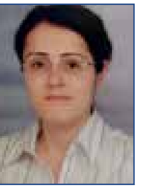
Green synthesis of silver nanoparticles using common poppy (*Papaver rhoeas L.*) and evaluation of their potential antibacterial activity



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Abstract

Due to their easy and low-cost production and enhanced properties, noble metal nanoparticles are preferred as nano-additives in most pharmaceutical compositions. For example, silver nanoparticles (AgNPs) and gold nanoparticles (AuNPs) possess antiseptic and antimicrobial activity and they are generally preferred for obtaining antibacterial clothing and coatings. In the present study, we report a simple, low cost and green method for synthesizing AgNPs using aqueous extracts of common poppy (*Papaver rhoeas* L). Synthesised silver nanoparticles were characterised based on Field Emission Scanning Electron Microscopy equipped with energy dispersive X-ray spectroscopy, Fourier-Transform Infrared Spectroscopy, and X-ray diffraction analysis. The synthesised AgNPs were also tested for antimicrobial activity using the agar well diffusion method. Characterisation methods showed that the obtained AgNPs were spherical in shape, with a particle size ranging from 15 to 40 nm. According to the antimicrobial test results, AgNPs effectively inhibited the growth of various gram-positive and gram-negative bacteria. It was concluded that *Papaver rhoeas L.* extract is effective as a reducing agent for the preparation of stable and monodispersed AgNPs and obtained AgNPs could be useful in antibacterial applications in human and veterinary medicine.

Key words: *silver nanoparticles; Papaver rhoeas L.; biosynthesis; antibacterial*

Introduction

Nanoparticles (NPs) can exhibit unique physical and chemical properties because of their high surface area and nanoscale size. They are used in various fields such as electronics, biosensors, medicine, antimicrobial devices (such as wound dressings, implantable materials), etc. NPs have also been used in drug

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delivery systems due to their distinctive advantages. They can be modified with cell-specific ligands and deliver drugs to target areas in the optimum dosage. In this way, the highest benefit is obtained from the drug, and excessive drug use and side effects are also reduced (Khan et al., 2019).

NPs can be classified according to their physical and chemical characteristics. Carbon-based NPs, metal NPs (especially noble and alkali metals), ceramic NPs, semiconductor NPs, polymer NPs, and lipid-based NPs are common in various applications. NPs synthesised from noble metals (gold, silver, platinum, etc.) come to the forefront due to their optical properties under light radiation, also called localised surface plasmon resonance (LSPR) (Khan et al., 2019; Pryshchepa et al., 2020). In addition, thanks to their easy and low-cost production and enhanced properties, noble metal NPs are preferred as nano-additives in most pharmaceutical compositions (Khan et al., 2019). Silver has low melting and boiling points and high electrical and thermal conductivity compared to other noble metals. Due to the improved characteristics of silver in NP form, it is increasingly used in many technical and medical fields such as the generation and storage of solar energy, development of electronic devices, enhancement of analytical methods, catalytic reactions, environmental applications, biomedical imaging, antimicrobial applications or cancer treatments. Silver is also frequently preferred in many studies due to its high reactivity and effectiveness against various microorganisms (Pryshchepa et al., 2020).

In addition, there are several other reasons why silver nanoparticles (AgNPs) have received more attention than other metallic NPs. For example, gold (AuNPs) and platinum NPs (PtNPs) have a high production cost, while AgNPs can be produced at a much lower cost. The use of copper NPs (CuNPs) is not preferred due to their high sensitivity to oxidation. Zinc oxide (ZnO) or zirconium oxide (ZrO_2) NPs can be used in antibacterial applications instead of AgNPs. However, the long-term use of silver for antimicrobial purposes and the fact that *P. stutceri* is the only bacteria (lives in silver mines) resistant to silver ions increases the interest in AgNPs compared to ZnO and ZrO_2 NPs (Pryshchepa et al., 2020).

There are many methods for the production of NPs. Some of these methods require toxic chemicals, and others need complex, expensive devices, and high energy. Therefore, many studies have been performed to develop reliable, sustainable, and environmentally friendly new production methods of NPs. Plants, fungi, and biologically active molecules such as amino acids and phytochemicals are used in these green production methods (Jiang et al., 2018).

Papaver rhoeas L., the common poppy in English and *gelincik* in Turkish, belongs to the family Papaveraceae (Dogan and Bagci, 2014). *P. rhoeas L.* contains different phytochemicals, such as alkaloids, anthocyanins, flavonoids, and essential oils. The alkaloid ingredients of *Papaver* species have important biological activities and are used for a range of health problems, such as diarrhea, inflammation, respiratory problems, sleep disorder, cough, etc. Poppy extracts have been used for their expectorant and bronchial calming effects since ancient times. The flower parts of poppy contain anthocyanin glycosides and isoquinoline alkaloids and are used to enhance flavor in food coloring and tea compositions. In addition, the leaves act as a softener and relieve the burning sensation when applied to irritated skin (Qiliang et al., 2018).

