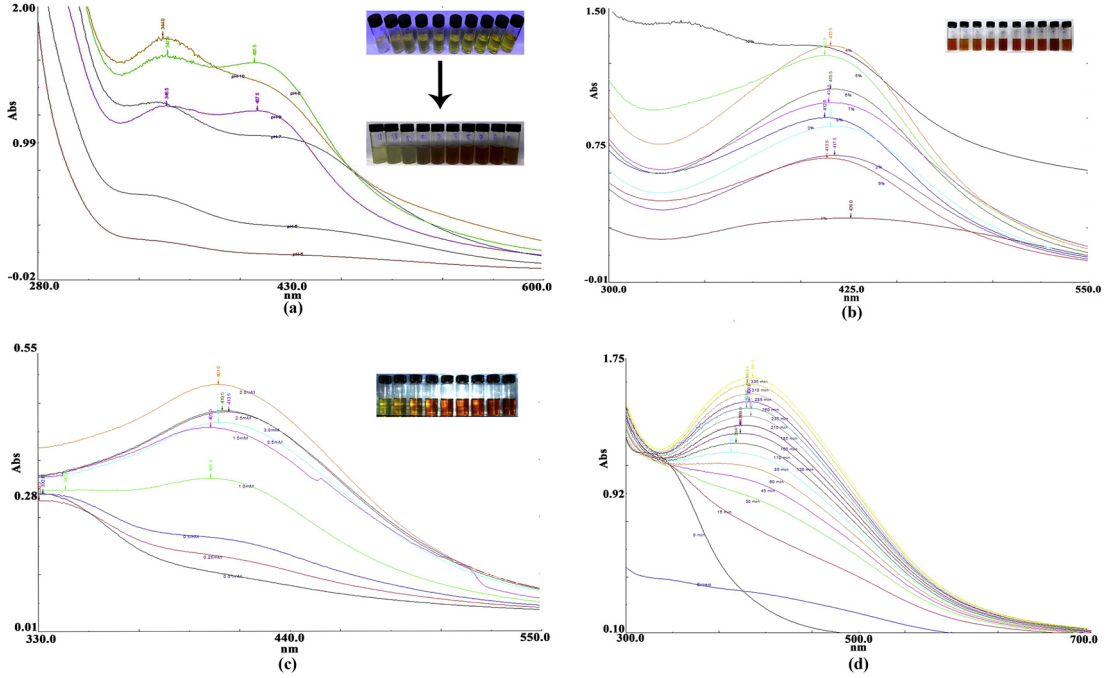

Fig. 1. (a) UV–Vis spectra of the AgNPs synthesized at different pH, (b) different percent of flower extract concentrations, (c) different Ag^+ ion concentrations, and (d) reaction time.

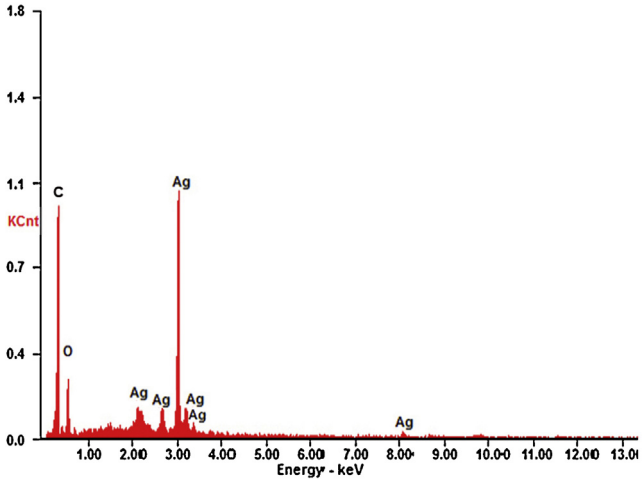

Fig. 2. EDX spectra of the AgNPs obtained at optimum parameters.

