Research Article

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Green Synthesis of Entrapped Silver Nanoparticles/ Poly (vinyl alcohol-ethylene glycol) Nanocomposite

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ABSTRACT

Plant-based synthetic silver nano-modified polymer nanocomposite films containing plant extracts that are harmless to the environment and human health have been produced. The bioactive packaging polyvinyl alcohol/ polyethylene glycol (P-VA/EG) films were prepared by incorporating green synthesized silver nanoparticles (AgNPs). The effect of *Tridax procumbens* leaf extract content on the green synthesis of AgNPs in P-VA/EG film was studied. The morphology of the prepared nanocomposite thin film was confirmed by XRD, FESEM, and EDAX analyses. The presence of functional groups on the silver nanocomposite was confirmed by FTIR spectroscopy. The optical properties of the nanocomposite thin film were studied by UV-Vis analysis.

Keywords: Silver nanoparticles; *Tridax procumbens*; Polyvinyl alcohol; Polyethylene glycol; Optical properties.

1.INTRODUCTION

In recent years, the fabrication of environmentally friendly and sustainable materials has drawn a lot of attention, especially in the area of bioactive packaging. Developing materials that not only preserve food and drugs but also reduce environmental impact and guarantee human safety is one of the main challenges in modern packaging solutions (Shankar and Rhim, 2016) The integration of green-synthesized nanoparticles into polymeric matrices has become a viable strategy among others. In this regard, synthetic silver nano-modified polymer nanocomposite films synthesized using plants provide a novel and environmentally responsible substitute for traditional packaging materials (Mittal *et al.*2020).

Since their antimicrobial, optical, and mechanical properties have been extensively researched, silver nanoparticles (AgNPs) are extremely valuable in both industrial and biomedical applications (Rai *et al.*2012). Because they are sustainable and non-toxic, green synthesis techniques for AgNPs, especially those that use plant extracts, have attracted more attention (Ahmed *et al.* 2016). These methods reduce environmental pollution and possible health risks by avoiding dangerous chemicals that are usually used in the synthesis of nanoparticles. *Tridax procumbens* contains bioactive phytochemicals that are effective reducing and stabilizing agents for nanoparticle synthesis (Jayaseelan *et al.*2017).

The current study used *Tridax procumbens* leaf extract to incorporate green-synthesized AgNPs into the bioactive polyvinyl alcohol/polyethylene glycol (P-VA/EG) film. This novel method guarantees the formation of nanocomposite film with improved functional and physicochemical characteristics. Energy-dispersive X-ray analysis (EDAX), field emission scanning electron microscopy (FESEM), and X-ray diffraction (XRD) were used to examine the morphological and structural properties of the film. Additionally, Fourier-transform infrared spectroscopy (FTIR) was used to confirm the presence of functional groups linked to the silver nanocomposite, and ultraviolet-visible (UV-Vis) spectroscopy was used to analyze the optical characteristics of the produced thin film. There is great potential for a number of industrial and medical uses when green-synthesized AgNPs are incorporated into polymer nanocomposites. The potential of plant-based nanocomposite materials in the fabrication of high-performing, environmentally friendly bioactive packaging solutions is highlighted by this study.

2. MATERIALS AND METHODS

The chemicals utilized for synthesizing nanomaterials and buffer solutions are typically sourced in the form of analytical grade or chemical pure grade. Specifically, polyvinyl alcohol and polyethylene glycol were procured from HiMedia, while $AgNO_3$ was obtained from Merck and used as supplied.

2.1 Instrumentation

Using a Labtronics model LT 291UV-Vis spectrometer, absorption spectra in the UV–Vis region were measured in quartz cuvettes (45 mm × 12.5 mm ×

12.5 mm). With a resolution of 4 cm^{-1} and an average of 100 scans, FTIR spectra were obtained at room temperature using Shimadzu IR Prestige 2 FTIR Spectrometer. Cu Kα radiation with a wavelength of 1.5406 Å was used in X-ray diffraction (XRD) analysis of the produced film. Energy dispersive analysis by X-ray (EDAX) was used to ascertain the chemical compositions of the nanocomposite film.