It has been reported that poppy species grown in Turkey contain rhoeadin, proaporfin, and benzylisoquinoline alkaloids. These components have analgesic and sedative properties. In addition, they are not addictive and do not contain morphine, unlike opium. The flower or petal parts of the poppy are edible, but the most widely consumed part is the seeds. Since they are rich in protein (about 21%) and oil ingredients (about 47%), poppyseeds are used in making breads, cakes, and in salads (Çoban et al., 2017; Grauso et al., 2021). Although there are some studies on the biological activities of *P. rhoeas*, to the best of our knowledge, there are no reports about AgNPs synthesis using aqueous extract of *P. rhoeas L.*

In this study, a low-cost and green bottom-up method was used for the synthesis of AgNPs using the plant extract of *P. rhoeas L.*, and its antibacterial activity on various microorganisms was evaluated.

Materials and Methods

Preparation of the plant extract

The aerial parts of *P. rhoeas* were collected from the natural habitats of Ondokuz Mayis District, Samsun, Turkey (41°29′40″N, 36°04′44″E) and washed to remove impurities before the extraction process. Poppies were divided into four parts: flower (FL), immature seedpod (SP), leaves (LEA), and stem (STE). For the extraction process, 75 mL deionised water was added to each 15 g plant part, and the mixtures were heated by stirring on a magnetic stirrer. The extracts were left to boil for 5 minutes and allowed to cool for 10 minutes. The aqueous extract was filtered and preserved at 4°C for further analysis (Jalilian et al., 2020).

Synthesis of AgNPs

The method applied by Ahmed et al. (2016) was followed to synthesise the AgNPs. Briefly, 1 and 3 mM aqueous solutions of $AgNO_3$ were prepared and mixed with extracts of different plant parts (FL, SP, LEA, and STE) to produce AgNPs. For each, 1 mL plant part extract was added into test tubes containing 1, 2, 4, 6, 8, or 10 mL aqueous solutions of $AgNO_3$ (1 mM and 3 mM). The test tubes were incubated for about 50 minutes at room temperature (25–30°C). A color change of the solution from colorless to brown was accepted as the reduction of Ag^+ to Ag^0 and the formation of Ag^0 was confirmed by UV-Visible spectrometry.

Characterization of AgNPs

Synthesised AgNPs were characterised based on UV-visible spectroscopy, Field Emission Scanning Electron Microscopy (FE-SEM) equipped with energy dispersive X-ray spectroscopy (EDS), Fourier-Transform Infrared Spectroscopy (FTIR), and X-ray diffraction (XRD) analysis.

Wavelengths between 200–1100 nm were scanned using a Thermo Array Evolution UV-Vis Spectrophotometer (USA). The surface morphology of AgNPs was studied by using a JEOL-JSM-7001F FE-SEM equipped with EDS (Japan). FTIR analysis was carried out using Bruker Tensor 27 FTIR Spectrometer (USA). The synthesised nanocrystalline powder of AgNPs was identified by using Rigaku Smartlab XRD (Japan).

Antibacterial activity of the AgNPs

Agar well diffusion method was used to evaluate the antimicrobial activities of the plant extracts and AgNPs on seven bacterial species: *Bacillus subtilis* (ATCC6633), *Escherichia coli* (ATCC25922), *Klebsiella pneumoniae (ATCC700603), Salmonella enterica* (ATCC13311), *Pseudomonas aeruginosa* (ATCC27859), *Listeria monocytogenes (NCTC5348), Brevibacillus brevis (ATCC35690)* and a yeast *Candida glabrata* (ATCC90030). A 100 µL volume of the microbial suspension adjusted to 0.5 McFarland (with a final concentration of $1x10^6$ CFU/mL) was spread on Mueller-Hinton agar plates. The holes with 6 mm diameter in agar were filled with 100 µL AgNPs in different concentrations ranging from 30 to 50 µg mL^{-1}. The plates were incubated at 37°C for 24 h and were examined for the zone of inhibition diameters in millimeters. Penicillin (10 µg/mL) was used as a positive control for the experiments (Perez, 1990; Ontong et al., 2019).