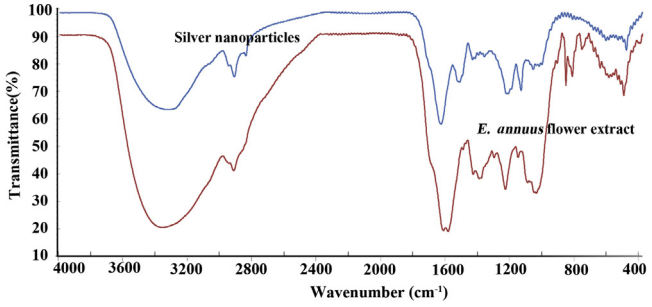

Fig. 4. FTIR spectrum of the AgNPs obtained at optimum parameters.

peaks at 3,200 cm^{-1}, 3,100 cm^{-1}, 2,850 cm^{-1}, 2,620 cm^{-1}, 1,300 cm^{-1}, 1,100 cm^{-1}, and 622 cm^{-1}. The peak for *E. annuus* flower extract appears at 3,300 cm^{-1}, 3,100 cm^{-1}, 2,850 cm^{-1}, 2,620 cm^{-1}, 1,100 cm^{-1}, and 600 cm^{-1}. The bands at 1,300 cm^{-1}, 1,100 cm^{-1}, and 622 cm^{-1} in the spectra of AgNPs and extract correspond to C≡C groups or aromatic rings or C≡O stretching (Vidhu & Philip, 2014) in carboxyl group (amide I &II band) of proteins. The strong broad peak at 2,620–3,300 cm^{-1} is a characteristic of the N—H stretching vibration. Also, the hydroxyl peaks at 3,420 cm^{-1} and 3,500 cm^{-1} decrease in the presence of nanoparticles, which indicates the Ag^+ ion reduced with the hydroxyl groups of the flavanoid; and polyphenol and the hydroxyl groups are oxidized to carbonyl groups (Ashokkumar, Ravi, Kathiravan, & Velmurugan, 2014). The sharp bands at 2850 cm^{-1} and 3100 cm^{-1} arise

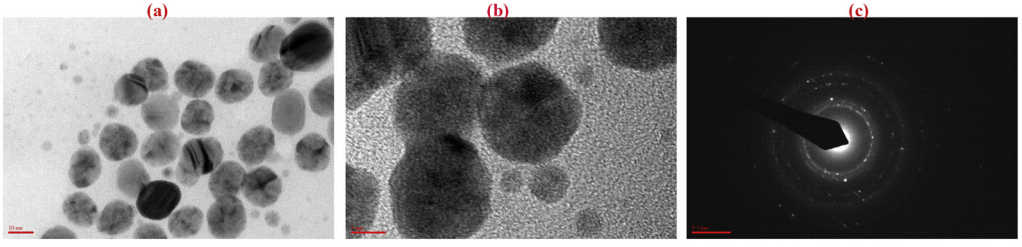

Fig. 3. TEM images of the AgNPs obtained at optimum parameters.

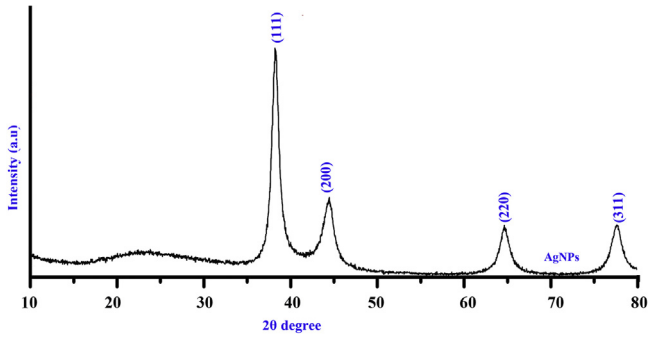

Fig. 5. XRD pattern of the AgNPs obtained at optimum parameters.

from C—H stretching modes. In particular, the 1300 cm^{-1} band arises most probably from the C—O group of polyols, such as hydroxyl flavones. The XRD pattern of AgNPs shows few intense peaks in the whole spectrum of 2θ values ranging from 20 to 80 (Fig. 5). The AgNPs show four peaks with a characteristic of metallic face-centered cubic silver phase (PDF-2 4-0738) at 39.1°, 44.2°, 64.9°, and 78.0°, in 2θ. The standard XRD patterns for Ag are almost similar [Joint Committee on Powder Diffraction Standards (JCPDS) file no: 04-0783 for Ag]. The XRD patterns clearly show that the obtained AgNPs are crystalline in nature.