2.2 Plant Material Collection and Preparation of Leaf Extracts

Leaves of *Tridax procumbens* were harvested and subjected to a washing process using distilled water to eliminate any dust particles present. Subsequently, the leaves were dried by exposure to sunlight. The dried leaves were subsequently pulverized using a sterile mortar and pestle. Approximately 5g of leaves was combined with 50mL of distilled water. Then, the solution was heated at 50°C for 1 hour. The extract underwent a triple filtration process to eliminate any particulate matter and obtain a clear solution, which was stored at 4°C for future use.

2.3 Green Synthesis of Silver Nanoparticles

The synthesis of silver nanoparticles was carried out following the procedure outlined by Mankad *et al*. (2020) with minor adjustments. A total of 5 mL of the plant extract was added to a solution containing 20 mL of 1 mM aqueous silver nitrate ($AgNO_3$) at room temperature. Subsequently, the solution was stirred using a magnetic stirrer until its color changed to dark brown, indicating the successful formation of silver nanoparticles (AgNPs). The nanoparticles obtained were collected by centrifugation at a speed of 10000 revolutions per minute (rpm) for 15 minutes. The resultant solution was washed with distilled water to isolate pure AgNPs. Finally, the solution was dried in a hot air oven set at 50°C for 24 hours.

2.4 Preparation of (P-VA/EG)–AgNPs Film

Polyvinyl alcohol-poly ethelyne glycol-silver nanoparticle ((P-VA/EG)-AgNPs) composite film was synthesized by the solvent casting method. The PVA solution was prepared by combining 5mL of PVA with 100mL of distilled water. The mixture was then heated to a temperature of 50°C for 3 hours, ensuring the complete dissociation of the PVA. Then, the solution was brought to room temperature. Following the cooling process, 7.5 g of PEG was introduced into the solution mentioned earlier. The solution mixture was stirred for 2 hours. The resulting solution was then poured into Petri plates and subjected to drying in a hot air oven at a temperature of 50°C for 24 hours.

3. RESULTS AND DISCUSSION

3.1 Visual Observation

The initial color of the *Tridax procumbens* leaf extract was observed to be dark green (Fig. 1) prior to its exposure to a solution of silver nitrate. However, following the reaction, the color of the extract transformed into dark brown. This change in color suggests the occurrence of a chemical reaction resulting in the formation of silver nanoparticles. This reaction is attributed to the reduction of silver ions by the active molecules present in the extract. This color is a result of the phenomenon known as surface plasmon resonance (SPR), which is a property of nanoparticles that varies depending on their size.