Results

Synthesis and characterisation of AgNPs

The monodispersed NPs were prepared using 1 and 3 mM aqueous solutions of $AgNO_3$. During the biosynthesis of AgNPs, color changes were observed in the solutions, which indicate the reduction of silver ions Ag^+ to Ag^0 by the plant extract. The formation of AgNPs was monitored based on the localised surface plasmon resonance (LSPR) peak in the UV-visible spectroscopy. The highest peak intensity was observed in the 1:1 ratio (VSP/$VAgNO_3$), 1:1 ratio (VFL/$VAgNO_3$) for the SP and FL extracts, respectively, at 1 mM $AgNO_3$ (Figure 1). For 3 mM $AgNO_3$ the highest peak intensity was seen in the 1:4 ratio (VLEA/$VAgNO_3$), 1:2 ratio (VSTE / $VAgNO_3$), 1:1 ratio (VSP/$VAgNO_3$), 1:1 ratio (VFL/$VAgNO_3$) for the LEA, STE, SP and FL extracts, respectively (Figure 2).

The size and shape of AgNPs were determined by using SEM images. Figure 3 shows that the AgNPs were spherical in shape, with a particle size ranging from 15 to 40 nm. The EDS detector combined with the SEM instrument was used for the elemental analyses of AgNPs. EDS

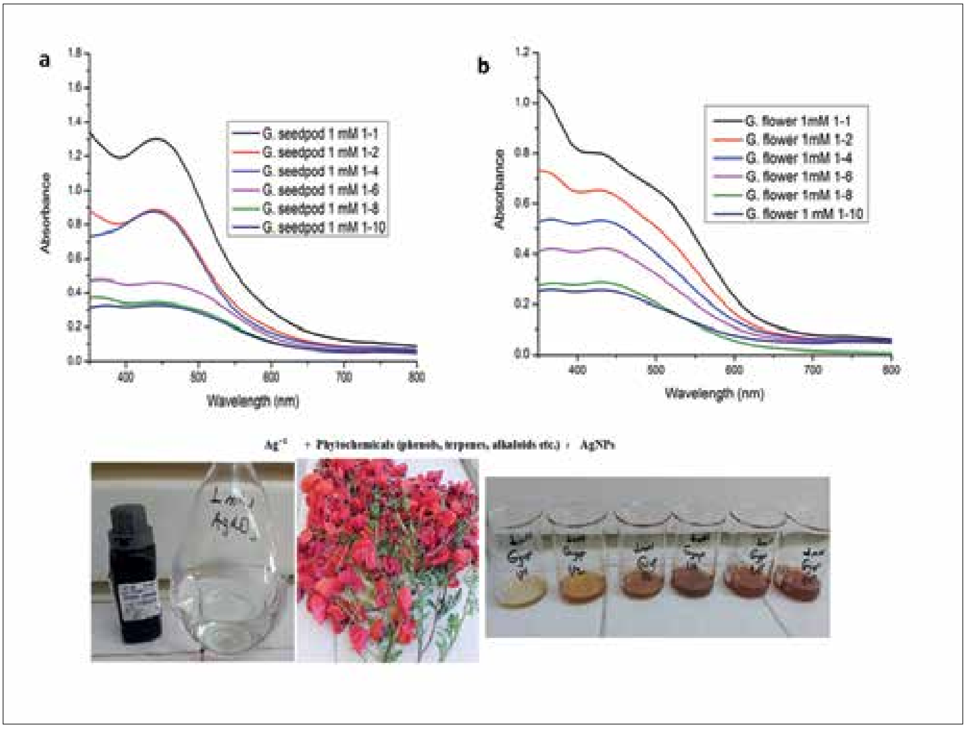

Figure 1. UV-Vis spectra of AgNPs synthesised by seedpod extract (a) and flower extract (b) using 1 mM $AgNO_3$ (The numbers 1-1, 1-2, 1-4, 1-6, 1-8 and 1-10 indicate the volume fraction of the plant extract and $AgNO_3$ solution)