3.3. Antimicrobial activity mechanism of silver nanoparticles

Silver nanoparticles are extensively used in commercial products as antibacterial additives to fight against infections and spoilage. However, the mechanism of AgNPs is only partially understood. Earlier, few mechanism have been proposed for the interaction of AgNPs/Ag^+, bacteria and fabric are as follows; Hebeish et al. (2013) reported that the prepared AgNPs, the oxidation of zerovalent silver (Ag^0) to silver ion (Ag^+), occur to a great extent due to their extreme sensitivity to oxygen or to the interaction with water molecules. Hence, the sulfur or phosphorus acts as a key factor for antibacterial effect with high affinity. The bacterial cell surface with sulfur containing protein membrane could enhance that AgNPs/Ag^+ ion, to react in and out of the cell membrane, to turn off its cell viability (Mijakovic, Petranovic, Bottini, & Deutscher, 2005; El-Rafie, Mohamed, Shaheen Th, & Hebeish, 2010; Hebeish et al., 2013). The inhibition of enzyme functions through inactivation of DNA replication by AgNPs/Ag^+ ion by reacting with the phosphorus moieties present in the DNA (El-Rafie et al., 2010). The reaction of Ag^+ with the cell protein contains nucleophilic amino acid residues which attach to sulfhydryl, amino, imidazole, phosphate and carboxyl groups of membrane, or enzyme proteins will lead to denaturation of protein followed by cell death (Sathishkumar et al., 2009; Hebeish et al., 2013). The AgNPs can also catalyze the production of oxygen radicals that oxidize molecular structure of bacteria by the release of Ag^+. This will occur as the oxygen diffuses from the fiber to the surrounding environment (Wright, 2002; El-Rafie et al., 2010; Dastjerdi et al., 2010). Few similar mechanisms could be possible for the antibacterial activity in leather. However, extensive research is needed to elucidate the antibacterial mechanism of AgNPs embedded leather.

3.4. Antibacterial efficacy of AgNPs embedded on to cotton fabrics and tanned leather

The ZOI and MBC of the cotton fabrics and tanned leather samples embedded with AgNPs, Ag^+ ion, and blend of AgNPs with flower extract against *B. linens* and *S. epidermidis* are shown in Fig. 6a–f and Table 1. These results indicated that the combination of AgNPs with flower extract loaded cotton fabric exhibited greater reduction of *B. linens* growth (Fig. 6c), followed by leather sample. *S. epidermidis* shows a uniform ZOI in cotton fabric and leather samples embedded with other three materials in Table 1. The possibility of maximum antibacterial activity in extract and AgNPs combination is due to the possibility that extract might act as a binder for the nanoparticles. The possible mechanism for antibacterial activity of AgNPs were previously reported as follows; (1) due to the size of nanoparticles and as well as faster release of AgNPs into the media (Ravindra et al., 2010), (2) formation of chemical bond between silver and alcoholic groups of fabrics, and physical surface assimilation of AgNPs on the material surface (Hebeish et al., 2011), (3) the antibacterial activity was closely related to wetness of the coated fabrics because of their hydrophobic surface (Budama, Cakir, Topel, & Hoda, 2013), (4) AgNPs disturb the bacterial function by attach to the surface of the cell membrane, penetrate and release Ag (Yang & Li, 2013), (5) the AgNPs target the bacterial membrane, leading