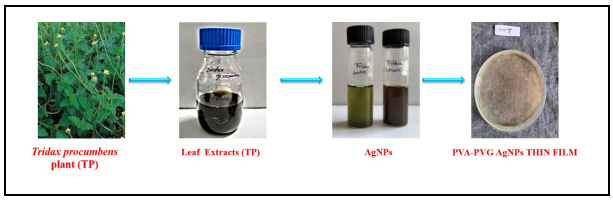


Fig.1: Preparation of (P-VA/EG)–AgNPs film

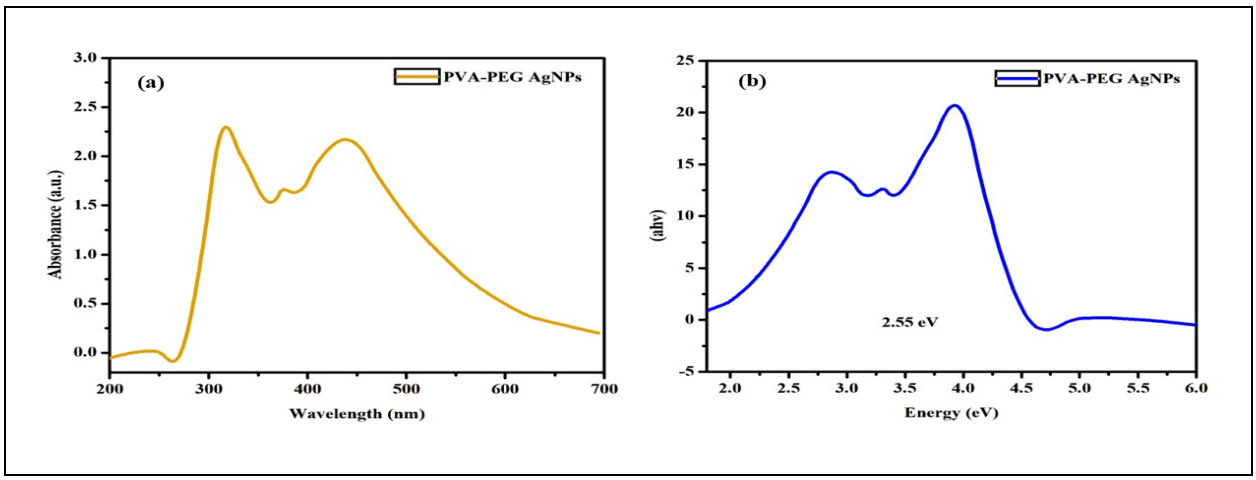


Fig. 2: UV-visible spectrum of synthesized PVA-PEG AgNPs films (a) and surface plasma resonance (SPR)

3.2 UV Analysis of (PVA-PEG)–AgNPs Film

The colloidal solution was analyzed using UV–Vis absorption spectra to determine the presence of a broad SPR band between 390 and 475 nm (Fig.2a), indicating the presence of spherical AgNPs. The presence of a broad SPR band at 440 nm provides evidence for the formation of AgNPs. The SPR band observed for the AgNPs was a result of the bio-capping and bio-reduction by phytochemical compounds found in *Tridax Procumbens* leaf extract. The analysis indicates that the energy bandgap of the synthesized CQDs is approximately 2.55 eV, as determined through the utilization of the Tauc plot method, as depicted in Fig. 2(b).

3.3 X-Ray Diffraction (XRD) Analysis of (PVA-PEG)-AgNPs Film

The X-ray diffraction pattern of the composite film is presented in Fig. 3. The XRD pattern shows distinct peaks at 2θ values of 37.96°, 44.44°, 64.65°, and 77.48°, which can be attributed to the crystal planes (111), (200), (220), and (311), respectively. The presence of these peaks is ascribed to the PVA-PVG AgNPs crystal within the tetragonal crystalline system. The analysis demonstrates that the PVA-PVG AgNPs The crystal size and parameters obtained from X-ray diffraction data are presented in the table provided.

$$D = \frac{k\lambda}{\beta \cos\theta} \quad \ldots (1)$$

In the provided equation, K is a constant equal to 0.94;λ denotes the measure of radiation intensity and β denotes the full width at half maximum. θ denotes the Bragg angle. From equation 1, the average crystal size of PVA-PVG AgNPs was calculated to be 10.37 nm.