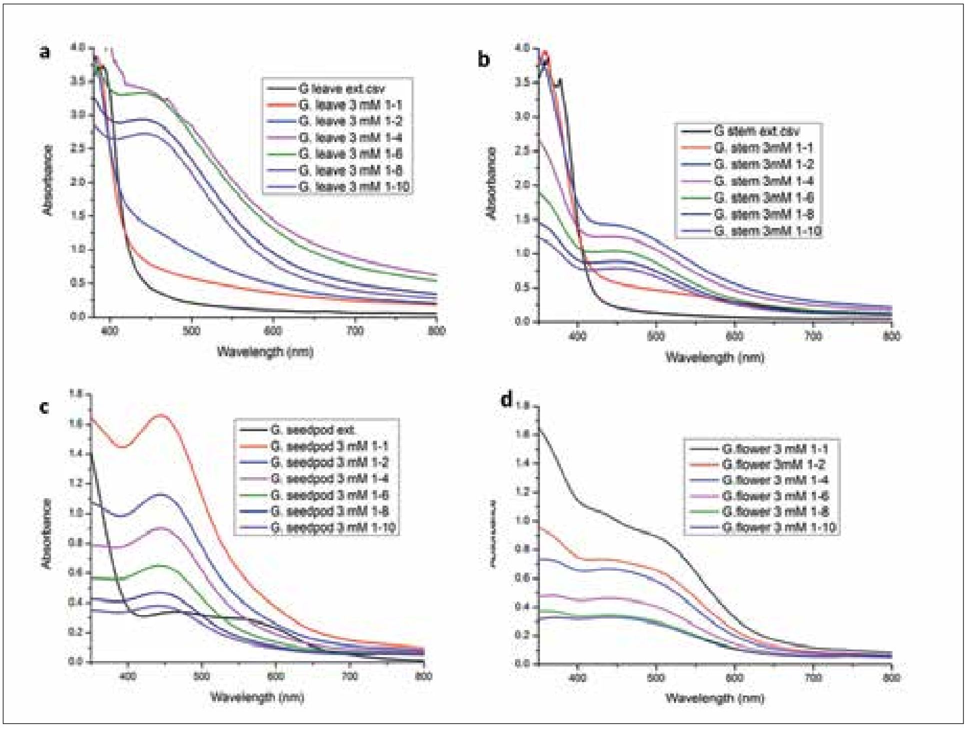

Figure 2. UV-Vis spectra of AgNPs synthesised by leave extract (a), stem extract (b), seedpod extract (c) and flower extract (d) using 3 mM $AgNO_3$ (The numbers 1-1,1-2, 1-4, 1-6, 1-8 and 1-10 indicate the volume fraction of the plant extract and $AgNO_3$ solution)

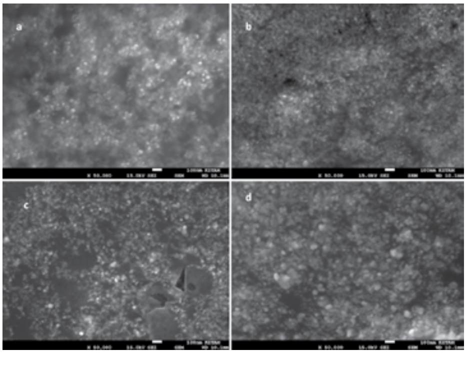

Figure 3. SEM images of the AgNPs synthesised from leaf extract (a), stem extract (b), seedpod extract (c) and flower extract (d) of common poppy using 3 mM $AgNO_3$

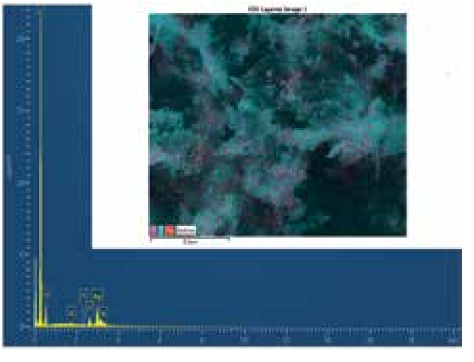

Figure 4. EDS spectrum of the AgNPs synthesised using seedpod extract

results that include strong silver signals at 3 keV confirmed the presence of AgNPs (Devaki et al., 2014), as seen in Figure 4.

The infrared spectrums were recorded in the range of 4000–500 cm^{-1} at 4 cm^{-1} resolutions with an FTIR. The FTIR