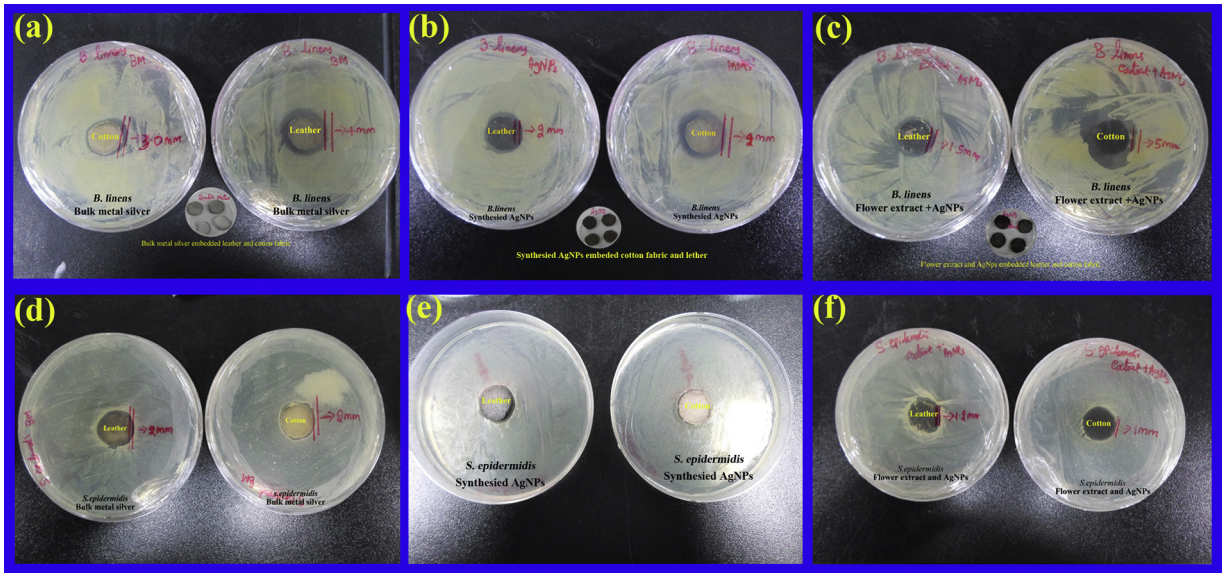

Fig. 6. (a–f) Antibacterial efficacy of fabric and leather coated with Ag^+ ion, AgNPs and flower extract with AgNPs against *B. linens* (a) Ag^+ ion, (b) AgNPs, (c) flower extract with AgNPs and *S. epidermidis* (d) Ag^+ ion, (e) AgNPs, and (f) flower extract with AgNPs.

Table 1
Antibacterial activity of cotton fabric and leather samples embedded with AgNPs, Ag^+ and AgNPs with flower extract (ZOI and MBC) against odor causing bacteria *B. linens* and *S. epidermidis*.

Bacterial strains	Embedded material	Embedding material	ZOI (mm)	MBC (%)
B. linens	Cotton fabric	Control	No zone	220.0 ± 12.02
		Bulk metal (Ag^+)	3.0 ± 0.2	77.27 ± 09.02
		AgNPs	2.0 ± 0.3	63.63 ± 12.04
		Flower extract + AgNPs	1.5 ± 0.5	65.45 ± 10.06
	Tanned leather	Control	No zone	220.0 ± 12.02
		Bulk metal (Ag^+)	4.0± 0.4	81.36 ± 09.02
		AgNPs	2.0± 0.6	73.18 ± 08.06
		Flower extract + AgNPs	5.0± 0.1	30.27 ± 11.08
S. epidermidis	Cotton fabric	Control	No zone	220.0 ± 12.02
		Bulk metal (Ag^+)	2.0 ± 0.6	61.81 ± 14.04
		AgNPs	2.0 ± 0.3	62.72 ± 08.09
		Flower extract + AgNPs	1.2 ± 0.2	45.45 ± 12.08
	Tanned leather	Control	No zone	220.0 ± 12.02
		Bulk metal (Ag^+)	2.0 ± 0.4	60.90 ± 10.02
		AgNPs	2.0 ± 0.1	58.63 ± 10.04
		Flower extract + AgNPs	1.0 ± 0.7	46.63 ± 11.08

Values are mean ± SD; $n = 3$.