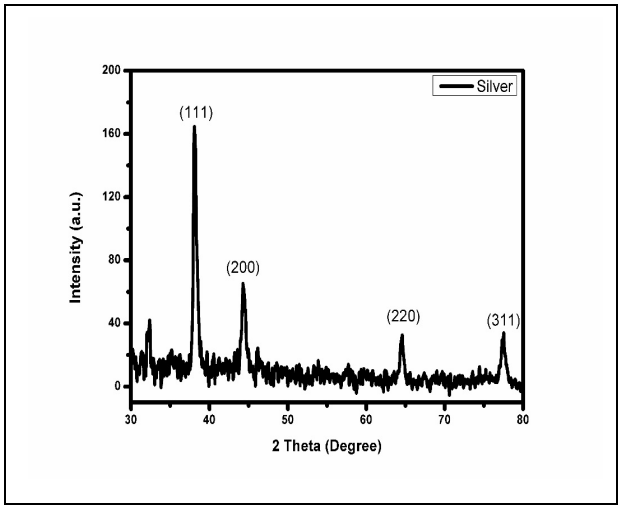


Fig.3: X-Ray Diffraction of (PVA-PEG)-AgNPs

Table 1. Average-Crystallite size D of (PVA-PEG)-AgNPs

2θ (°)	hkl Plane	FWHM (β, radians)	d-spacing (Å)	Crystallite Size D (nm)
37.96	111	0.0089	2.37	10.12
44.4	200	0.0092	2.04	10.45
64.65	220	0.0085	1.44	10.21
77.48	311	0.009	1.23	10.7
Average-Crystallite Size D (nm)				10.37

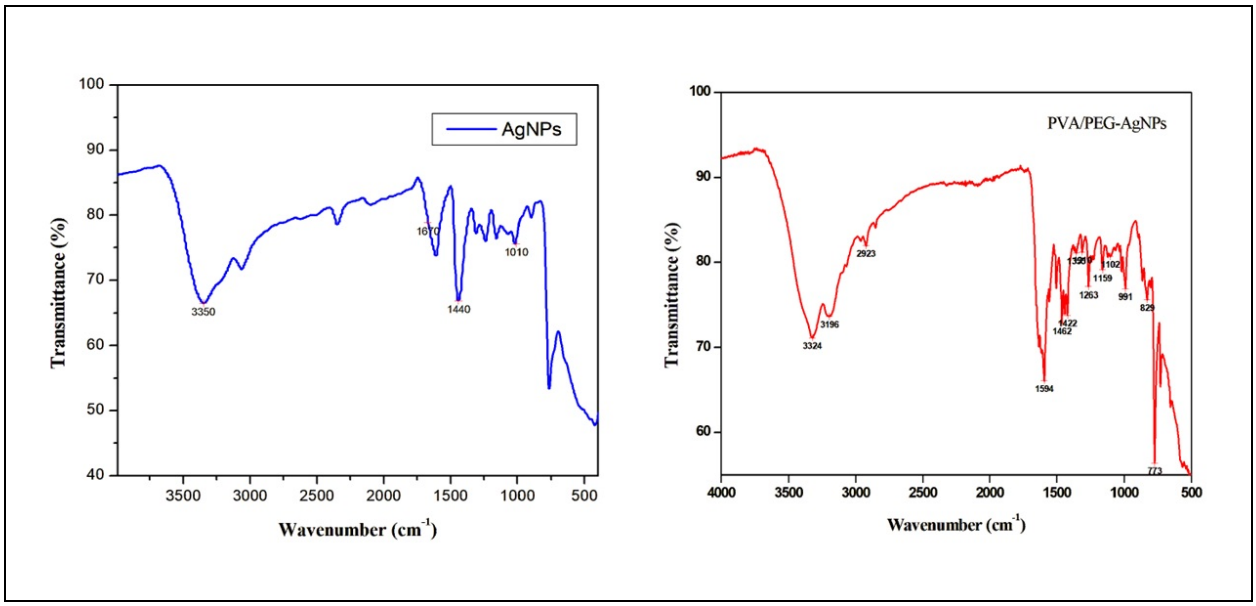


Fig. 4: FTIR spectra of green synthesized silver nanoparticles and PVA-PEG AgNPs

3.4 Fourier Transform Infrared (FTIR) Analysis of (PVA-PEG)-AgNPs Film

The FTIR spectra of (PVA-PEG)–AgNP films and green-synthesized AgNPs are illustrated in Fig. 4. For AgNPs, a broad absorption band observed around 3350 cm^{-1} corresponds to O–H stretching vibrations of phenolic groups and hydrogen bonding associated with plant-derived proteins. The band at 1440 cm^{-1} is attributed to C–N stretching of amine groups, while the peak at 1615 cm^{-1} corresponds to C=O stretching vibrations from polyphenolic carbonyl compounds. The signal near 1010 cm^{-1} arises from C–O–C stretching vibrations, suggesting the involvement of flavonoids and tannins in the reduction of Ag^{+} ions.