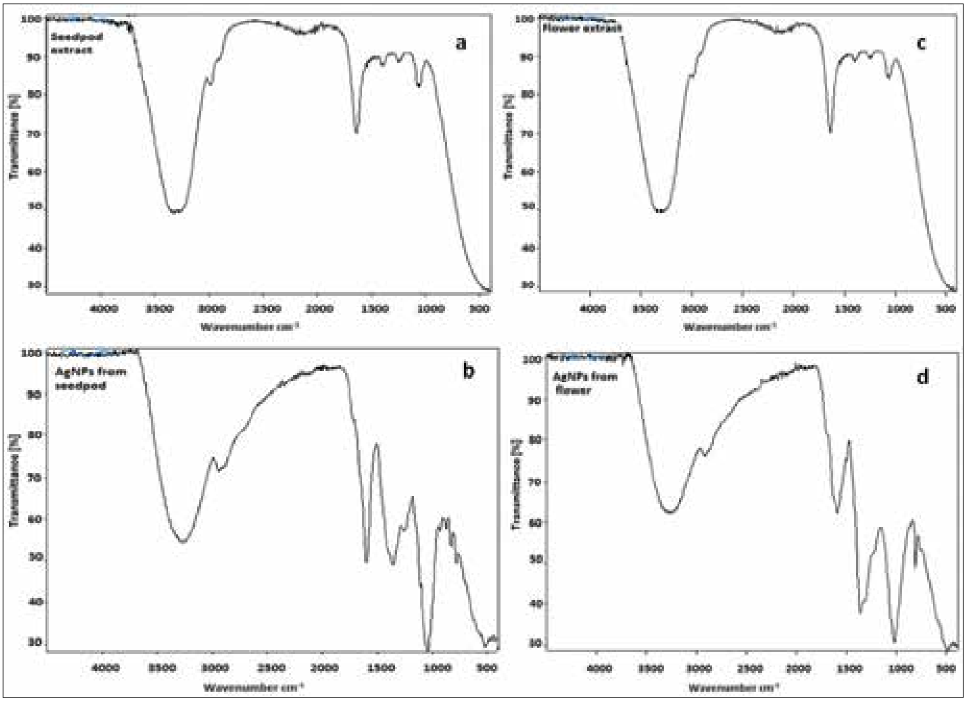

Figure 5. FTIR spectrum of the seedpod extract (a), AgNPs obtained from seedpod extract (b), flower extract (c) and AgNPs obtained from flower extract (d)

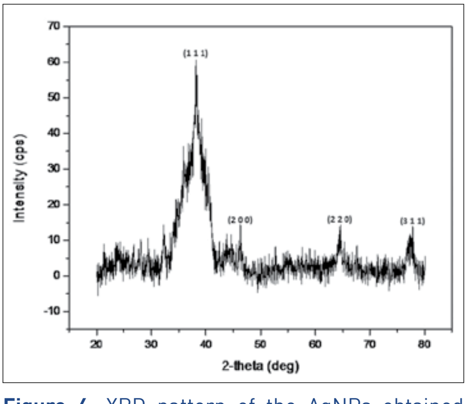

Figure 6. XRD pattern of the AgNPs obtained from the seedpod extract

spectra of the AgNPs showed strong vibration bands as shown in Figure 5.

AgNPs were characterised using Cu Kα radiation in the 2θ range from 20° to 80°. The crystalline nature of the AgNPs was proved by the XRD spectrum shown in Figure 6.

Antibacterial activity of AgNPs

The zones of microorganism growth inhibition of AgNPs were highest against *B. subtilis* (10.5±2.1 mm), *E. coli* (10.0±0.0 mm), *S. enterica* (12.0±2.8 mm), *P. aeruginosa* (13.0±2.8 mm), *K. pneumoniae* (12.0±2.8 mm), *L. monocytogenes* (10.5±0.7 mm), *B. brevis* (11.0±1.4 mm) and *C. glabrata* (11.0±1.4 mm) as shown in Figure 7. The plant extracts did not show an inhibitory effect on the studied microorganisms. It was observed that the AgNPs synthesised using different parts of *P. rhoeas L.* exhibited different antimicrobial activities. The maximum zone of inhibition diameters of the AgNPs synthesised using different concentrations of $AgNO_3$ and plant parts are also shown in Table 1.