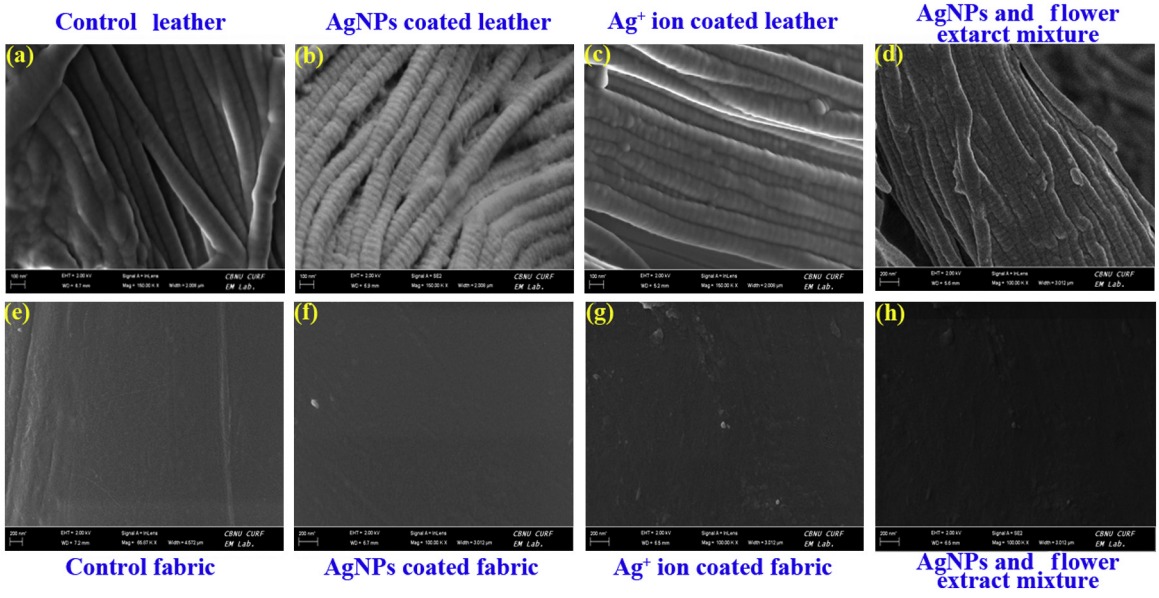

Fig. 7. (a–h) The FE-SEM micrograph of treated fabric and leather embedded with (a) control leather, (b) leather with AgNPs, (c) leather with Ag^+ ion, (d) leather-AgNPs with flower extract, (e) control fabric, (f) fabric with AgNPs, (g) fabric with Ag^+ ion, and (h) fabric-AgNPs with flower extract.

to a dissipation of the proton motive force (Yang & Li, 2013). There is no remarkable zone formation in commercial AgNPs and flower extract. The mechanism or action part would need additional elucidation for leather antibacterial activity; further studies are required to investigate with various strains of bacteria for potential widening of their applications particularly for textile and leather product for its commercial applications.

3.5. Morphology of the cotton fabrics and tanned leather (treated and untreated)

FE-SEM micrographs (Fig. 7a–h) demonstrate the homogeneous depositions of AgNPs, Ag^+ ion, and blend of AgNPs with flower extract on the leather and fabric samples. The SEM image in Fig. 7a and e demonstrates the smooth structure of the leather and cotton fabrics before coating (control). After embedding, the homogeneous deposition of AgNPs, Ag^+ ion, and combination of AgNPs with flower extract on the leather samples are shown in Fig. 7b–d and cotton fabrics are shown in Fig. 7f–h, respectively.

4. Conclusion

Recently, nanobiology is playing a key role in nanotechnology in order to obtain environment-friendly products with antibacterial capacity. In this, silver has been used for past few decades as a remedy for burns, wounds and different bacterial infections. Silver nanoparticles were successfully prepared using green approach with optimum production by analyzing (pH, Ag^+ ion concentration, flower extract concentration and production time) it. Purity and structure were analyzed using various instrumental techniques like UV–Vis spectroscopy, HR-TEM, EDX, FT-IR, and XRD. FE-SEM image exhibits the morphological distribution of metal and nano particles on the surface of cotton fabric and leather. It is found that combination of flower extract with AgNPs is more enough to exhibit excellent antibacterial activity against *B. linens* and *S. epidermidis*. The FE-SEM image shows that the AgNPs, Ag^+ ion, and blend of flower extract with AgNPs were well dispersed on the cotton fabric and leather. The flower extract might play as a binder for nanoparticles, which shows maximum antibacterial efficiency

of the treated cotton fabrics and leather. To test the permanency of embedded fabric and leather, samples were undergone for several hand washings using detergent. The fabric and leather samples exhibited superior antibacterial activity even after several washings, indicating their applicability in textile and leather product in order to prevent infections and odors. Based on this study, it is possible to use *E. annuus* flower extract as well as synthesized AgNPs to fabricate antibacterial rich cotton fabrics and leather products like shoes and/or socks for sports personalities in order to get rid of bad odors and bacterial infections.

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