In the PVA/PEG–AgNP composite film, a broad band ranging from 3324 to 3196 cm^{-1} is related to O–H stretching due to hydroxyl groups and hydrogen bonding in PVA, PEG, and phytoconstituents. The absorption at 2923 cm^{-1} is ascribed to C–H stretching of aliphatic groups. The band at 1452 cm^{-1} corresponds to C–H bending vibrations, whereas the one at 1594 cm^{-1} is linked to C=O stretching of carbonyl groups. Peaks at 1350, 1263, and 1159 cm^{-1} represent C–N and C–O stretching modes.

Additionally, ether linkages (C–O–C vibrations) are indicated by the peaks at 1091 and 991 cm^{-1}. Bands at 842 and 773 cm^{-1} are associated with out-of-plane bending of aromatic C–H bonds. Altogether, these spectral features confirm the presence of PVA, PEG, and phytochemical functional groups, which play a vital role in stabilizing and reducing Ag^{+} ions and promoting the formation of (PVA/PEG)–AgNP films.

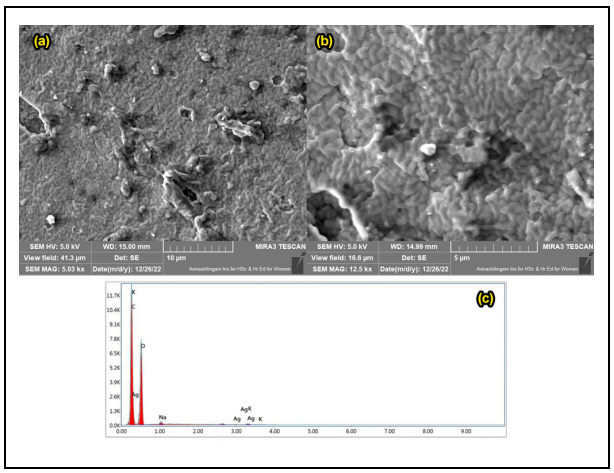


Fig.5: (a & b) Scanning Electron Microscopy (SEM) with PVA-PEG AgNPs and (c) Energy-dispersive X-ray (EDX) spectrum of synthesized nanoparticle confirms the presence 81.25% of silver (Ag)

3.5 Field Emission Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) Analysis of PVA-PEG AgNPs Films

The scanning electron microscopy (SEM) images (Fig. 5a and b) of the synthesized polyvinyl alcohol-polyethylene glycol silver nanoparticles (PVA-PEG AgNPs) film are observed at a magnification of 6000X in the photomicrograph. Initially, the particles were spherical. However, due to agglomeration, their shape became elongated, although it is not well-defined.

The energy-dispersive spectroscopy analysis showed the elemental composition of the film. It contained81.25% silver (Ag),8.21% carbon (C), 5.82% oxygen (O), 3.41% nitrogen (N), 1.07% potassium (N) and 0.24% magnesium (Mg), indicating the high level of purity of the silver nanoparticles (Fig.5c).

4. CONCLUSION

The study successfully demonstrated the fabrication of plant-based silver nanoparticle-modified polymer nanocomposite films using Tridax procumbens leaf extract as a green reducing and stabilizing agent. The incorporation of AgNPs into PVA/PEG films was confirmed through structural, morphological, and spectroscopic analyses, including XRD, FESEM, EDAX, FTIR, and UV-Vis studies. The findings highlight the eco-friendly synthesis approach and the potential application of these bioactive nanocomposite films in sustainable and safe packaging materials.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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