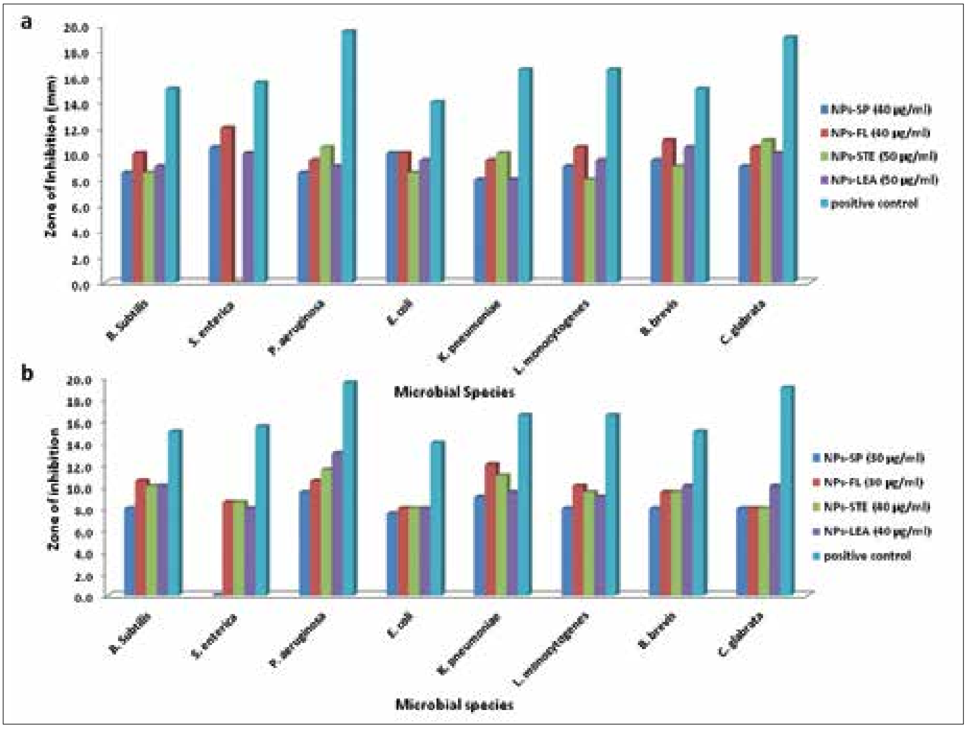

Figure 7. Antimicrobial activity of the AgNPs obtained using 3 mM $AgNO_3$ (a) and 1 mM $AgNO_3$ (b)

Table 1. Maximum zone of inhibition diameters of AgNPs synthesised using different concentrations of $AgNO_3$ and plant parts.

Test pathogens	$AgNO_3$ concentration	Plant part	Maximum zone of inhibition (mm)
B. subtilis	1 mM	Flower	10.5±2.1
S. enterica	3 mM	Flower	12.0±2.8
P. aeruginosa	1 mM	Leaves	13.0±2.8
E. coli	3 mM	Flower, Seedpod	10.0±0.0
K. pneumoniae	1 mM	Flower	12.0±2.8
L. monocytogenes	3 mM	Flower	10.5±0.7
B. brevis	3 mM	Flower	11.0±1.4
C. glabrata	3 mM	Stem	11.0±1.4

Discussion

Green synthesis methods using bacteria or plants are non-toxic, biocompatible, inexpensive, fast, and one-step processes. The extracts prepared using plant materials with different solvents play a critical role in reducing silver ions and stabilizing AgNPs by surrounding them due to their phytochemical ingredients. Also, NPs are wrapped with an organic matrix, in an attempt to obtain safer nanostructures by reducing the toxicity of metallic NPs. Jalilian et al. (2020) investigated plant-mediated synthesis of AgNPs using aqueous extract of *Allium ampeloprasum*, and it was found that this extract could be used in various applications in the medical field due to its antioxidant and antibacterial effects, and acceptable level of cytotoxicity on cervical cancer cells. Sriranjani et al. (2016) used *Clerodendrum phlomidis L.* leaves for preparing AgNPs. The synthesised AgNPs showed anticancer and antioxidant activity (Sriranjani et al., 2016).

In this study, a green synthesis method was performed to synthesise AgNPs from different parts of *P. rhoeas L.* The monodispersed NPs were obtained using 1 and 3 mM aqueous solutions of $AgNO_3$. Although increasing the $AgNO_3$ concentration contributes to the formation of large amounts of NPs, it is recommended not for concentrations to exceed 5 mM to ensure the monodispersion of nanoparticles (Nayak et al., 2011).

Color changes of the solutions indicated the reduction of silver ions Ag^+ to Ag^0 by the plant extract. In addition, the synthesis of the AgNPs was shown with the LSPR peaks in the UV-visible spectroscopy. LSPR is caused by the interaction of free electrons in the conduction and valence bands, which are very close to each other on the surface of metal NPs, with the light coming to the surface. Free electrons oscillate collectively in resonance with the light wave (Wu et al., 2015). The LSPR bands were found between 450 and 500 nm and confirmed the formation of the AgNPs. Also, an increase in absorbance intensities was observed due to the increase in the number of formed NPs (Valli and Vaseeharan, 2012). Optimum volume ratios with the highest number of particles were determined using the highest absorbance intensities. The highest peak intensity was observed in different ratios of SP, and FL extracts at 1 mM $AgNO_{3,}$ and in the LEA, STE, SP, and FL extracts at 3 mM $AgNO_3$. It was thought that when 1 mM $AgNO_3$ solution was used in the synthesis, the decrease in AgNPs formation also caused a decrease in the absorption values.

The size, shape, and surface area are the main properties of the NPs and have important effects on biological systems (Zhou et al., 2006). A large surface area of small particles can cause significant toxic effects. The increase in the dissolution rate of particles with dimensions less than 10 nm causes an increase in the number of silver ions released into the environment. In this case, toxic effects and damages are observed in organs such as liver, spleen, lung, and kidney (Wei et al., 2015). SEM uses a high-energy beam of electrons, lenses, magnets, and detectors to scan and monitor the surface morphology of solid substances. In the present study, SEM images showed that the AgNPs were spherical, and that particle size ranged from 15 to 40 nm. Also, EDS results showed strong silver signals at 3 keV and confirmed the presence of AgNPs (Devaki et al., 2014).

FTIR analysis was used to determine the functional groups of bioactive molecules present in the aqueous plant extracts and AgNPs suspensions. These functional groups are involved in forming and stabiliaing NPs by wrapping around them (Bankar et al., 2010). In this study, the FTIR spectra of the AgNPs showed strong vibration bands. The broad absorption bands between 3500 and 3100 cm^{-1} demonstrate the stretching vibrations of hydroxyl (-OH) groups of phenolic compounds and alcohols. A vibration band appearing at 2930 cm^{-1} is due to the methyl (-CH) stretching vibration. The band at 1630 cm^{-1} is attributed to the stretching vibration of the carboxyl group (-C=O) and can be attributed to stretching of the CO-(NH) group. The bands in the 1450 and 1200 cm^{-1} range indicate the presence of aromatic rings. The band at 1074 cm^{-1} showed the presence of an ether linkage (C-O-C). The presence of groups such as -OH, -NH, and -CH in FTIR results of AgNPs showed the involvement of these groups in the production of AgNPs. As a result, alkaloids and flavonoids acting as reducing and stabilising agents played an essential role in synthesising the AgNPs (Parveen et al., 2016).

XRD is an analysis technique used to investigate the crystallographic structure and chemical composition of materials (Selvan et al., 2021). The AgNPs were characterised using Cu Kα radiation in the 2θ range from 20° to 80°. The XRD spectrum verified the crystalline nature of the AgNPs. The peaks observed at 2θ values (38.35°, 43.84°, 65.48°, 77.22°) correspond to the (1 1 1), (2 0 0), (2 2 0) and (3 1 1) planes, respectively, which are characteristic for Ag. The XRD spectra showed the synthesised AgNPs were face-centered cubic structure in nature (Kharat and Mendhulkar, 2016; Parveen et al., 2016, Araújo et al., 2017; Paulkumar et al., 2017).

Various hypotheses have been proposed to explain the antibacterial activity of AgNPs. Particle contact, release of silver ions, and formation of reactive oxygen species (ROS) are associated with antibacterial activity. NPs enter the microorganism by destroying the membrane structure and forming ROS, which cause the inactivation of proteins such as respiratory enzymes and DNA damage. The immune system cells easily eliminate these damaged microorganisms (Das et al., 2017).

In the present study, AgNPs synthesised from different parts of *P. rhoeas* were found to be effective on both Gram-positive and Gram-negative bacteria as well as yeast *C. glabrata*. The highest zones of microorganism growth inhibition were observed against *B. subtilis* (10.5±2.1 mm), *E. coli* (10.0±0.0 mm), *S. enterica* (12.0±2.8 mm), *P. aeruginosa* (13.0±2.8 mm), *K. pneumoniae* (12.0±2.8 mm), *L. monocytogenes* (10.5±0.7 mm), *B. brevis* (11.0±1.4 mm) and *C. glabrata* (11.0±1.4 mm).

Many studies have focused on the antibacterial activities of AgNPs. Zhang and Jiang (2020) prepared a composite film (CS/TP-AgNPs) composed of chitosan, tea polyphenols (TP), and AgNPs. In addition to its antioxidant properties, TPs acted as reducing agents in the conversion of silver ions into NPs and as crosslinkers in the composite. It was stated that the TP-AgNPs added composite has antibacterial and antioxidant properties and can be used in food packaging (Zhang and Jiang, 2020). Vijayakumar et al. (2019) used an aqueous garlic extract to prepare AgNPs. The obtained AgNPs inhibited the growth of methicillin-resistant pathogens (*S. aureus* and *P. aerigunosa*) at a concentration of 100 μg mL^{-1}. The zones of inhibition were measured as 17.4 and 19.2 mm for *S. aureus* and *P. aerigunosa*, respectively. Masurkar et al. (2011) synthesised AgNPs using the leaf extract of lemongrass (*Cymbopogan citratus*) and investigated the antibacterial activity of the AgNPs against *E. coli, S. aureus, P. mirabilis, S. typhi*, and *K. pnuemoniae*. The diameters of the inhibition zones of the AgNPs ranged from 13 to 16 mm for tested pathogens and 15 to 18 mm for tested fungus, *C. albicans*.

The costs and toxic effects of antibiotics and chemotherapeutic drugs used in cancer treatment have led researchers to work on alternative medications. AgNPs synthesised using biological sources are being tested as an alternative to many drugs or in combination with drugs due to their high efficiency, low cost, and low toxic effects. Mohammed et al. (2018) investigated the antibacterial activities of AgNPs synthesised from the extract of *Ferula asafetida, Phoenix dactylifer*, and *Acacia nilotica* against some pathogenic microorganisms and their effects on the suppression of growth in colon cancer cells. Cytotoxic potentials of AgNPs against LoVo cell lines were evaluated with the MTT test. It has been concluded that the AgNPs can be used to produce antibiotics and anticancer drugs (Mohammed et al., 2018).

Selvam et al. (2017) synthesised AgNPs using *Tinospora cordifolia*, and the antibacterial activity of the AgNPs was determined against *K. pneumoniae* and *B. subtilis*. The diameter of the inhibition zones was 12.3 mm for *K. pneumoniae* and 10.5 mm for *B. subtilis* at 10 μg mL^{-1} (Selvam et al., 2017). Arokiyaraj et al. (2017) used *Rheum palmatum* as a biosource for the production of AgNPs and tested the AgNPs against *P. aeruginosa*. The NPs exhibited the maximum bactericidal effect against *P. aeruginosa* with an inhibition zone of 13 mm at 30 μg mL^{-1} (Arokiyaraj et al., 2017). Ontong et al. (2019) investigated the antibacterial potential of AgNPs synthesised from aqueous *Senna alata* bark extract. The AgNPs displayed inhibitory activity against the bacterial species *E. coli* (13.12 mm) and *K. pneumoniae* (12.75 mm) at a concentration of 50 μg/well (Ontong et al., 2019).

Conclusion

This study presents an eco-friendly biosynthesis of AgNPs using *P. rhoeas* extracts as a bio-reductant. The phytochemicals of the plant served as capping and stabilising agents in the synthesis of AgNPs. UV–Vis spectrometer, FTIR, and SEM-EDS suggested that suitable AgNPs were obtained, with spherical particles in the size range of 15 to 40 nm. Bio-reduced AgNPs showed considerable growth inhibition against bacterial species, and higher effectiveness was found against *P. aeruginosa, S. enterica*, and *K. pneumoniae.* It was concluded that the obtained biogenic, low cost, and biocompatible AgNPs could be applied in antibacterial applications' in human and veterinary medicine, such as wound dressing and drug delivery.

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Zelena sinteza nanočestica srebra uporabom maka turčinaka (*Papaver rhoeas* L.) i procjena njihovog potencijalnog antibakterijskog učinka

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Zahvaljujući njihovoj jednostavnoj i jeftinoj proizvodnji i pojačanim svojstvima, nanočestice plemenitih metala preferirani su nano-aditivi u većini farmaceutskih spojeva. Na primjer, nanočestice srebra (AgNP) i nanočestice zlata (AuNP) posjeduju antiseptička i antimikrobna svojstva i općenito se preferiraju u proizvodnji antibakterijske odjeće i premaza. U ovoj studiji donosimo jednostavnu, jeftinu i zelenu metodu sintetiziranja AgNP čestica uporabom vodenih ekstrakata maka turčinaka (*Papaver rhoeas* L.). Sintetizirane nanočestice srebra okarakterizirane su na temelju pretražne mikroskopije emisijom elektrona primjenom polja (*Field Emission Scanning Electron Microscopy*) opremljene energetski disperzivnom RTG spektroskopijom, infracrvenom spektroskopijom s Fourierovom transformacijom i rendgenskom difrakcijskom analizom. Sintetizirane AgNP čestice ispitane su i na antimikrobnu aktivnost uporabom metode difuzije u agaru. Metode karakterizacije pokazale su da su dobivene AgNP čestice sfernog oblika, a veličina čestica kretala se između 15 i 40 nm. Prema rezultatima antimikrobnih ispitivanja, AgNP čestice učinkovito su spriječile rast različitih gram-pozitivnih i gram-negativnih bakterija. Zaključeno je da je ekstrakt *Papaver rhoeas* L. učinkovit kao reducens za pripremu stabilnih i monodisperziranih AgNP čestica, a dobivene AgNP čestice mogle bi biti korisne za primjene u humanoj i veterinarskoj medicini kada je potreban antibakterijski učinak.

Ključne riječi: *nanočestice srebra, Papaver rhoeas L., biosinteza, antibakterijski*